



European  
Commission



# SCIENCE, RESEARCH AND INNOVATION PERFORMANCE OF THE EU 2018

Strengthening  
the foundations  
for Europe's future

Research and  
Innovation

**Science, Research and Innovation Performance of the EU 2018**  
**Strengthening the foundations for Europe's future**

European Commission  
Directorate-General for Research and Innovation  
Directorate A — Policy Development and Coordination  
Unit A4 — Analysis and monitoring of national research and innovation policies

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PERFORMANCE  
OF THE EU  
2018**

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## Foreword

The importance of research, science and innovation as key drivers of prosperity is now greater than ever before. I believe that we are at the cusp of a new wave of much deeper and transformative innovations, a new era where digital technologies will increasingly merge with the physical world. This new wave of innovation will go more and more into 'deep tech'. Technology and engineering will combine with areas such as connectivity and computing, data analytics and intelligence, new advanced materials and production processes. This will have a profound impact on our economies - far greater than what we have experienced over the past two decades - and will demand a much deeper engagement with end-users and citizens.



A new innovation race is about to begin and Europe needs to get ready to start in pole-position. This report presents a wealth of data and empirical analyses that show that Europe currently benefits from distinctive strengths, but also faces weaknesses that we need to address. Europe is the world's largest producer of high quality scientific knowledge, and yet its innovation performance remains far below its potential. The EU invests around 2% of its GDP in R&D, while the United States, Japan and South Korea invest 2.8%, 3.3% and 4.2% respectively. China, at 2.1%, has also recently overtaken the EU. Its venture capital is only one-fifth of that of the United States and remains fragmented into small size funds. And while Europe has some innovation hotspots, many regions lag behind in innovation capacity. Europe generates many exciting start-ups but has been largely left behind in the development of major new digital platforms, and lacks those transformational entrepreneurs that have disrupted entire industries at a global scale.



A window of opportunity lies ahead and Europe needs to show determined leadership. We must prioritise investment and fill in the gap in relation to breakthrough innovation. We need to adopt regulatory frameworks that encourage rather than hinder innovation, and foster innovation-friendly and vibrant business environments.

The purpose of this report is to provide a better grasp of the changing dynamics of science, research and innovation and their impact for Europe. As such, I am convinced that it is a powerful tool to inform research and innovation policy-making and ensure that our responses to a rapidly changing world remain fully fit for purpose.



**Carlos Moedas,**  
European Commissioner for Research, Science and Innovation

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## EXECUTIVE SUMMARY

Research and innovation (R&I) and their impacts on the economy and social prosperity: opportunities and risks

***Economic growth has returned to Europe, but sluggish productivity growth, which largely depends on R&I, continues to hold back more robust growth ...***

After years of economic and political crisis, resilient economic growth has returned to Europe, unemployment is falling and Europe is ready to set the foundations for its future. In order to solidify the recovery and ensure higher levels of prosperity, it needs to address its sluggish productivity growth, which has remained flat for almost a decade, and ensure that economic prosperity is widely shared and leads to a more cohesive society.

***... a phenomenon that is common to other advanced economies, but is particularly acute in Europe and hinders its ability to bridge the productivity gap compared to the United States.***

In recent years, despite the rise and emergence of many new technologies which hold the promise of large productivity gains, these gains have yet to fully materialise. This phenomenon, common to several advanced economies, and notably the United States and Japan, is particularly acute in Europe, although there are large differences across the Member States. Europe's labour productivity gap compared to the United States has not been bridged and remains nearly 12% lower, driven primarily by insufficient progress in particular segments of the economy, notably its inability to substantially increase its productivity levels in high-tech sectors and knowledge-intensive services that continue to be less productive and less present in Europe.

***While R&I are crucial for new and better job creation, new technologies can increasingly, and more quickly, affect job and wage polarisation and income disparities.***

While R&I spur the creation of new and better-quality jobs, and while overall employment rates remain high in Europe, the rise of new technologies, such as robotics and artificial intelligence, and the increase in task automation have led to some polarisation in the labour market. There has been a fall in the number of medium-routine jobs, estimated at around 9% in the European Union, and there is pressure on wage dispersion in several countries. This leads to market-led rising inequality, which increased more than 5% percent between 2007 and 2013. The broader development and implementation of many of these new technologies generates a risk of fast-paced and large-scope destruction of routine tasks with an accompanying risk of rising inequality, notably if new innovation-related jobs mainly benefit the smaller segments of the population. Overall, this trend in job and wage polarisation is likely to continue, if not accelerate, should divergences in innovation and productivity growth continue to grow across companies, sectors and countries, bringing consequences for greater inequality and the economic, social and political consequences associated with it.

***These phenomena, while not new, seem to suggest deep changes in innovation dynamics ...***

Against this backdrop, understanding the role and economic impacts of R&I is crucial, as they are the main drivers of productivity and economic growth, notably for advanced economies, and affect job-creation patterns and the demand for skills as well as overall income distribution and inequality.

## Changes in the innovation landscape

***... that are largely driven by long-term socio-economic forces, such as demographical changes in an ageing population, climate change, globalisation and digitalisation ...***

Understanding the role and impact of innovation in our economies and societies primarily requires understanding the main forces shaping those innovations. Changing demographics, in an ageing population, climate change, the rise of globalisation and notably with digitalisation and digital technologies, that are merging the digital and physical spheres, are drastically altering the nature, mechanisms and impacts of the innovation process.

***... that lead to faster pace, deeply transformative and increasingly science-based and complex innovations resulting in a higher concentration of benefits in particular firms, hindering innovation diffusion ...***

Innovation, notably of the most disruptive type, is increasingly linked to the exploitation of synergetic elements stemming from the convergence of several technologies, very often enabled by digitalisation and more science and technology rich than recent digital innovations, such as application developments. These upcoming innovations, which bring the digital and physical spheres closer together, are based on several technologies that are not easy to master or to obtain off the shelf. To fully reap the benefits of innovation, a change in business models is needed, which usually requires the investment of substantial economic, and at times financial, capacity. Many disruptive innovations are being introduced quickly on to the market, bringing about complete game-change scenarios into increasingly converging industries and markets. This gives rise to new global superstar companies, notably in the United States, that are leading in all the market

capitalisation rankings. More precisely, among the top 15 largest global companies by market capitalisation, two – i.e. Facebook and Alibaba – did not even exist a decade ago, while others have since multiplied their market capitalisation by eight to twelve times, e.g. Apple or Amazon. Many of the benefits from innovations are being concentrated more and more in ‘winner takes most’ markets and industries, where innovation diffusion across firms tends to slow down. More precisely, recent research by the Organisation for Economic Co-operation and Development (OECD) has shown that productivity grew by a robust 30-40% among the most productive companies in the manufacturing and business-services sectors, from 2001 to 2013, respectively, while in the remaining companies, the rise in productivity was well below 10%.

***... and that can explain recent trends in productivity and inequality and shed some light on future trends.***

These changes in the nature of innovation are likely to be behind many of the productivity and inequality patterns currently observed and, beyond potential statistical mismeasurements, they are responsible for two facts. These are: the general slowdown in the impacts of recent innovations which may not be disruptive enough to support productivity increases; and, second, for the sharp increase in the differences in productivity growth across firms, within and across sectors, which suggests a slowdown in innovation dissemination.

A new way of analysing innovation performance is needed

***Traditional analyses of R&I performance must become attuned to cater for the changing nature of innovation dynamics and the new ways through which innovation is spurring productivity growth and generating socio-economic impact ...***

These changes in the innovation landscape are affecting how we analyse and assess R&I performance, notably in relation to how R&I is carried out and what determinants influence their ability to maximise socio-economic impacts. High-quality socio-economic innovation impacts are sought. Analyses should increasingly attempt to capture how R&I ecosystems deliver those innovation impacts and should aim to examine proxies for the speed of innovation diffusion while identifying bottlenecks which impede that diffusion.

***... because, while we have yet to acquire a full understanding of all the drivers of innovation creation and innovation diffusion in this changing context ...***

Currently, there are a number of empirical limitations in properly accounting for the impact of innovations. For example, there are no specific indicators that can be used to directly track and monitor innovation quality and innovation diffusion per se, although there are some good analytical proxies, such as high-growth transformational entrepreneurship or the dispersion of productivity growth across firms and sectors. Moreover, our understanding of the drivers and bottlenecks that influence the impacts and ability of high-quality innovation to accrue and diffuse must be further refined.

***... there are, however, a number of factors which go beyond the traditional science and technology metrics, which are very important to provide a more nuanced picture ...***

Notwithstanding these limitations, which bring a degree of uncertainty to the analysis of innovation performance and policy formulation, there is a set of factors that drive R&I performance. Investment in high-quality research, skills development, ICT or economic competences result in the production of high-quality scientific and technological outputs and innovations, and also enhance the ability to absorb technologies and innovations developed elsewhere, thereby facilitating the diffusion of innovation.

Moreover, innovation eco-systems that facilitate the flow of knowledge across innovation agents also help to improve the innovation quality and diffusion. Finally, good framework conditions for innovation are crucial to enable and foster innovation creation and diffusion; from effective regulation frameworks to well-functioning markets that facilitate the (re)allocation of resources to innovative and productive activities, or the availability and demand for risk capital that can finance high-risk projects, both at the inception and scale-up phases, of innovative projects.

***... such as the analysis of: the role and impact of intangible assets, the development and deployment of a country's scientific excellence, the capacity of an economy to engage in transformational entrepreneurship<sup>1</sup> or the role of framework conditions, such as regulation, competition or access to risk capital, to spur innovation.***

These factors have been and continue to be crucial to ensure high-impact innovation. However, in

1 Transformational entrepreneurship concerns those new businesses which, from the onset, have the ambition to become big and provide “disproportionately large contributions to net job creation” (Haltiwanger, 2014) and which invest more in R&D, proportionally, than older ones (Surowiecki, 2016). Very often, transformational entrepreneurship is opposed to subsistence entrepreneurship, the ambition of which is to gain some measure of financial independence, but not to scale up and grow in large numbers (Schoar, 2010).

the current context of fierce change in innovation dynamics, there are a number of aspects that are particularly important and which require a fresher and more nuanced analysis in order to get the correct picture of innovation performance:

- ▶ The importance of combining several types of innovation-prone assets to spur the creation and adoption of innovations, from R&D to ICT investment, to skills development or managerial and organisational skills changes. a 'silo approach', focusing solely on, for example, R&D or ICT performance in isolation may not provide a good basis for understanding the complexity of the innovation process.
- ▶ The enhanced role of skills and their development to support innovation and ensure the broader ability of a country to contribute to and benefit from innovations.
- ▶ Developing an upgrade of a country's science base is critical to spur and speed up scientific excellence and to nurture the development and adoption of disruptive innovations and technological performance.
- ▶ Knowledge flows and creating the conditions for stronger knowledge flows are increasingly important to support the building up of scientific excellence and its fast diffusion and transformation into innovations.
- ▶ Innovation-led entrepreneurship. While traditional indicators of entrepreneurship remain important, it is particularly important to monitor transformational entrepreneurship given that it deeply disrupts existing markets through innovation and is responsible for the creation of many new jobs.
- ▶ In the context of rapid change, where access to competitive factors, such as data, is rapidly shifting, framework conditions that allow for disruptive innovations to accrue, scale up and diffuse, are gaining in importance. This is particularly relevant in relation to: the availability of risk capital for innovation and entrepreneurship at all stages; regulations that enable (and do not hinder) innovation diffusion across sectors; well-functioning markets that allow for the rapid and frictionless reallocation of resources; and a level playing field through effective competition policy.

## The EU's research and innovation performance

***The Report presents a dedicated, nuanced and fresh analysis of R&I performance that defines a number of findings. Overall, Europe remains a global research and innovation powerhouse ...***

Overall, Europe is a global R&I powerhouse and the leading economy in terms of public investment in R&D and the number of researchers. It is a front runner in terms of scientific productions, including high-quality publications<sup>2</sup> (nearly one-third of all high-quality publications worldwide are European), albeit not at the very top level<sup>3</sup>. More precisely, the EU accounts for one-fifth of the world's R&D investment, and 23% of the global public R&D. Moreover, with more than 1.8 million researchers, the EU is the economy with largest number of researchers, ahead of China and the United States, with 1.6 million and 1.3 million researchers, respectively.

***... although it fails to invest as much as other economies, notably the United States, in business R&D, education and skills development, ICT and economic competences ...***

Notwithstanding its public R&D investment capacity and scientific performance, Europe lags behind the United States, Japan South Korea and even China in private and overall R&D investment levels. In this respect, the EU accounts for less than one-fifth of the world's business R&D investment, in contrast to the United States or China which account for 28% and 24%, respectively. Business R&D intensity in the EU stands at 1.3% compared to almost 2% for the United States and nearly triple that for South Korea, at almost 3.5%. Also, in comparison to the United States, Europe trails behind in ICT investment which hinders its ability to reap the benefits of digitalisation, education or economic competences<sup>4</sup>.

***... a trend that has been widening ...***

This investment gap, notably for private R&D investment, has been widening in recent years, providing evidence of challenges that are hindering Europe's ability to bridge the investment gap in intangible assets. More precisely, while business R&D intensity held up well during the financial and economic crisis of 2007–2012, growing at around 2.5% on average annually, since then the annual growth rates have fallen to around 0.5%, well below the 2% in the United States and 3% in China.

***... and is coupled with relatively weaker knowledge flows among stakeholders ...***

In addition, and even if they have been rising over time, knowledge flows among stakeholders, which are partially influenced by, and the result of, lower investment levels among them, tend to be lower in Europe compared to the United States.

While on the rise, the share of open access publications, which help to spread excellence and knowledge diffusion, remains low in Europe (around 30%) compared to the United States (35%), as is the number of public-private co-publications, an indicator of science-based public-private co-operation, where Europe's score is half (30 public-private co-publications per million population) that of the United States (63.4). On a positive note, Europe is capitalising on the globalisation of science by tapping into international knowledge pools, as nearly half of its publications are the result of international collaborations.

***... that affect Europe's technological and innovation output and results in it failing to capitalise sufficiently on its scientific capacity and scientific excellence.***

These lower investment levels in many relevant assets for innovation and the somewhat lower

<sup>2</sup> High-quality publications are measured as the number of top 10% highly cited publications.

<sup>3</sup> Excellent publications are measured as the number of top 1% highly cited publications.

<sup>4</sup> Economic competences encompass brand equity, organisational capital and training.



knowledge flows among different stakeholders translate into Europe's limited ability to capitalise on its strong and excellent scientific base to spur technological development and innovation.

Despite being anchored in fields where Europe performs strongly, the proportion of patents in the economy, notably in emerging technology fields such as big data or the Internet of Things, is lower than in other economies and has been declining over time. Nonetheless, Europe's performance in patents in quantum computing and telecommunication is promising, linked to its strong scientific position in these areas. Europe also lags behind the United States and Japan in terms of the share of employment in knowledge-intensive activities in business industries, a broad proxy for innovation performance, where Europe gathers around 14% of the jobs in this category against 16-17% for the United States and Japan.

***Moreover, weaker framework conditions for innovation and innovation-led entrepreneurship ...***

More stringent labour and goods market conditions in Europe than in the United States and other advanced economies are hindering Europe's ability to effectively reallocate resources towards more innovative and productive activities. These rigidities lead to companies sinking in significant financial resources which can be regarded as unproductive and that do not exit the market at the necessary or expected speed. In this regard, the OECD estimates that around 16% to 19% of all available capital is sunk into unproductive companies in Italy and Spain. As a result, and even if the relationship between competition and innovation is far from linear, Europe's level of competition is continuously perceived to be lower than that of the United States, even if in the latter there has been an overall visible increase in the concentration of sales, employment and R&D in recent years.

This situation seems to persist despite significant progress in undertaking deep structural reforms in several Member States, a process that has

nonetheless recently lost momentum. Despite progress, Europe's market continues to be fragmented, notably in areas such as digital technologies, the provision of capital or services, which hinders the ability of companies to mobilise and scale up innovations quickly. Finally, while access to finance has drastically improved in Europe, leaving behind the worst periods of the financial crisis, risk capital, notably for growing and scaling up practices, continues to be very scarce, and at a fraction of that available in the United States.

***... result in lower transformational entrepreneurship levels, despite a good performance in more traditional entrepreneurship indicators ...***

With weaker framework conditions and a narrow capacity to translate its scientific excellence into technological performance and innovation, Europe appears capped in its ability to foster transformational entrepreneurship. The creation and scale-up of new companies that grow into global giants, and which seem to be reaping many of the innovation benefits across the world, is rather limited in Europe. While Europe scores relatively well on traditional entrepreneurship indicators, the gap with the United States is very large in both the number and relative importance of rapid high-growth companies, such as the unicorns, which are disrupting existing markets and largely reaping the benefits of innovation. More precisely, recent estimates point out that there were 20 private companies valued at US\$ 1 billion or more in Europe, while there were 106 in the United States and 50 in China.

***... and affect Europe's ability to support the faster structural change of its economy towards more productive and innovative activities. This, in turn, influences its capacity to invest in intangible assets.***

As a result of Europe's lower entrepreneurship and innovation capacity, its structural change towards a more knowledge-based economy able

to support higher productivity levels and larger investments in intangible assets is not progressing at the required speed. On average, the share of knowledge-intensive activities<sup>5</sup> in the value added of the European economy grew by less than 0.5% annually from 2000 to 2015. As a result, in 2015, less than 50% of the European value added was produced in one of these sectors, while in the United States or South Korea the share was above this threshold. Decisive policy and strategy actions will be necessary to escape from this vicious feed-back loop.

***However, this aggregate analysis masks large differences across the Member States ...***

This aggregated analysis of Europe's R&I performance masks important national differences in terms of its capacity to support productivity growth at the current level of economic prosperity, investment and performance dynamics in the EU economies.

***... and while the innovation divide persists in Europe, it is now more nuanced, notably for investment patterns ...***

Overall, R&I tend to play a different role in spurring productivity growth depending on the stage of economic prosperity in the country concerned. While for some lower- and middle-income countries R&I can improve productivity, thanks to factors such as foreign direct investment (FDI), investment in infrastructure or the better functioning of markets, in the long run, research, innovation and entrepreneurship are key to spur productivity and growth.

The scientific and innovation divide in Europe used to be clearly divided between north and south and west and east. Although that division is still present, it is becoming much more nuanced, notably in terms of investment levels, where certain

countries have made significant progress to catch up and others have not. More precisely, Slovakia, Bulgaria, Poland and the Czech Republic have significantly increased their R&D investment intensity over the past decade. In some cases, e.g. the Czech Republic, this has allowed for a strong convergence towards the EU average. On the other hand, countries like Romania, Portugal and Spain have exhibited disappointing R&D investment-intensity records. It should be noted that in some countries, much of the progress has been driven by public efforts, e.g. Poland, and very often supported by European funding. This, of course, can cast doubts about the longer-term sustainability of these investments. It should not be overlooked that some countries building their R&I capacity have used their public R&I investments to improve not only their scientific capacity but, often to a lesser extent, technological output as well.

***... although significant challenges in transforming investment into scientific and technological outputs still persist in restructuring systems.***

However, this divide remains much more pronounced in terms of scientific and technological outputs than in terms of innovation. When it comes to scientific excellence, for example, the regional rankings continue to be solidly led by countries like the United Kingdom, the Netherlands, Denmark and Belgium, while Central and Eastern European Member States continue to significantly trail behind with values often as low as a third of the leading countries in the share of highly cited publications. This reflects the lower efficiency of the national R&I systems in the laggard countries in transforming R&D investment into scientific and technological output. While it is too early to clearly identify the real causes behind these proportionally weaker results, they may hint at particular bottlenecks which need to be addressed through tailored structural reforms to improve the quality and efficiency of the underlying national R&I systems.

5 Knowledge-intensive activities are defined as those in high-technology manufacturing, medium-high-tech manufacturing and knowledge-intensive services.

## Policy implications<sup>6</sup>

*Against the backdrop of the deep process of transformation in the nature and dynamics of innovation, and bearing in mind that robust evidence is still not always at hand, the analysis in this Report of Europe's R&I performance leads to a set of policy implications. Europe needs to:*

### 1. Boost its investment in intangible assets

Enhancing public investment in R&I and other intangible assets can help bridge Europe's current investment gap compared to other economies. Active labour market policies aimed at developing the skills needed for a changing economy will contribute not only to spurring innovation but also to mitigating the risks associated with potential job losses which might be brought about by task automation. While Member States benefit from different fiscal spaces for public investment, those able to do so should invest more in intangible assets. In addition, this will bring spillover benefits to other countries. Member States that have experienced low or even declining public R&I investments should make it a priority to cement the basis of future growth on such investments. In addition, the leveraging of business R&D investment, an area in which Europe particularly lags behind, is critical. The right framework conditions for private companies to innovate must be in place.

### 2. Urgently rethink public support for R&I, notably for market-creating breakthrough innovations

Europe lacks sufficient investment in market-creating disrupting innovations, where private capital shies away. Supporting bot-

tom-up transformative innovative projects can bridge this gap. In addition, public R&D investment will benefit from moving away from supporting specific fields towards more comprehensive mission-oriented policy approaches that maximise the impacts of public R&D and galvanise private investment. Policy experimentation in these fields can help achieve more robust evidence about the impacts of these changes in public R&D funding.

### 3. Improve the conditions for speeding up knowledge creation and diffusion by opening up national science and innovation systems

Supporting investment in R&I and other intangible assets improves the economy's absorptive capacity and its ability to diffuse knowledge. Measures to open up science and innovation systems within Europe, and to the world, will support faster and stronger knowledge flows. Initiatives to build up the conditions for open science, thanks to the opportunities offered by digital technologies, and for open innovation, including through stronger science-business links, are critically important.

### 4. Ensure innovation-friendly regulations and innovation-demand policies that support transformative innovation and innovation diffusion across sectors

It is crucial to develop innovation-friendly regulations that facilitate the smoother adoption of innovations, notably in relation to the myriad of opportunities that digital technologies offer, across all sectors of the economy and specifically in relation to highly regulated sectors such as education, health or transportation. In addition, innovation-demand policies, such as public procurement or

<sup>6</sup> The views expressed in this publication are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission

the empowerment of consumers to develop consumer-based innovations will be critical. These actions will speed up the creation of benefits from innovation.

#### **5. Rethink competition policy in a digitised economy**

While sufficient evidence is still unavailable, it appears that changes in the innovation dynamics are leading to a higher concentration of innovation benefits and to the creation of potential monopolies or dominant positions in relation to the access and use of key new resources, such as data, and notably big data. This may have implications for ensuring a level playing field with equal opportunities for transformative innovations.

#### **6. Complete the internal market in all sectors to support the rapid scale-up of European innovation**

Europe's ability to scale up innovations is being hindered by an incomplete internal market, notably in strategic areas such as digital or services. Achieving that internal market in all areas is crucial to give innovations 'born in Europe' the opportunity to scale up and become global players.

#### **7. Boost sufficient access to risk capital in Europe to support innovation**

Risk and patient capital, while recovering, remain very low in comparison to the United States. Public efforts to invest and leverage private risk capital are crucial. Initiatives like the Capital Markets Union or the creation of a pan-European Venture Capital 'Fund of Funds' aiming at making European capital markets deeper, broader, better integrated and with greater capacity to leverage business resources will help bridge this gap.

#### **8. Strengthen the pace of structural reforms and improve framework conditions for the creation, growth and orderly exit of firms, to unlock resources from unproductive companies**

Continuing structural reforms that allow markets to react better and faster to the changes that innovations bring to the markets and which facilitate the entry, as well as the orderly exit of firms, will help reallocate resources towards the most innovative and productive companies, avoiding the negative lock-in of resources in unproductive and zombie companies.

#### **9. Raise R&I capacity across the EU**

Bridging the innovation divide in Europe in order to build the foundations of sustained growth across all Member States and regions will require renewed efforts to sustain investments in R&I and other intangible assets. It will also require the design, implementation and evaluation of the necessary accompanying reforms to boost the quality, efficiency and institutional capacity in R&I. The mobilisation of national and European resources towards these activities will bring scientific excellence and impactful innovation performance.

#### **10. Europe must capitalise on the increasingly global innovation landscape by opening up its science and innovation to the world**

As the global R&I landscape has changed profoundly with the rise of new innovation poles, Europe needs to ensure that it capitalises on all the new knowledge that is created around the world by building strong R&I partnerships and supporting the strengthening of R&I capacity in other countries, so that global knowledge can quickly expand and more countries can contribute to and benefit from global progress.

## Avenues for future analysis

The current analysis has unveiled a number of areas where there is a lack of sufficiently robust evidence to underpin policy decisions. These include:

- ▶ How can public R&D investment better leverage private R&D investment? What role is there for mission-led public R&I to increasingly mobilise public and private R&D investments?
- ▶ How can investment in intangible assets support innovation and innovation diffusion and what mechanisms are in place at the microeconomic level?
- ▶ How can synergies between R&I, ICT, skills and social policies be best ensured for more impactful innovations with a wider sharing of benefits in society?
- ▶ How is the current level of innovation concentration, notably in the United States, affecting the creation of a level playing field where incumbents and new entrants can compete fairly? What role is there for regulation and competition policy, notably in relation to data use?
- ▶ How do labour and market regulations affect skills development and innovation diffusion in a digitised economy?
- ▶ How can R&I policy instruments best support the diffusion of innovation?

These are areas where we will continue to work to shed more light and reduce the uncertainty that the current changes in innovation dynamics are creating for the purpose of policy formulation.

The current Report presents profound insight into several of these areas in Part II.



# CHAPTER

# I

# CHAPTER

# I.1



# INTRODUCTION

After several years of economic, political and social crisis, Europe is now ready to set the foundations for its future. In contrast to enhanced uncertainty in the United States, the European Union (EU) is increasingly perceived as an area of stability, which opens up new opportunities. New and bold economic and political initiatives are being put forward in order to leave the crisis mode behind and put Europe into a construction mode. Resilient economic growth at around 2% has returned; employment rates are high, and pan-European reinvigorated political support for bolder European initiatives seems to be gaining strength.

While these are all positive signals, Europe needs to ensure that the recovery solidifies, not only from a macroeconomic perspective, but also from a microeconomic perspective, so that people see Europe as a platform that supports social and economic prosperity for all. In other words, Europe needs to ensure solid economic growth that creates new opportunities for larger segments of the population and helps to fund our ambitious and inclusive social system.

However, productivity growth remains sluggish and is holding back stronger economic growth. The rise and diffusion of new technologies, such as The Internet of Things, big data, artificial intelligence or robotics promises large market-creating disruptive innovations and productivity gains, but also generates uncertainty and risks about potential negative effects on jobs and inequality.

In this changing context, more than ever before, research and innovation (R&I) are regarded as crucial drivers of Europe's competitiveness and its ability to ensure solid economic and social prosperity by setting sturdy foundations for the present and notably the future of our societies.

It is against this backdrop that this Science, Research and Innovation Performance 2018 Report ('The Report') analyses the long-term forces that shape the role and expectations that society places on R&I, the dynamics that change the nature and impacts of innovation in a digitised society, as well as the R&I performance of Europe and its Members States. The objectives of this analysis are to provide analytical foundations for evidence-based policymaking, identify areas where more research and analytical work is needed, and contribute to the debate on how R&I policies should be shaped and adapted to today's dynamic changes in the innovation landscape, so that their economic and societal impacts can be maximised.

More precisely, to achieve these goals, the Report is organised into two main parts. Part I depicts an indicator-based macro-analysis to provide an overview of the R&I ecosystem in Europe, focusing notably on the influence of R&I on productivity growth and on shaping the work world of the future and, through it, affecting the patterns of inequality. It also identifies Europe's main strengths and weaknesses in a global context, as well as differences across Member States, paying particular attention to the evolution of the innovation divide

in Europe. In so doing, it analyses investment levels and trends in R&I and other intangible assets; scientific performance and notably scientific excellence; knowledge flows and their determinants; technological and innovation performance; the framework conditions for R&I; as well as transformative entrepreneurship and shifts in the economic structure towards higher added value. In addition, Part I also benefits from a set of reflections and qualitative analyses contributed by renowned experts in particular fields to complement the indicator-based analysis. These reflections aim at stimulating the debate and deepening our understanding in areas such as the role innovation plays in an ageing society and in the future of energy or how skills and R&I and social policies behave in a rapidly changing economy that seems to alter 'our social contract' model.

Part II of the Report complements the macro-based analysis in Part I by presenting micro-oriented analysis and conceptual work carried out by leading scholars and researchers from international organisations, academ-

ic institutions and think-tanks, such as the Organisation for Economic Co-operation and Development (OECD), the European Investment Bank (EIB), Bruegel, UNU-MERIT and the European Commission's DG Joint Research Centre. These analyses aim to provide 'deep insight' into particular fields of interest, i.e. the complementarity between R&D and ICT, the degree of concentration of R&D, employment and sales in "superstar firms", productivity and wage divergence patterns across companies, differences in productivity across regions and sectors among large R&D investors, the role and conditions for financing innovation, and the role of mission-oriented public research.

The Report builds on a long tradition of indicator and economic analysis at the European Commission's Directorate-General for Research and Innovation, and as the second edition of this biennial publication, it complements other reports such as the European Innovation Scoreboard<sup>1</sup>, the EU R&D Industrial Investment Scoreboard<sup>2</sup> and the European Research and Innovation Area (ERA) Progress Report<sup>3</sup>.

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1 [http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards\\_en](http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en)

2 <http://iri.jrc.ec.europa.eu/scoreboard16.html>

3 [http://ec.europa.eu/research/era/eraprogress\\_en.htm](http://ec.europa.eu/research/era/eraprogress_en.htm)

# CHAPTER

# I.2

# INNOVATION, PRODUCTIVITY, JOBS AND INEQUALITY

Research and innovation (R&I) are widely regarded as crucial drivers of economic and social prosperity. Their impacts have been widely documented by a wealth of theoretical and empirical literature<sup>1</sup> (European Commission, 2017) showing their crucial contribution to fostering economic growth, create new and better jobs, improve health outcomes and develop new sustainable energy technologies that can help fight and mitigate climate change. The nature and impacts of R&I are affected by a set of long-term forces, such as digitalisation, globalisation, demographics of climate change which, on the one hand shape innovation, and on the other hand determine the role that R&I plays in ensuring prosperity.

Against this backdrop, this chapter analyses some of these long-term forces shaping the nature of R&I, and identifies the existing and expected impacts of R&I on productivity, jobs, skills and inequality.

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1 See European Commission (2017): 'The Economic rationale for public R&I and its impacts', for a review of the economic impacts of R&I in general, and public R&I in particular.

## CHAPTER 1.2 – A: LONG-TERM FORCES SHAPING INNOVATION

*Our economies and societies are constantly being shaped by long-term forces that influence our needs as well as the role and impact R&I have in addressing these needs.*

Our needs as a society are constantly evolving and are largely influenced by a set of powerful, long-lasting and intertwined social, economic, technological and environmental forces. These forces, once they start to kick in, have deep and long-lasting effects on our societies, largely shaping our needs and influencing the role, nature and impact that R&I have in addressing those societal needs: from ensuring broad-base prosperity, to improving health outcomes, mitigating climate change and achieving macroeconomic stability.

While there are many of these forces at play, ranging from increasing urbanisation to changing family and household structures and global migration patterns, there are four forces that we would like to focus on, given their particular importance in shaping R&I policy responses. These forces are demographics, and notably Europe's ageing population, globalisation, climate change, and digitalisation and the emergence of digital technologies.

*Demographics, and notably Europe's ageing, is a crucial force that affects the expectations we place on R&I to support future growth and address the demand for ageing-related innovations.*

Europe's population has rapidly aged due to the lower birth rates and higher life expectancy that has drastically transformed what used to be called the demographic pyramid, with the larger share of the population concentrated among younger generations. Currently, the larger share of population by age cohorts tend to be located around the 45-55 age range, with a large number of 'baby boomers' approaching retirement. This ageing of the population is expected to intensify in the coming years thanks to further improvements in life expectancy and stagnation in the current low birth rates. As a result, we expect larger cohorts of population in the older age groups, with notable increases in the groups of 65 years and over.

This ageing of the population will have consequences for R&I at different levels. Notably, there will be increasing reliance on innovation to drive productivity and economic growth, due to the impossibility to rely on a growing labour force or given the need to develop more and more age-related innovative products and services to match the growing demands of an ageing population<sup>2</sup>.

2 For further information, see European Commission (2017): 'Employment and Social Developments in Europe' Annual Review (pp. 56-67).

## BOX 1: ‘Unfavourable’ demographic change in Europe

*Dr Stuart Gietel-Basten – The Hong Kong University of Science and Technology*

Demography in Europe is rarely far from the top of the agenda.

Europe’s population is ageing<sup>3</sup>. In some parts of Europe – especially at the regional level<sup>4</sup> – population is also declining<sup>5</sup>. The refugee crisis has generated widespread concern about the relationship between Europe and its territorial neighbours (and near neighbours) in terms of migration. Finally, it could be argued that Brexit is as much a rejection of freedom of movement within movement as a rejection of the politics of the EU.

These demographic concerns are often linked to a wide variety of policy issues: ranging from voting behaviour to the sustainability of social welfare and healthcare systems; and from the cultural and political impact of migration through to the future of depopulated, rural areas. But how are these demographic changes linked to innovation?

The most standard narrative we read is that all these demographic changes will be bad for innovation and research in Europe.

As the older-age population grows, public money will necessarily be diverted into the maintenance of pension and healthcare systems. Expenditure on social care, in particular, is likely to balloon. This could have an impact upon public bodies continuing to act as the main client for research and innovation services around Europe.

On the other hand, the younger population will see a continual decline across almost all of Europe. Given that this particular age group is strongly associated with a greater flexibility in terms of willingness to move as well as in terms of the capacity to pick up new technologies, this is also seen as an important potential brake on innovation.

There is also the possibility that positive feedback loops can develop. Population ageing and decline is classically associated with (beyond a certain level) lower overall levels of economic growth and productivity, having an impact upon, among other things, public tax receipts. Similarly, as the electorate ages (and as politicians look for support) pro-elder bias can feature in government spending plans<sup>6</sup> – once again impacting on expenditure on education, research and innovation.

Finally, we have already seen the impact that threatening European freedom of movement has had on research and innovation in the wake of Brexit<sup>7</sup>. As well as potentially losing access to EU funding streams, the emigration of a sizeable number of EU scientists shows how important access to stable migrant status is. This is an issue not just for the UK, but for the EU as a whole, given that 53.5% of UK international collaborations in science are with EU partners<sup>8</sup>.

So far, so gloomy.

3 Rechel, B. et al. Ageing in the European Union. *Lancet* 381, 1312-1322 (2013).

4 Bayona-i-Carrasco, J. and Gil-Alonso, F. Is Foreign Immigration the Solution to Rural Depopulation? The Case of Catalonia (1996-2009). *Sociol. Ruralis* 53, 26-51 (2013).

5 Coleman, D. and Rowthorn, R. Who’s afraid of population decline? A critical examination of its consequences. *Popul. Dev. Rev.* 37, 217-248 (2011).

6 Vanhuyse, P. Intergenerational Justice and Public Policy in Europe. *Eur. Soc. Obs. Pap. Ser. Opin. Pap. No. 16* (2014).

7 Gietel-Basten, S. Why Brexit? The Toxic Mix of Immigration and Austerity. *Popul. Dev. Rev.* 42 (2016).

8 Stokstad, E. U.K. scientists prepare for impending break with European Union. *Science* (80) (2017). doi:10.1126/science.aal0908

## A role for innovation in the face of Europe's demographic 'challenges'

There is, however, an alternative view. Rather than seeing these demographic changes as solely 'unfavourable', we could rather think of them as being 'challenges' in the truest sense of the word; of being a new set of circumstances requiring a more innovative response.

Throughout history, technological bottlenecks have been overcome as a consequence of a high degree of pressure on the prevailing system. In this sense, an ageing population could serve as a *driver* of research and innovation. Although life expectancy and longevity are generally increasing, there is still uncertainty about the extent to which the period of life spent with chronic disease and mobility-functioning loss is declining or, indeed, increasing<sup>9,10,11</sup>. In this vein, while medical and public health innovations have been instrumental in almost eradicating infectious disease and childhood mortality in Europe, leading to ever longer life expectancy, the need for innovation and research to 'compress morbidity' – especially in older age – has never been greater.

Furthermore, the particularities of older-age chronic illness are such that the boundaries between health and social care are becoming ever more blurred – see, for example, the European Commission's Fifth Framework Programme pro-

ject 'Providing integrated health and social care for older persons'<sup>12</sup>. It is possible to argue that it is *socially* demographically more demanding, in the sense of patients requiring ongoing physical support. Given the future squeeze on the potential pool of labour to work in social care – and the unwillingness of many young people to work in this sector – this clearly presents another set of demographic 'challenges'. The traditional response has been the 'plug this gap' with a demographic solution – through the immigration of social care workers. However, the demand for innovation and research into new systems of social care has never been higher because of changes in both the demands of the ageing population and the supply of labour.

As well as general solutions and innovations, the emerging field of gerontechnology is gathering pace, especially in the rapidly ageing societies and technology-embracing states of East Asia<sup>13</sup>. This field is seeing significant developments in innovations in the prevention, diagnosis and management of chronic illness. As well as general innovations to support well-being, more finely-honed developments can be seen – see, for example, the EC-funded project on using ICT devices to prevent falls in the home<sup>14,15</sup>. Furthermore, with greater stress now on being person-centred, these innovations can have a significant impact on quality of life and the capability of older people to 'age in place' rather than be moved into institutional care<sup>16</sup>.

9 Cutler, D., Ghosh, K. and Landrum, M.B. *Evidence for Significant Compression of Morbidity In the Elderly U.S. Population*. (2013). doi:10.3386/w19268.

10 Crimmins, E.M. and Beltrán-Sánchez, H. Mortality and morbidity trends: is there compression of morbidity? *J. Gerontol. B. Psychol. Sci. Soc. Sci.* 66, 75-86 (2011).

11 Heger, D. and Kolodziej, I.W.K. Changes in morbidity over time: Evidence from Europe. *Ruhr Econ. Pap.* (2016).

12 Leichsenring, K. Developing integrated health and social care services for older persons in Europe. *Int. J. Integr. Care* 4 (2004).

13 Graafmans, J.A.M. The Emerging Field of Gerontechnology.

14 Università di Bologna. Farseeing. Available at: <http://farseeingresearch.eu/about-us/> (Accessed: 27 June 2017).

15 Jansen, S., Boye, N., Becker, C., Mellone, S. and Chiari, L. Fall prevention and gerontechnology. *Eur. Geriatr. Med.* 4, S2 (2013).

16 Peek, S.T.M. et al. Factors influencing acceptance of technology for aging in place: a systematic review. *Int. J. Med. Inform.* 83, 235-248 (2014).



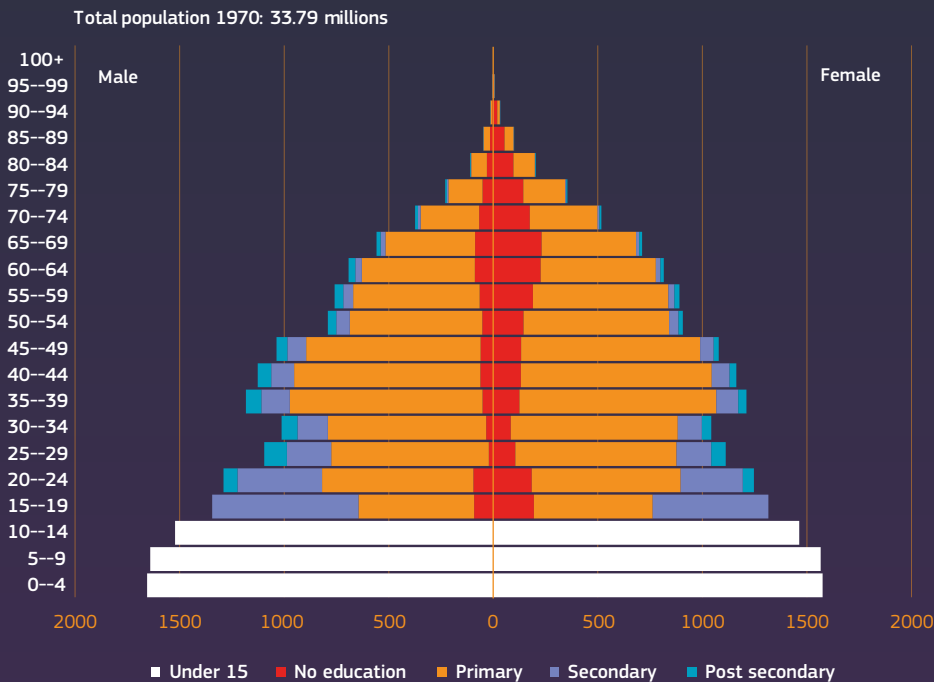
## Demographic ‘potential’

Europe’s demographic travails are well known. But as well as considering the overall shape of the population, it is just as important to consider its characteristics. Take Spain, for example. It is well known that Spain is one of Europe’s most rapidly ageing countries<sup>17</sup>.

Figure A compares not only the age structure of past, present and future Spain, but also lev-

els of educational attainment<sup>18</sup>. We can see, of course, the change in the age structure of the population between 1970 and today, in particular the transition to an aged population over the next decades. However, we can also see a complete revolution in the levels of educational attainment among the Spanish population – ageing between 1970 and today, and forecast into the future. This kind of transition is common throughout Europe<sup>19</sup>.

Figure A: Spain - population by age-group and educational attainment



Science, Research and Innovation performance of the EU 2018

Source: WIC Data Explorer <http://witt.null2.net/shiny/wic/>

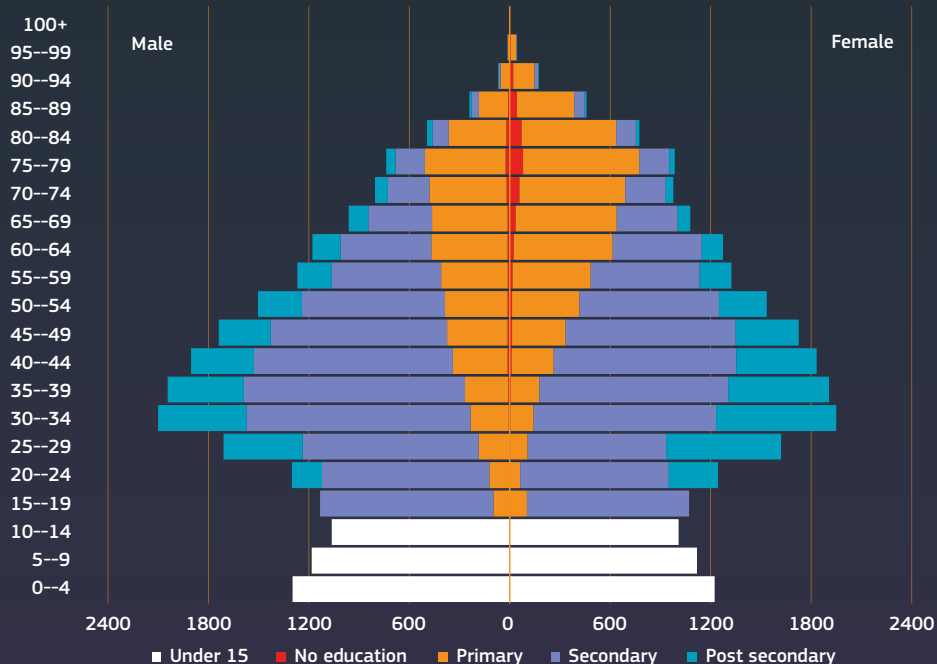
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/box\\_a\\_1970.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/box_a_1970.xlsx)

17 Costa-Font, J., Elvira, D. and Mascarilla-Miró, O. ‘Ageing in Place?’ Exploring Elderly People’s Housing Preferences in Spain. *Urban Stud.* 46, 295-316 (2009).

18 WIC Wittgenstein Centre Graphic Explorer (2015).

19 Kc, S., Barakat, B., Goujon, A., Skirbekk, V. and Lutz, W. Projection of populations by level of educational attainment, age, and sex for 120 countries for 2005-2050. *Demogr. Res.* 22, 383-472 (2010).

Total population 2010: 46.08 million

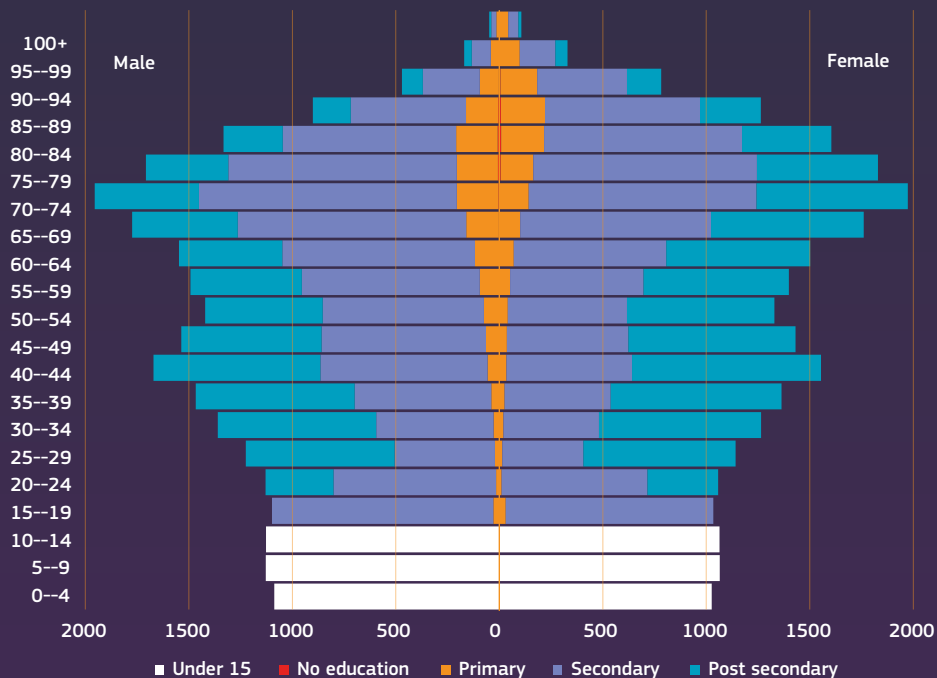


Science, Research and Innovation performance of the EU 2018

Source: WIC Data Explorer <http://witt.null2.net/shiny/wic/>

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/box\\_a\\_2010.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/box_a_2010.xlsx)

Total population 2050: 51.53 million



Science, Research and Innovation performance of the EU 2018

Source: WIC Data Explorer <http://witt.null2.net/shiny/wic/>

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/box\\_a\\_2050.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/box_a_2050.xlsx)

First, this means that while we see an older population, we also see a population which is better educated and healthier. The *potential* for this population to engage in changes in innovation is great – and at all ages. The pool of younger people who have the potential to move into innovation through university, skilled apprenticeships and vocational training is high. The higher skill set means that retraining and reskilling to meet the changing demands of the workforce as well as in response to developments in innovation are likely to be more feasible. As cohorts age, comfort with technology and ‘digital literacy’ will increase, again *potentially* leading to a more inclusive gerontechnology. Under these circumstances of a levelling out of educational attainment by cohort, the traditional linear relationship between age and adaptability to technology is likely to change, which could offset some of the demographic ‘challenges’ outlined above. It is not unreasonable to see entrepreneurship and innovation at the micro-level grow under these conditions.

Furthermore, the current ‘refugee crisis’ in Europe has the potential to be turned from what is being presented as a ‘demographic challenge’ to a boon. It has been suggested that such migration could serve to mediate the overall impact of population ageing and decline. Looking at policies to boost labour supply in Germany, for example, the IMF cites “integrating the current wave of refugees into the labour market” as a key area for development<sup>20</sup>. It is important to remember, however, that such ‘replacement migration’ is unlikely to have any meaningful impact on the macro-demographic circumstanc-

es of the continent<sup>21</sup> in terms of reducing the dependency ratio between workers and pensioners.

A more focused approach, however, involves exploring the skill set of said refugees. Many of those affected are highly skilled workers who can contribute to the development and implementation of research and innovation across the continent as well as plugging skills gaps. In this sense, the EC’s *science4refugees* initiative to “provide research refugee friendly internships, part-time and full-time jobs, access to a European Research Community, as well as a complete range of information and support services on working and living in Europe” has the potential to reap significant rewards<sup>22</sup>. Again, in terms of meeting demographic challenges, it is as much the characteristics of the population as the size.

### Innovation as a ‘silver bullet’

As noted earlier, the number of younger people in Europe is forecast to decline over the coming decades. Indeed, in many countries this will be the continuation of a downward trend. To take just one example: in the Czech Republic, the population aged 20–24 peaked at around 900 000 in 1998. Since then, as a consequence of lower fertility and emigration, it has fallen by roughly a third to 615 000 in 2015; and is estimated to fall further to around 415 000 by 2022<sup>23</sup>.

Looking at the long-run of human history, a scarcity of labour has usually resulted in an upturn in overall employment rates as well as

20 IMF. Germany: Staff Concluding Statement of the 2016 Article IV Mission. (2016). Available at: <https://www.imf.org/en/News/Articles/2015/09/28/04/52/mcs050916> (Accessed: 27 June 2017).

21 Bijak, J., Kupiszewska, D. and Kupiszewski, M. Replacement Migration Revisited: Simulations of the Effects of Selected Population and Labor Market Strategies for the Aging Europe, 2002–2052. *Popul. Res. Policy Rev.* 27, 321–342 (2008).

22 European Commission. Commission launches initiative to help refugee scientists and researchers - News Alert. *EC Research & Innovation* (2016). Available at: <http://ec.europa.eu/research/index.cfm?pg=newsalert&year=2015&na=na-051015> (Accessed: 27 June 2017).

23 UNPD. World Population Prospects: The 2015 Revision. *World Population Prospects: The 2015 Revision* (2015). Available at: <http://esa.un.org/unpd/wpp/DVD/> (Accessed: 4 August 2015).

improved wages and conditions. The high levels of wage inflation in China, for example, are a response to this demographic ‘tightening’ of the labour force<sup>24</sup>.

However, rather than being a golden age for labour in Europe, unemployment – and especially youth unemployment – is high. Furthermore, Europe’s labour force – especially among the young and migrants – is increasingly being characterised by instability and fragility<sup>25</sup>. This is certainly acute in Spain, the country given as an example above. In addition, it is impossible to deny the potential for innovation to strip Europe of ever more jobs. Indeed, there is a website which allows you to insert your job and then presents the probability that you will be supplanted by a robot over the next decade<sup>26</sup>. In 2015, for example, it was claimed that nearly half of all jobs in Japan could be performed by robots<sup>27</sup>.

This last example presents just one view which could lead us to take a more cautious approach to the relationship between demographic and technological change. While innovation could solve many demographic challenges, it can also present others. As a worst-case scenario, for example, job-sapping innovation without retraining, reskilling and decent employment in other sectors, coupled with a growing pro-elderly bias,

could have a catastrophic effect on Europe’s young population. Indeed, the authors of a recent report on work and technology state that: “At the policy level ... rather than offsetting the challenges from shrinking and ageing populations, rapid technological change may offer another layer of growing challenges, potentially complicating the necessary policy response and possibly magnifying it”<sup>25</sup>. To summarise, what is needed is not just a strong research and innovation policy to cope with the demographic challenges Europe faces but, just as importantly, a strong demographic policy to cope with the challenges that innovation will bring! This demographic policy will involve thinking hard about the relative value of different sources of labour as well as the sustainability of work in different fields. It will also require a revolution in skills training to ensure that Europe’s younger population are able to reap the benefits of automation, rather than be its victims. It will require more careful thought, too, to avoid negative unintended consequences. If we are able to completely remove the role of the (expensive) care worker from the home as a result of changes in innovation, what impact might this have on loneliness and mental well-being?

Finally, a holistic set of policies which consider both the challenges and possibilities of changes in demography as well as innovation is urgently required.

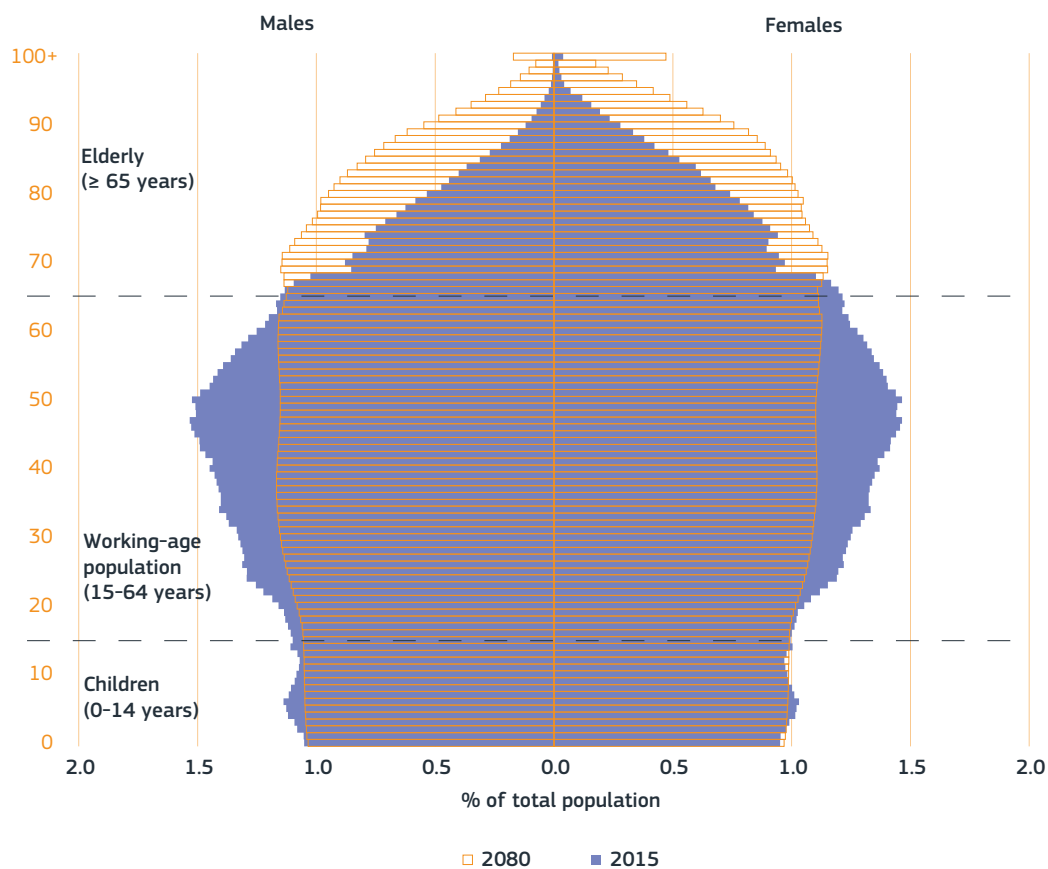
24 Heerink, N. et al. China has reached the Lewis turning point. *China Econ. Rev.* 22, 542-554 (2011).

25 Emmenegger, P., Hausermann, S., Palier, B. and Seeleib-Kaiser, M. *The Age of Dualization: The Changing Face of Inequality in Deindustrializing Societies* (2012).

26 @mubashariqbal. Will a Robot Take My Job? <https://willrobotstakemyjob.com/> (2017). Available at: <https://willrobotstakemyjob.com/>

27 Citi GPS & Oxford Martin School. *Technology at Work 2.0: The future is not what it used to be* (2016).

**Figure I.2-A.1** Projected evolution of the EU population by age group between 2015 and 2080



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

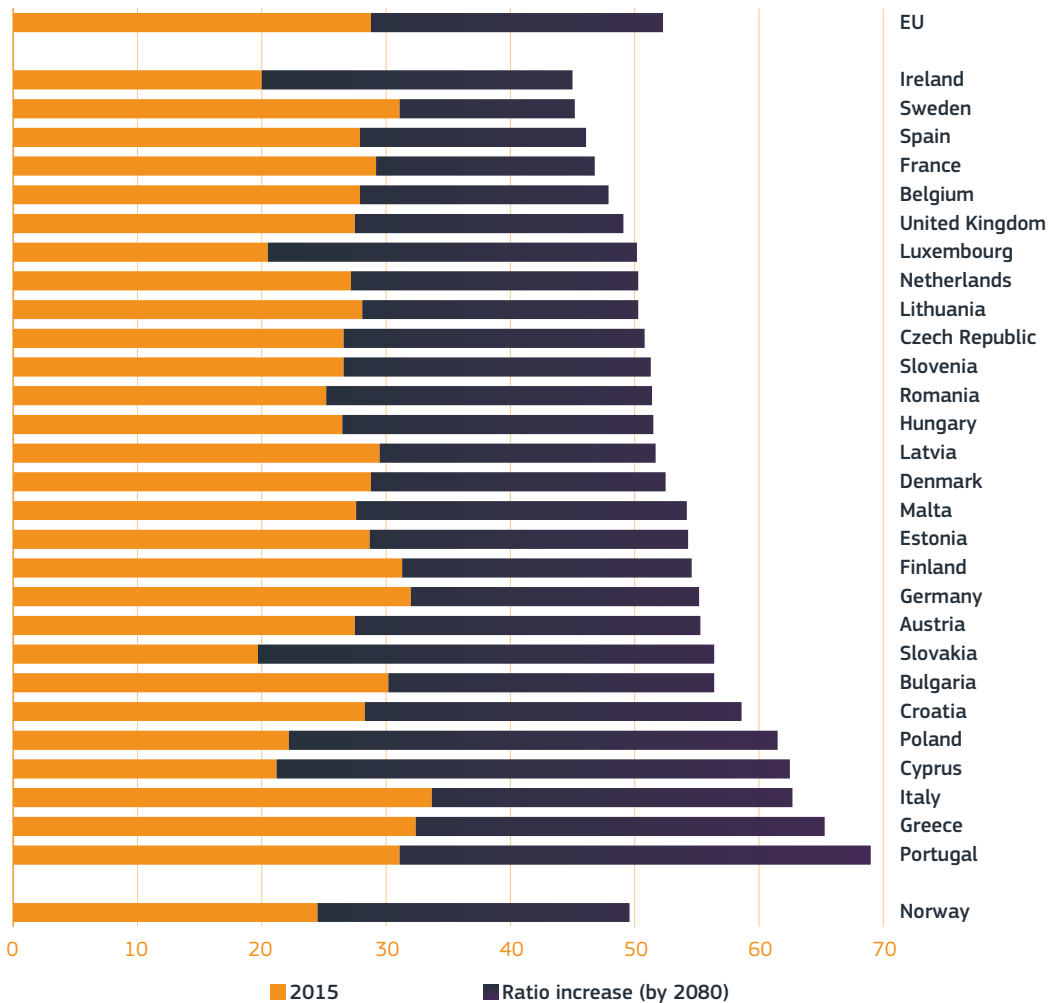
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/fi2a1\\_population\\_pyramid.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a1_population_pyramid.xlsx)

*Innovation will also need to play a crucial role to sustain social cohesion and public finances, as the old age dependency ratio, or the ability of those actively working to sustain those who are on a pension, is expected to increase significantly.*

As a result of an ageing population, the dependency ratio, or the share of people who are

not actively working and who will need to be supported by those who are actively working, will increase to a large extent<sup>28</sup>. To ensure social cohesion and sustainable public finances, large productivity gains, driven by innovation, will be required. This places enhanced expectations about the role that R&I will have to play to support future shared prosperity.

**Figure I.2-A.2 Old-age dependency ratio, 2015 and 2080**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/fi2a2\\_old\\_age\\_dependency.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a2_old_age_dependency.xlsx)

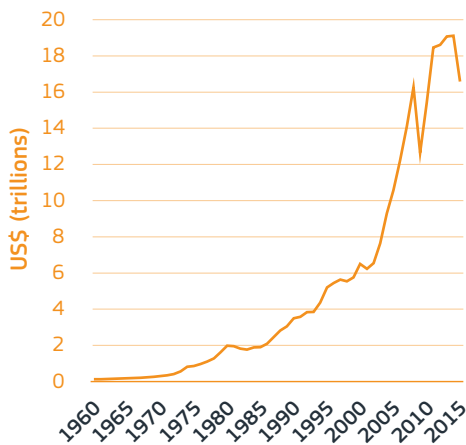
<sup>28</sup> It is likely that new forms and organisation of work arrangements may be established to allow people over retirement age to continue working in different schemes, which should help to partially alleviate the explosion in the dependency ratio.

*Globalisation, and the rise of an increasingly interconnected global economy, following improvements in technology and transportation, are leading to increasing levels of global trade and investment.*

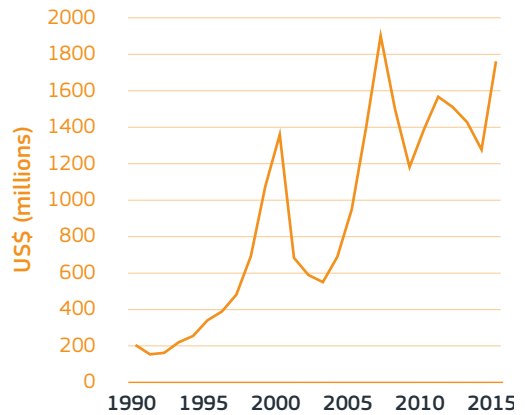
Technological progress has facilitated and reduced the costs of transportation and commu-

nication activities across the globe. Coupled with a global trend of policy liberalisation in the past decades, and despite recent concerns, this has led to an exponential increase in global trade and investment, notably in the last couple of decades and despite the global and financial crisis.

**Figure I.2-A.3** World merchandise exports in trillions of current US dollars, 1960-2015



**Figure I.2-A.4** World inflows of foreign direct investment (FDI) in millions of current US dollars, 1990-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: World Bank - World Development Indicators, UNCTAD (World Investment Report 2016)

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/fi2a3\\_and\\_fi2a4\\_exports\\_and\\_fdi.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a3_and_fi2a4_exports_and_fdi.xlsx)

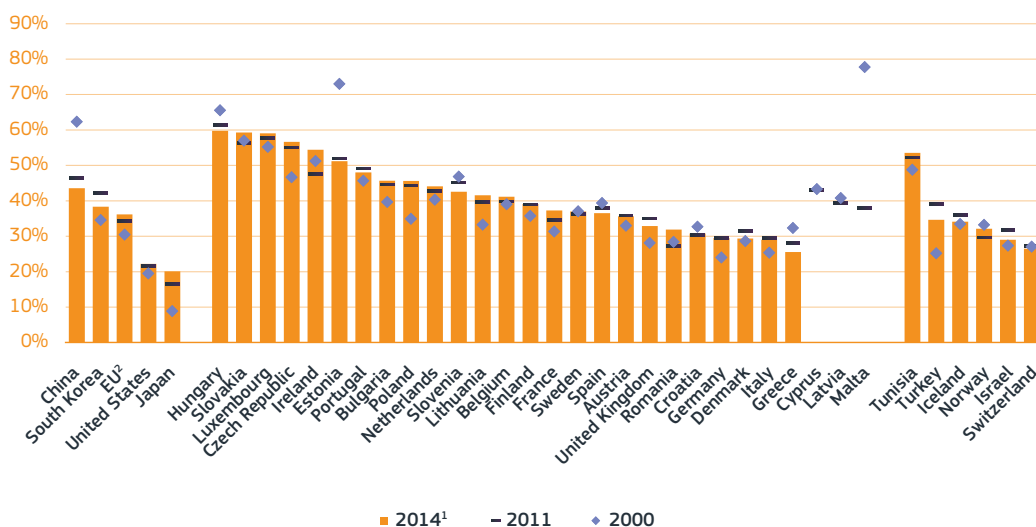
*This increase in trade and investment facilitates the rise of global value chains and the emergence of several production and innovation hubs that transform our economies and change the way in which R&I and production activities have been typically organised.*

Globalisation has allowed companies to reorganise their operations, optimising different parts of their production processes across different locations in order to benefit from the specific assets existing in each location. This has given rise to global value chains, where much of the production and value added is produced in different locations. For some

economies, the share of foreign value added from its production is very large, even above the 50% threshold, and overall, this has been increasing over time. This process has provided significant benefits to society<sup>29</sup>, but has also given rise to public concerns associated with job losses and downward pressures on wage and working conditions in Europe.

In addition, globalisation has also had deep consequences for R&I. As new innovation hubs emerge, international knowledge flows become increasingly important for the expansion of domestic knowledge. Moreover, the location of R&I activities sometimes follows production patterns.

**Figure I.2-A.5 Foreign value added share (%) of gross exports in high-tech and medium-high-tech sectors, 2000, 2011 and 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD Trade in Value Added (TiVA) Database

Notes: <sup>1</sup>The nowcast approach was used for 2014. <sup>2</sup>EU for 2014 was estimated from the available data and does not include CY, LV and MT.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/fi2a5\\_foreign\\_va\\_ht\\_mht.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a5_foreign_va_ht_mht.xlsx)

29 The European Commission estimates that about one-fifth of the increase in living standards of the EU-15 (countries with EU membership before 2004) over the past 50 years can be attributed to world economic integration ([https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/international-economic-relations/globalisation-and-eu-economy\\_en](https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/international-economic-relations/globalisation-and-eu-economy_en)).

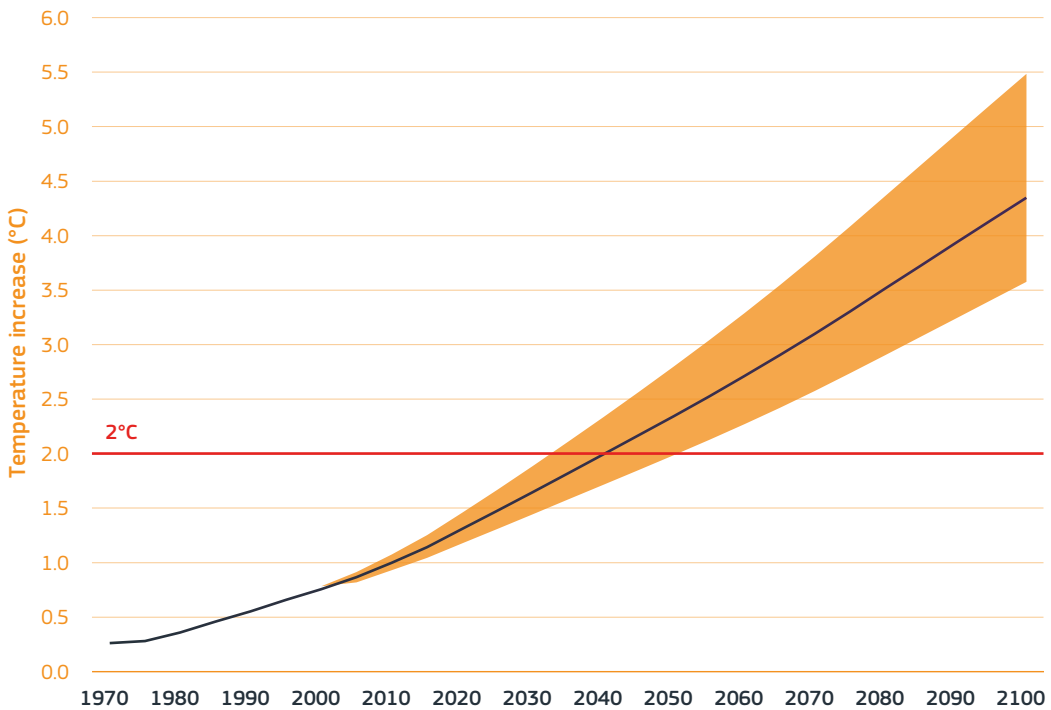


*Innovation is also required to mitigate the devastating consequences of climate change and its associated rise in global temperatures.*

As the European Commission underlines<sup>30</sup>, climate change is expected to have significant impacts on natural resources, the world economy and human health. It will bring about higher temperatures, rising sea levels, altered precipitation patterns and increased frequencies

of extreme weather events such as floods and droughts. Such impacts will occur even if the world achieves the objective of limiting global temperature increase to within two degrees above its pre-industrial level. Tackling climate change will require the adoption of several policy measures to avoid the current trend in temperature upswing that could lead to an average temperature increase of between 3 and 6 degrees by 2100, with devastating consequences.

**Figure I.2-A.6** Long-run temperature increase: Baseline 1970-2100



Science, Research and Innovation performance of the EU 2018

Source: OECD Environmental Outlook Baseline

Note: Baseline scenario refers to temperature rises following the current dynamics with no measures being adopted.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/fi2a6\\_temperature.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a6_temperature.xlsx)

30 <https://ec.europa.eu/jrc/en/research-topic/climate-change>

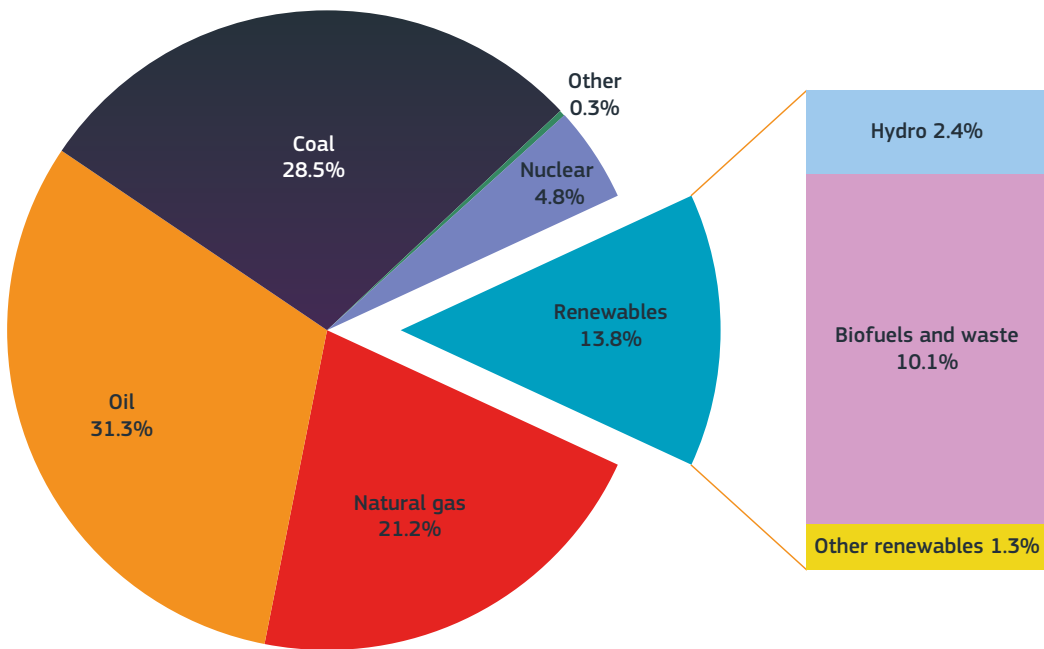
***Innovation is particularly important to enable non-polluting affordable sources of energy.***

Coordinated global efforts must be adopted to reduce and mitigate the risks of climate change by *inter alia* reducing emissions of greenhouse gases. This will require the development of less-polluting and affordable energy sources. Currently,

around 80% of the global energy mix relies on coal, oil or gas.

The adoption and transformation of our current energy system to make it more sustainable and accessible will require adopting R&I-enabled technologies and innovations.

**Figure I.2-A.7 Global energy mix - energy sources in world total primary energy supply - % shares, 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: International Energy Agency (IEA)

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-a\\_figures/fi2a7\\_global\\_energy\\_mix.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a7_global_energy_mix.xlsx)

## BOX 2: The future of energy in an interconnected world

*Prof. Laura Diaz Anadon - Professor of Climate Change Policy - Department of Land Economy - University of Cambridge, United Kingdom*

Energy is essential to the well-being of human kind. Energy sustains life and economic activity, with major societal transitions since the Industrial Revolution being inextricably linked to changes in the use of different forms of energy. The replacement of human and animal power with coal and the steam engine in the 18th century changed how people lived, made things and travelled. The emergence of the internal combustion engine at the end of the 19th century and the large-scale use of other fossil fuels (oil and gas) and of nuclear power in the 20th century have similarly shaped the structure of our economy and society. Because energy is intertwined with almost every aspect of the human enterprise, it is not surprising that the provision and distribution of energy alone is a multi-trillion-dollar business each year.

Yet, in spite of the enormity of the scale of the energy sector globally and its contribution to improving the standard of living of many, the energy system we rely upon is at a crossroads. Addressing some of the most difficult challenges of the 21st century, including improving energy access and economic development while reducing the health and environmental impacts of energy, will require a major transformation of our energy system in just a few decades.

Poverty alleviation is a key major driver of energy transformation. As of 2016, the International Energy Agency estimates that 1.2 billion people are still without access to electricity, mainly in sub-Saharan Africa, and over one-third of the world's population (2.7 billion people) rely on traditional biomass for cooking (mainly in developing Asia and, to a lesser ex-

tent, in sub-Saharan Africa). It has long been recognised – and recently codified in the 7th Sustainable Development Goal in 2015 which aims for universal access to modern energy services by 2030 – that access to modern energy is an essential precondition for socio-economic development.

Addressing the significant adverse health effects from air pollution is another pressing challenge facing our energy system. The lack of access to modern sources of energy, mainly in rural areas in low-income countries, is estimated to lead to 3.5 million deaths per year from indoor air pollution. Health harms from the current energy system are not limited to low-income countries. The World Health Organization attributes 3 million deaths globally every year to outdoor (as opposed to indoor) air pollution, mainly from the combustion of fossil fuels in power plants and vehicles. Of these, 87% occur in low- and middle-income countries, with almost 300 000 of the 400 000 deaths in high-income countries taking place in Europe.

The environmental impacts of the energy system on air, water and land pollution as well as biodiversity have been the subject of much policy action since the second half of the 20th century. By the start of the new millennium, reducing the contribution of our fossil-based energy system to global climate change became a major additional driver for the energy transformation. The Intergovernmental Panel on Climate Change points to severe risks from not taking stronger action to address climate change, including accelerated sea-level rise,

larger and more frequent drought and fires (with impacts on food and water availability), and loss in fisheries and biodiversity, among many others. Indeed, climate change is arguably the largest and most difficult challenge posed by our energy system.

Some progress has been made, as exemplified by the fact that the energy sector's contributions to greenhouse gas (GHG) emissions have remained flat over the past three years, but there are three key reasons why it is difficult to reduce energy GHG emissions sufficiently and in a timely manner.

First, the magnitude of the change needed is vast. Over three-quarters of the world's energy still comes from fossil fuels (from oil, coal and natural gas, in that order) which, combined with the scale of such systems, explains why the production and use of energy are responsible for two-thirds of the world's GHG emissions. Thus, to meet the 2015 Paris Agreement goal to limit the global average temperature to 2°C above pre-industrial levels, the energy system – which is made up of costly and long-lived physical infrastructures and strong institutions and interests – will require very substantial decarbonisation in just a few of decades. Second, it is difficult to mobilise decisive action to tackle a problem that will see most (but not all) of its damage in the future and costs today. And third, addressing climate change is a global problem, which no individual action or nation alone can address – i.e. the concentration of anthropogenic GHG in the atmosphere is the product of everyone's behaviour across the world. Even though the Paris Agreement was an important step towards mobilising global action, it is widely considered to be insufficient.

In spite of these difficulties, the magnitude of the energy challenges combined with the significant economic opportunities at stake (the IEA estimates that moving to a low-carbon energy system will result in a market of US\$ 2-3 trillion a year in investment until 2050) are indubitably resulting in the beginnings of a major energy transformation driven by government policy, civil society and the entrepreneurial spirit of the private sector. While different countries and regions rely on different sources of energy to different extents and have different local contexts, and while it is impossible to say what the energy system will look like in 2030 or 2050, it seems likely that the energy system of the future will, with local variations, be more reliant on renewables and energy efficiency, electrification, a greater variety in the sources of energy for transportation, and a greater reliance on information and communications technologies.

The beginnings of the transformation to a more sustainable and accessible energy system has both contributed to and been spurred by an acceleration in technological innovation in energy technologies. This innovation is exemplified by the fact that, between 2010 and 2016 alone, the costs of solar PV modules and of lithium-ion battery packs for electric vehicles have fallen by approximately 75% and 50%, respectively (note that the cost of solar PV modules has come down by a factor of 50 since the 1980s). Since 2012, the majority of new installed power capacity worldwide has come from renewables, mainly wind and solar power; 154 GW of renewable power capacity was installed in 2015, making up 61% of all new power capacity.

Innovation in public policy, as well as in technology, has been and will continue to be instrumental in enabling the transformation of our energy system. Research has shown that the rapid pace of innovation and deployment in some key energy technologies (from nuclear power to solar panels, and from solid-state lighting through hydraulic fracturing) has often been underpinned by decades of publicly funded research combined with other relatively stable policies, most prominently support for deployment. Since the 2000s, there has been significant policy innovation and learning in countries and regions across the globe, including the design of public institutions to promote energy R&D to the design of auctions, procurement, standards, and information campaigns. As a result, there are opportunities to learn.

The size, dynamicity and prospects of these 'new' energy markets means that the EU is not alone. For example, China is now both the largest man-

ufacturer and market (in terms of deployment) of both solar panels and wind turbines. In addition, the Chinese government is positioning itself aggressively in the battery-manufacturing market through both R&D and deployment policies, in line with China surpassing the EU in terms of the R&D intensity of its economy and being on track to surpass the United States. Global competition and trade in the energy field are fierce, as demonstrated by suits brought against the World Trade Organization concerning particular national policies supporting solar and wind manufacturing.

To sum up, addressing the energy challenges also constitutes an opportunity for the EU. But it is an opportunity that will require additional, timely and innovative action by policymakers at all levels guided by a holistic and international perspective because of the nature of the needs (e.g. access, climate change), of the energy sector (e.g. trade, competition), and of the policy experimentation that has taken place.

***Digitalisation<sup>31</sup> is drastically transforming how our economies and societies are organised. It is disrupting markets through innovations that are enabled by new digital technologies.***

The significant and rapid development of digital technologies, that is transforming economic activity from atoms to bits, and the emergence of technologies such as the Internet of Things, big data, robotics and artificial intelligence, are deeply transforming our economies by enabling the development of new products and services, new business models that are deeply disrupting existing sectors and economies in general. In this respect, in one decade, only three companies that were in the top-10 ranking of companies by market capitalisation have remained in this position, one of them being Microsoft, a technology-based company closely associated with the digital revolution. In 2016, seven of the top-10 companies were associated with the ICT sector, with Apple, Alphabet and Microsoft leading the overall rankings.

The fast development of these technologies has been enabled thanks to a sharp increase in the

global levels of connectivity, the progressive convergence of the digital and physical spheres and an explosion in the creation and use of vast amounts of data<sup>32</sup> that can be increasingly used to improve the ability of goods and services to address consumers' needs or make production and delivery processes more efficient and satisfactory.

These digital technologies hold the promise of enhancing innovations by creating new and improved products and services and boosting more inclusive and sustainable growth by facilitating access to these innovations to larger segments of the population. At the same time, as these innovations are disruptive, they can deeply affect their nature, benefits and distributional impact.

***Ageing, globalisation, climate change and digitalisation are key forces that shape and shake our societies, and that provide opportunities but also introduce potential risks. These changes generate uncertainty about the role, nature and impacts of R&I and should lead us to rethink how public policies are developed and implemented, in order to maximise their impacts.***

31 A thorough revision of digitalisation and investments in ICT can be found in chapter I.3-C of the Report.

32 An example of the explosion of data creation is represented by the fact that every second there are 7549 tweets, 2.5 million emails are written, over 60 000 Google searches are carried out, 69 000 videos are viewed on YouTube, or 44 127 GB of internet traffic occurs.

**Figure I.2-A.8 Top 100 global companies (1-15) by market capitalisation, 2017 and 2009**

Company	Industry	Country	31 March 2017		31 March 2009		Change in rank between 31 March 2009 and 31 March 2017
			Rank	Market Capitalisation (US\$bn)	Rank	Market Capitalisation (US\$bn)	
Apple Inc	Technology	United States	1	754	33	94	+32
Alphabet Inc-CL A	Technology	United States	2	579	22	110	+20
Microsoft Corp	Technology	United States	3	509	6	163	+3
Amazon.Com Inc	Consumer Services	United States	4	423	:	31	-
Berkshire Hathaway Inc-CL A	Financials	United States	5	411	12	134	+7
Facebook Inc-A	Technology	United States	6	411	-	-	-
Exxon Mobil Corp	Oil & Gas	United States	7	340	1	337	-6
Johnson & Johnson	Health Care	United States	8	338	8	145	0
Jpmorgan Chase & Co	Financials	United States	9	314	28	100	+19
Wells Fargo & Co	Financials	United States	10	279	55	60	+45
Tencent Holdings Ltd	Technology	China	11	272	-	13	-
Alibaba Group Holding-Sp Adr	Consumer Services	China	12	269	-	-	-
General Electric Co	Industrials	United States	13	260	24	107	+11
Samsung Electronics Co Ltd	Consumer Goods	South Korea	14	259	53	61	+39
At&T Inc	Telecommunications	United States	15	256	7	149	-8

Science, Research and Innovation performance of the EU 2018

Source: Bloomberg and PwC analysis

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/part/i\\_2-a\\_figures/fi2a8\\_top\\_100\\_companies.xlsx](https://ec.europa.eu/info/sites/info/files/srip/part/i_2-a_figures/fi2a8_top_100_companies.xlsx)

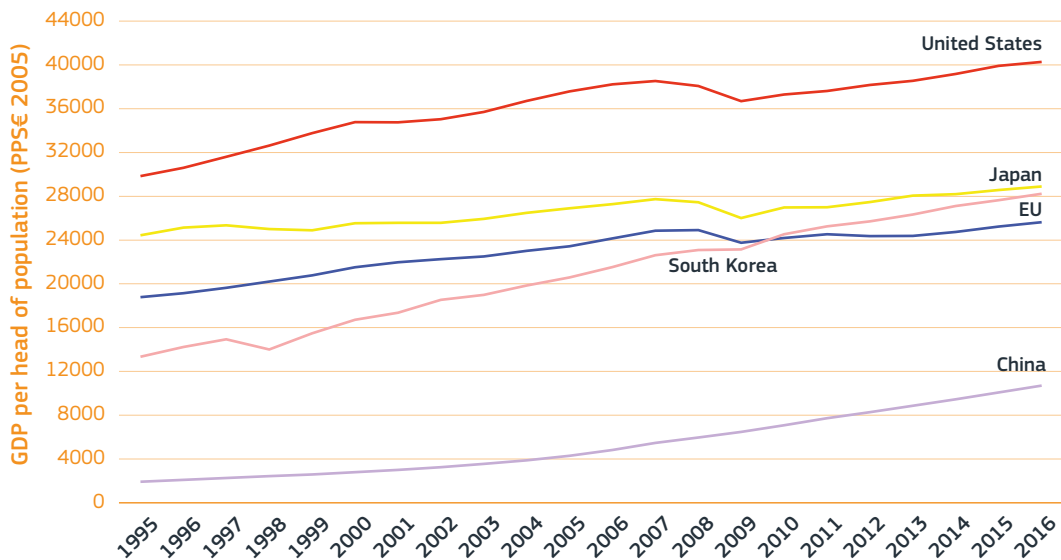
## CHAPTER I.2- B: PRODUCTIVITY AND ECONOMIC GROWTH

*Although resilient economic growth has returned, Europe will have to step up its efforts in order to ensure higher levels of prosperity. Boosting Europe's productivity is crucial to achieving robust growth and reducing output gaps with other advanced economies.*

In recent years, resilient economic growth has returned to Europe, leaving behind one of the worst economic and financial crisis in decades and enabling the European economy to recover to its

pre-crisis peak. Unemployment is falling and after several years at double digits, it has reached the one-digit level, although in countries such as Spain and Greece, it is still unacceptably high. Despite this progress, economic growth remains modest and is forecast to be below 2% in the coming years. Ensuring higher levels of prosperity, more solid economic growth and a reduction in Europe's output gap against competitor economies such as the United States, Japan and South Korea<sup>33</sup>, will require a boost to Europe's productivity.

**Figure I.2-B.1 Evolution of real GDP per head of population<sup>1</sup>, 1995-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, DG Economic and Financial Affairs

Note: <sup>1</sup>GDP per head of population in PPS€ at 2005 prices and exchange rates.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-b\\_figures/figure\\_i\\_2-b\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_1.xlsx)

33 In the past two decades, South Korea has experienced an acceleration in economic growth that has enabled it to surpass the EU and converge towards Japan's economic level.

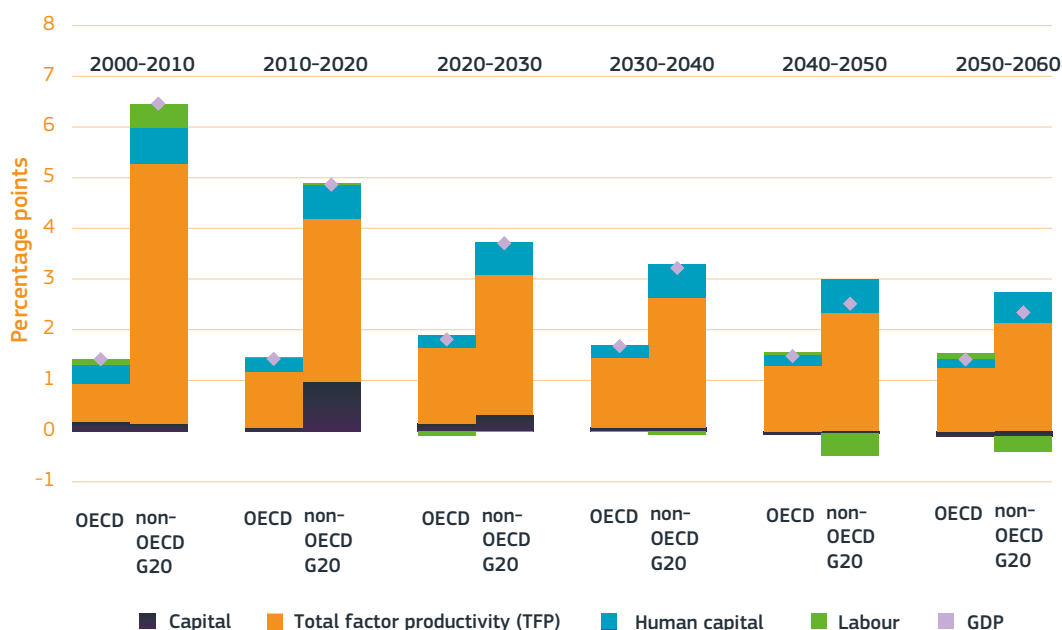


*Productivity growth is and will increasingly be the most important driver for Europe's long-term growth.*

In Europe, as in other advanced economies and emerging economies, economic growth will increasingly rely on Europe's ability to

raise its productivity levels. Based on OECD's long-term growth estimations, around 80% of all economic growth in OECD economies will derive from improvements in productivity, notably as the contribution of labour, in the context of an ageing population, will become much more limited.

**Figure I.2-B.2 Contribution to growth in GDP per capita, 2000-2060 (annual average)**



Science, Research and Innovation performance of the EU 2018

Source: Braconier H, Nicoletti G and Westmore B, (2014), OECD

Note: The non-OECD G20 countries are Argentina, Brazil, China, India, Indonesia, Russian Federation, Saudi Arabia and South Africa.

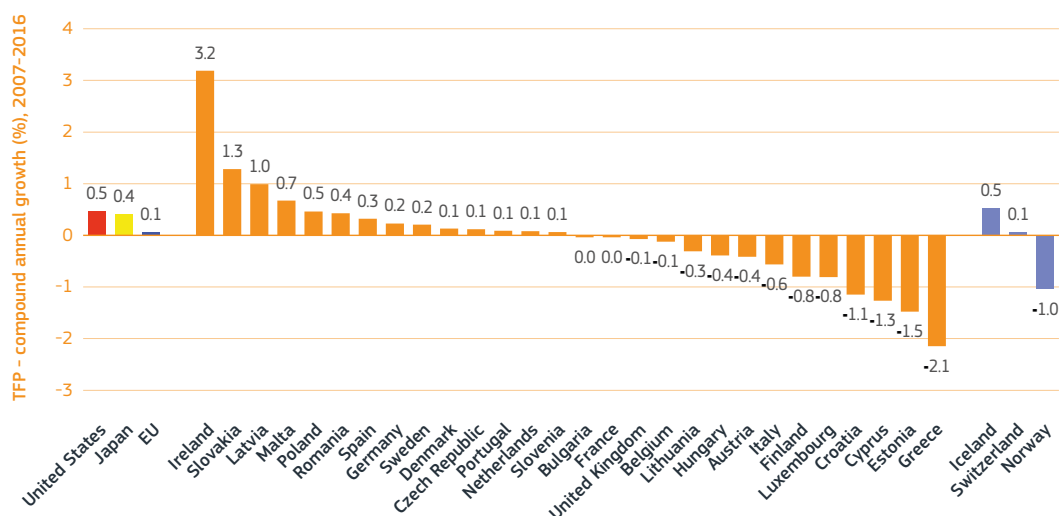
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*However, total factor productivity (TFP) growth has stalled in Europe in the past decade, despite significant progress in some Member States.*

Over the past decade, productivity growth, measured by TFP – a measure of the efficiency in the combination of production factors such as labour and capital to generate economic output – has stalled in the EU. While the TFP was also low in other advanced economies, such as the United

States or Japan, which only score growth rates below 1%, the slowdown in productivity growth was particularly acute in the EU. This stagnation in productivity growth in the EU was mainly driven by a decline in several Member States, such as Greece, Estonia, Finland, Italy, Austria, Belgium and the United Kingdom. On the other hand, only a handful of countries managed to significantly increase their TFP values, notably Ireland<sup>34</sup>, Slovakia and Latvia, with values above or equal to 1% per cent over the last decade.

**Figure I.2-B.3 Total factor productivity - compound annual growth, 2007-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG Economic and Financial Affairs

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-b\\_figures/figure\\_i\\_2-b\\_3\\_updated.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_3_updated.xlsx)

<sup>34</sup> It should be noted that productivity growth levels in Ireland are largely affected by a large statistical effect following a revision in the calculation of GDP that led to a GDP growth rate of 26% in 2015. Therefore, productivity values for Ireland should be analysed with caution.

***This has not contributed to bridging Europe's persistent labour productivity gap against that of the United States.***

Labour productivity growth measures the amount of value added produced per work hour and is very often considered a good measure of the overall efficiency of the economy. It is often used as a proxy of society's level of prosperity<sup>35</sup>. Labour productivity growth depends notably on three main factors: capital investment,

employed labour<sup>36</sup>, and the efficiency in combining capital and labour, also known as TFP.

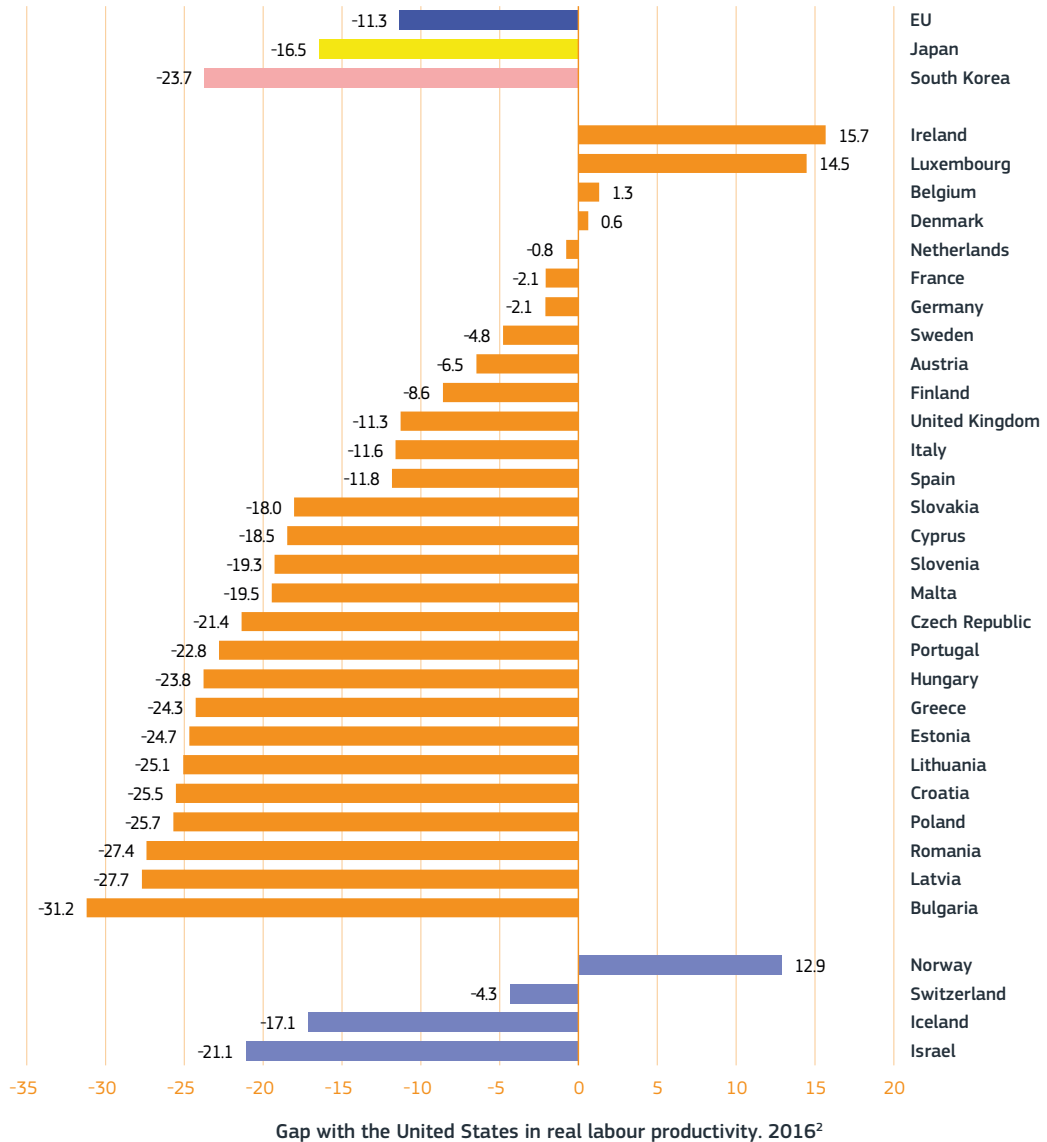
Europe's labour productivity continues to fall short of that of the United States, although there are large differences across Member States, with some countries scoring similar or above values to the United States, such as Luxembourg, Ireland, Denmark, Belgium and France, while others are lagging significantly behind, notably in Eastern and Southern Europe.

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<sup>35</sup> Increasing labour productivity can traditionally be associated with the ability to raise the returns to the production factors, notably capital, labour and technology. In recent years, there have been questions about the potentially unequal distribution of labour productivity gains across production factors.

<sup>36</sup> The ratio of extra capital invested by unit of labour is commonly known as capital deepening.

**Figure I.2-B.4** The gap in real labour productivity (GDP per hour worked<sup>1</sup>) between each country and the United States, 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, DG Economic and Financial Affairs, OECD

Notes: <sup>1</sup>GDP per hour worked in PPS€ at 2010 prices and exchange rates. <sup>2</sup>IS, CH, JP, KR: 2015.

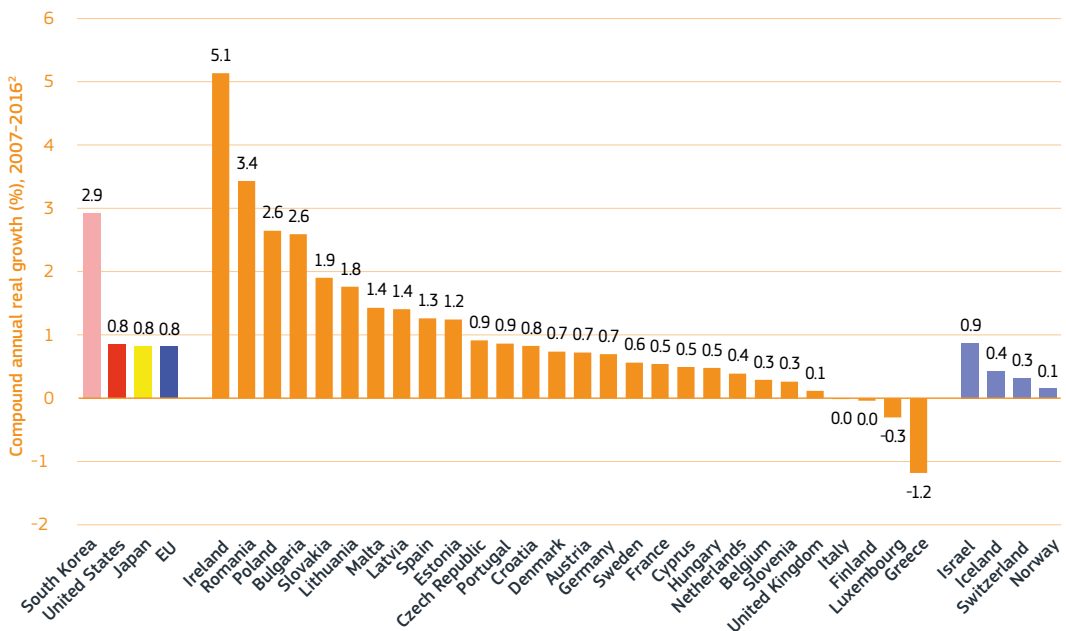
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**Significant progress has been made by some Member States, notably from Central and Eastern Europe.**

Overall, the labour productivity gap between the United States and Europe has slightly widened in the past decade, in contrast to South Korea's gap with the United States, which has declined sharply. Within the EU, several countries, such as Ireland, Romania, Poland,

Bulgaria and Slovakia, underwent a sharp acceleration in labour productivity growth, with many of them experiencing a catch-up process. Countries like Greece, Finland, Italy and the United Kingdom suffered from falling or stagnating labour productivity values. Europe and several Member States face a sharp productivity challenge, which must be overcome in order to unleash higher standards of living, as is presented later in the Report<sup>37</sup>.

**Figure I.2-B.5 Labour productivity (GDP per hour worked<sup>1</sup>) - compound annual real growth, 2007-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, DG Economic and Financial Affairs, OECD

Notes: <sup>1</sup>GDP per hour worked in PPS€ at 2010 prices and exchange rates. <sup>2</sup>IS, CH, JP, KR: 2007-2015.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-b\\_figures/figure\\_i\\_2-b\\_5\\_updated.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_5_updated.xlsx)

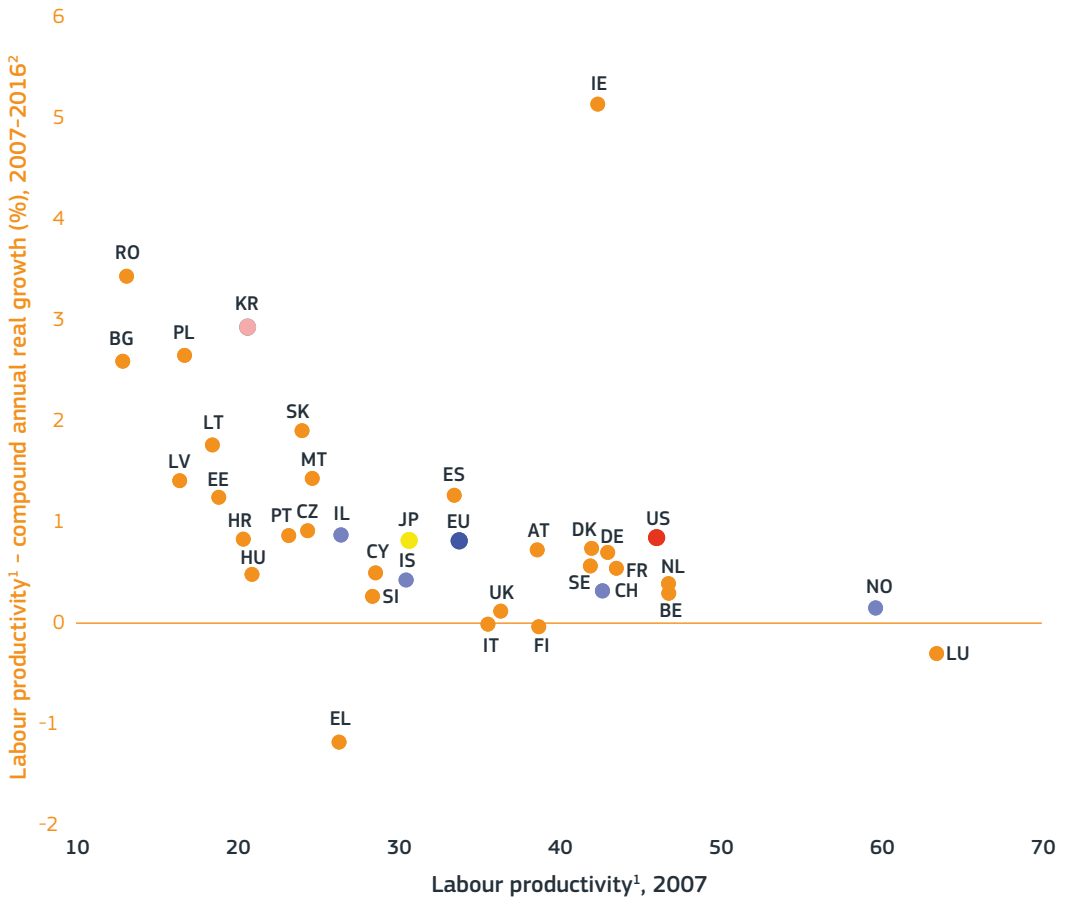
<sup>37</sup> See chapter I.2-C on inequality for further details.

*A catch-up process has enabled a number of Central and Eastern European economies to narrow their existing productivity gap with the United States.*

Labour productivity has increased in several Central and Eastern countries, such as Romania, Poland, Bulgaria and Slovakia, which have experimented with a catch-up process that has resulted in higher levels of prosperity for these countries. The question is whether these increases will be sustained.

However, not all countries benefitted from upwards convergence in labour productivity, and in some cases productivity growth has been low, e.g. for Hungary and Croatia, or even negative, e.g. for Greece. On the other hand, Ireland experienced a sharp increase in labour productivity which positioned it as EU leader, with values above the United States, in less than a decade and despite the sharp economic and financial crisis (see Figure I.2-B.6). Only South Korea is vaguely close to matching Ireland's productivity growth.

**Figure I.2-B.6** Labour productivity (GDP per hour worked<sup>1</sup>), 2007 and compound annual real growth, 2007-2016<sup>2</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, DG Economic and Financial Affairs, OECD

Notes: <sup>1</sup>GDP per hour worked in current PPS€; real growth was calculated from values at 2010 prices and exchange rates.

<sup>2</sup>IS, CH, JP, KR: 2007-2015.

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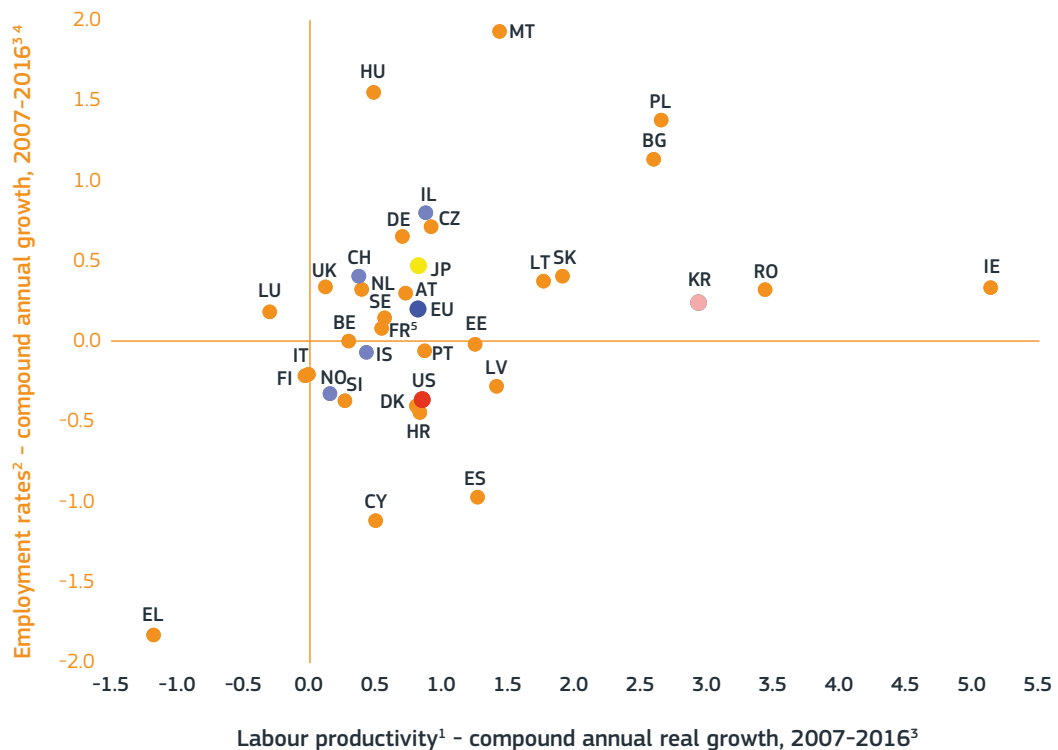
*However, other Member States have only managed to improve their labour productivity at the expense of lower employment rates, which is not sustainable in the long term.*

Any analysis of labour productivity growth needs to be duly complemented by an analysis of employment rates as, on many occasions, the destruction of jobs and the abandoning of less-productive activities leads to labour productivity growth. For example, this is the case for Spain, Cyprus and Latvia where gains in labour productivity may not be sustainable as they may

come at the expense of job opportunities for the broad-base population, and with significant consequences for inequality and cohesion<sup>38</sup>.

In analysing the data on productivity growth, it is also interesting to focus on the differences between the United States and the EU. Over the last decade, while labour productivity in the EU and the United States has been fairly similar, employment rates in the latter dropped, while rising slightly in Europe. This may reflect some structural weaknesses in the capacity of the American economy to generate productive job opportunities.

**Figure I.2-B.7 Real labour productivity<sup>1</sup> and employment rates<sup>2</sup> - compound annual growth, 2007-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, DG Economic and Financial Affairs, OECD

Notes: <sup>1</sup>GDP per hour worked in PPSE at 2010 prices and exchange rates. <sup>2</sup>Employment rates refer to the age group 20-64.

<sup>3</sup>DK, IS, JP, KR: 2007-2015; CH: 2010-2015. <sup>4</sup>BG, DE, IE, EL, CY, PL, PT, SK: Breaks in series occur in the employment rate data between 2007 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>5</sup>FR: Employment rates refer to Metropolitan France.

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<sup>38</sup> Industrial renewal may also reflect the transition towards new productive modes.

*Boosting TFP is a crucial factor to sustain increases in labour productivity growth in the long run in a socially sustainable manner.*

Boosting labour productivity growth depends mainly on two factors: capital deepening, or the ability of an economy to increase its available capital per hour worked; and the TFP or the ability of an economy to more efficiently

combine all its production resources to generate higher value added. In the long run, and as economies become more prosperous, the role of TFP becomes increasingly important. Figure I.2-B.8 shows the high correlation between both variables. Therefore, boosting total factor productivity is crucial to ensure that an economy can provide for higher prosperity among its citizens.

**Figure I.2-B.8 Total factor productivity and real labour productivity<sup>1</sup> - compound annual growth, 2007-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG Economic and Financial Affairs

Notes: <sup>1</sup>GDP per hour worked in PPSE at 2010 prices and exchange rates. <sup>2</sup>IS, CH, JP: 2007-2015.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-b\\_figures/figure\\_i\\_2-b\\_8\\_updated.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_8_updated.xlsx)



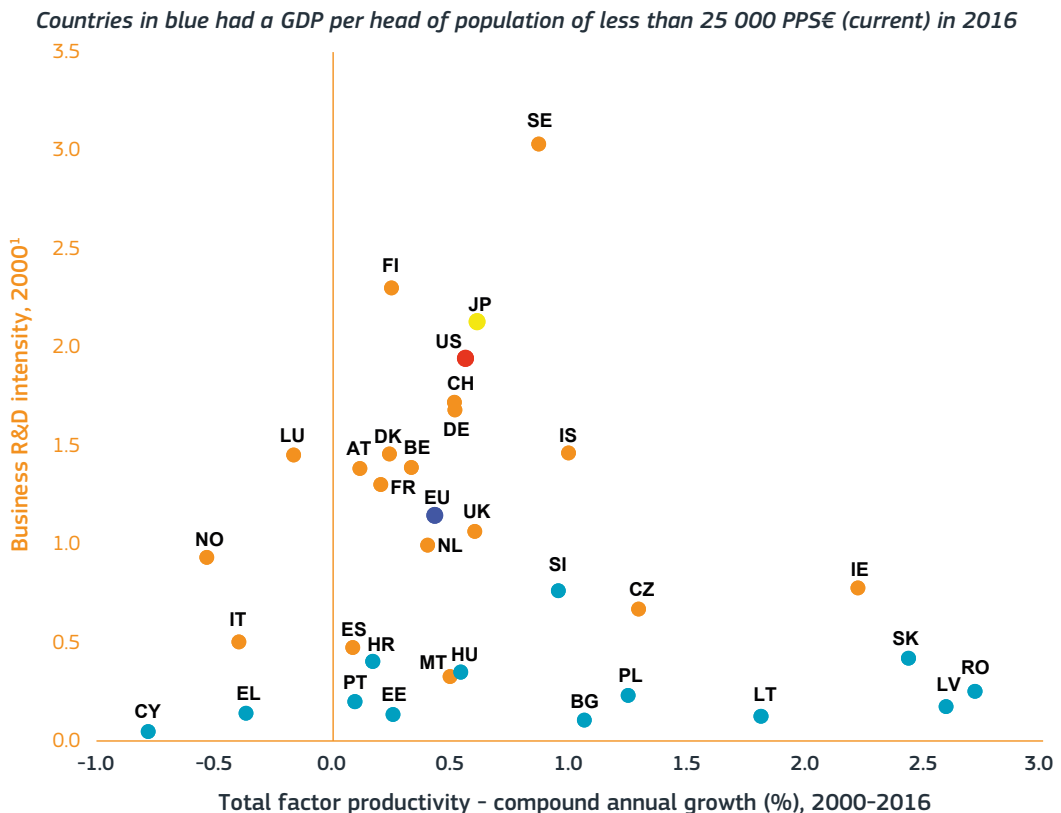
*TFP is driven by many factors, from capital investment to well-functioning institutions and markets. For advanced economies, however, R&I investments and investments in other intangible assets are essential to drive up TFP.*

There are many factors that drive TFP, from well-functioning institutions to capital investment in infrastructure or efficient markets that allow for an adequate allocation and reallocation of resources towards more productive activities. However, for advanced economies, and for economies that benefit from high levels of prosperity and high-quality, well-paid jobs, the key factor is their ability to innovate. The chart below clearly identifies two groups of countries where the relationship between TFP

growth and their ability to innovate, proxied by their business R&D investment, is different.

On the one hand, there is a correlation between TFP growth and business R&D investment for advanced economies, with high levels of economic prosperity. On the other hand, several Central and Eastern European countries have managed to sharply increase their TFP levels, albeit from low initial levels, thanks to improvements in other factors less closely related to innovation, such as foreign direct investment and access to new technologies or better access to markets. This casts doubts about the sustainability of these increases in TFP, notably in the absence of significant improvements in the innovation capacity of these economies.

**Figure I.2-B.9 Total factor productivity - compound annual growth, 2000-2016 and business R&D intensity, 2000**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG Economic and Financial Affairs

Notes: <sup>1</sup>SE, NO: 2001; HR, AT: 2002; MT: 2004. <sup>2</sup>US: Business expenditure on R&D (BERD) does not include most or all capital expenditure.

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***Despite the rise of several new disruptive technologies, productivity growth has slowed. We have yet to establish a good understanding of the full reasons behind that slowdown. Recent analyses<sup>39</sup> point to a divergence in productivity growth between highly productive firms, which continued to grow robustly, and laggard firms that stalled.***

Given the importance of productivity growth to spur prosperity, the productivity growth slowdown in Europe is worrying. This is notably the case because, at the same time, several new technologies spurred by digitalisation, robotics and the Internet of Things have emerged and are promising large productivity gains that have yet to materialise. Several hypotheses have been put forward to explain this *productivity* paradox that is affecting Europe and other advanced economies. These range from mis-measurement in productivity statistics (Syerson, 2016), to an overall innovation slowdown that does not produce significant disruptive gains, notably when compared to previous innovations such as electricity (Gordon 2012).

However, it is sometimes argued that there is no slowdown in innovation but that new technologies enter the market and have yet to reach full maturity to present their results in full (Brynjolfsson and McAfee, 2011). While this debate remains crucial, we have yet to establish

a conclusive answer. In any event, it would seem that innovation diffusion is not fast enough, and while highly productive firms at the productivity frontier exhibit sharp and robust growth rates, the remaining companies fall behind, with unsatisfactory improvements.

***This blockage in innovation diffusion seems to be present in all sectors of the economy and has strong implications not only for productivity growth, but also for rising inequality patterns.***

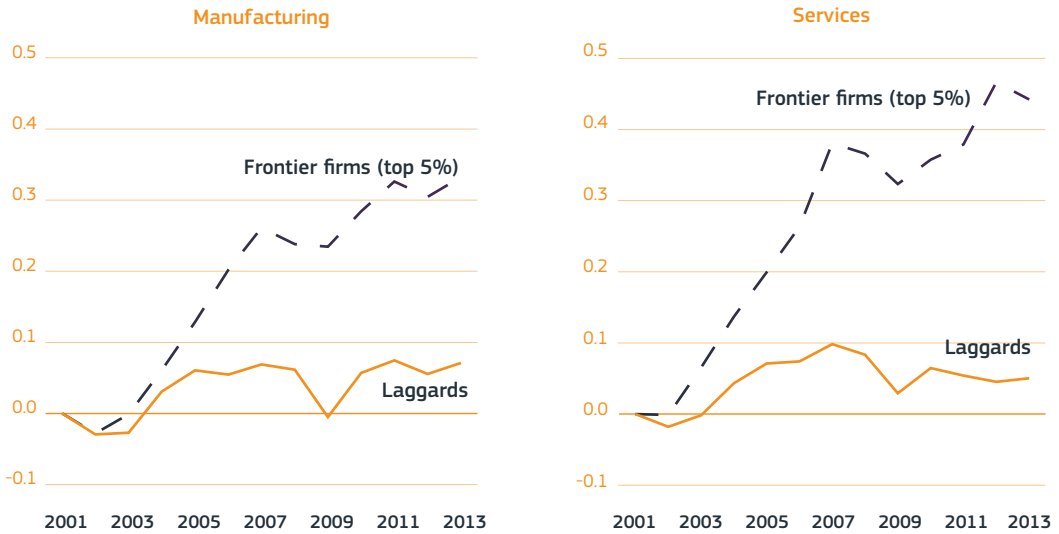
This gap in productivity performance between highly productive firms at the frontier and the remaining companies seems to occur across all sectors of the economy and is putting a brake on innovation diffusion (ECB 2016, OECD 2015).

***This slowdown in innovation diffusion appears to be closely related to the changes that digitalisation and other long-term forces have effected on innovation.***

Digitalisation has deeply transformed the nature of innovation, as well as its diffusion mechanisms and benefits. The fast pace of innovation change, the increased complexity of the innovation process and the growing concentration of benefits for fewer companies are key features of today's innovation dynamics. These features are described in more detail in Box 3.

39 For a thorough revision of this work, please see chapter on 'Slow and divided: what policies can lift economies and restart the engines of growth for all?' by Chiara Cricuolo, OECD, in Part II of this Report.

**Figure I.2-B.10** Labour productivity gap between global frontier firms and other firms<sup>1</sup>, 2001-2013



Science, Research and Innovation performance of the EU 2018

Source: Andrews et al. 2016(8)

Note: <sup>1</sup>The global frontier is measured by the average of log labour productivity for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalised to 0 in the starting year. The vertical axes represent log differences from the starting year: for instance, the frontier in manufacturing has a value of about 0.3 in the final year, which corresponds to approximately 30% higher in productivity in 2013 compared to 2001.

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## BOX 3: Innovation today: key features

In recent years, new, and in particular, digital technologies have redefined the way in which markets operate and have attracted more attention to high-growth innovative enterprises, e.g. unicorns (Google, Apple, Facebook, Amazon)<sup>40</sup>, a new set of global companies that reap large economic benefits. The traditional ‘innovation pipeline’ – research leading to discovery leading to innovation and growth – no longer describes the reality, or not necessarily in those terms.

The **main features** of the changing nature of innovation include:

**Celerity:** The pace of change in innovation has accelerated dramatically. What was innovative before becomes non-innovative extremely quickly. Mobile phones failed to make the transition to ‘smartphones’ on time and rapidly lost their market share and relevance.

**Complexity:** Innovations are increasingly the result of the convergence between different types of technologies to produce solutions for clients. Innovation in car manufacturing is the result of combining technologies that have their origin in ICT or nanomaterials. The full benefits of these technologies cannot be reaped without innovative business practices, skills development, leadership, vision and branding.

**Concentration of benefits:** Digitalisation led to the presence of ‘network effects’ that can only be

benefitted from thanks to scale and scope effects in innovation and to a highly populated community of users. Google’s or Facebook’s benefits lie on their ability to connect millions of users and, in an instant, exploit enormous volumes of information through complex algorithms. How to quickly scale up innovations remains an open policy issue. Moreover, the benefits of innovations are increasingly concentrated in a handful of ‘winner takes most’ companies that dominate global markets. This has macro consequences on the concentration of productivity gains in particular firms, sectors and countries, as well as in wage increases and job creation.

**Consumers:** More and more consumers demand ‘solutions’ rather than ‘products’ or ‘services’. Mass production is speedily changing into ‘customised’ solutions. The scale effects of ‘standardisation’ are being wiped off. Consumers are increasingly the drivers of innovations rather than the ‘users’. Innovation is becoming increasingly consumer-centred.

**Costs:** Alibaba has no inventories, Airbnb has no hotel beds, and Facebook does not sell anything. The importance of tangible ‘capital’ is slowly fading from some innovations. Many innovations have allowed companies to operate under ‘zero marginal cost’, e.g. developing an application has a one-off sunk cost but can be sold to an infinite number of clients at (nearly) zero cost, e.g. iTunes.

*Against the backdrop of the digital revolution and the changing nature of today’s innovation process, it is essential to understand how societies can best create the right*

*conditions for innovation-prone investments, promote the diffusion of innovations, and ensure the broad-based distribution of the benefits from these innovations.*

<sup>40</sup> These companies are also referred to collectively as GAFA.

## CHAPTER I.2-C: INNOVATION, JOBS, SKILLS AND INEQUALITY

The productivity growth slowdown and the apparent challenges in the diffusion of innovation across firms due to the rise in new digital-technology-enabled innovations and the changing nature of innovation has cast doubts about the potentially negative effects these technologies can have in terms of job destruction and the rise in inequality.

More precisely, R&I-enabled robotics, automation or artificial intelligence have led many analysts to wonder whether these technologies will result in cutting the total number of jobs and whether this will disproportionately affect particular segments of the population, notably the low- and medium-skilled. In other words, while these technologies and innovations will create new jobs, it is unclear if they will do so at the speed and scale needed to compensate for the job destruction they may also bring about. Moreover, the increasing productivity growth divergence across different types of firms and the role and rewards associated with different production factors, with a potentially growing bias towards technology, high skills and capital versus labour, also raises questions about the potential consequences that new technologies may have for particular skill segments and the quality of jobs that may result in greater inequality.

This section will look into these factors and shed some light, albeit incomplete, on the role that innovation plays and how changes in innovation driven by digitalisation may impact job creation, skill bias and ultimately inequality.

*Overall market income inequality<sup>41</sup> in the EU is rising, although it is difficult to disentangle its main drivers, e.g. the economic and financial crisis or technological change and innovation.*

To disentangle the effects, it is insightful to distinguish between three concepts of income inequality. The first concept, market income inequality, refers to inequality in household income before redistribution, i.e. transfers and taxes, whereas gross income inequality is a measure which includes transfers that contribute to gross household income. Inequality in disposable income measures the dispersion in income after transfers and taxes.

Since 2007, market income inequality in Europe has been on the rise, probably driven by a combination of factors, notably the effects of the Great Recession and the loss of jobs in some Member States, as well as the potential effects of technological change (Figure I.2-C.1). At the same time, we observe that the gap between 2007 and 2013 in inequality of disposable income is much less pronounced than the observed gap in market inequality. Hence, redistribution and transfers are largely responsible for reducing inequality in Member States. Redistribution through taxation plays a much smaller role, but also contributes to compressing the observed disparities in household income within countries towards a narrower distribution.

41 Market-driven inequality is defined as increases in income inequality that results from the labour market, before taxation or income transfers.

**Figure I.2-C.1** Evolution of market income<sup>1</sup> inequality of the working-age population (2007 = 100) in the EU<sup>2</sup>, 2007-2013



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD Income Distribution Database

Notes: <sup>1</sup>Labour and capital incomes plus private transfers. <sup>2</sup>EU is the unweighted average of the values of the Member States for which data are available.

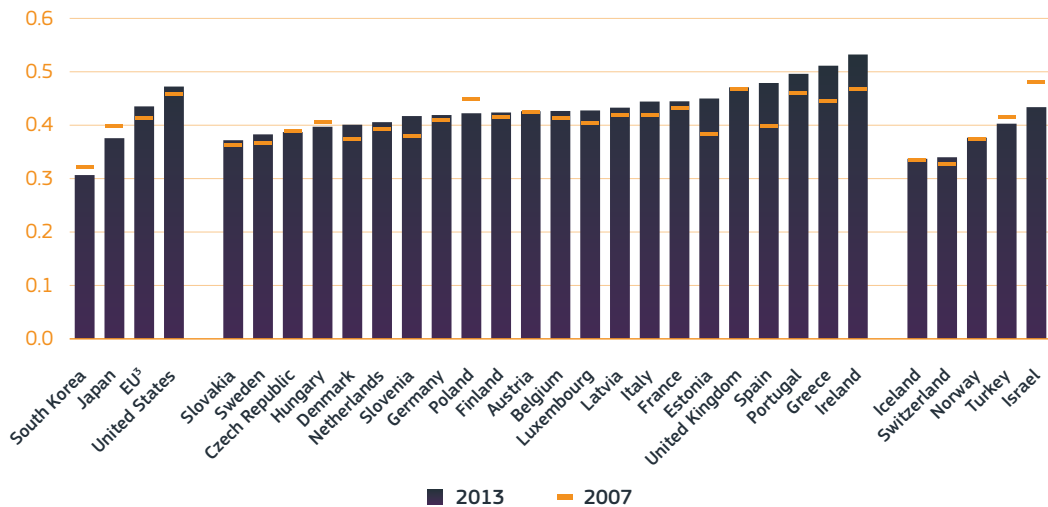
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*Market income inequality rose in Europe and the United States but declined in countries like South Korea and Japan, two innovation leaders. At the European level, there are substantial differences across Member States. While in Poland and the Czech Republic, market inequality declined, an increase has been observed in Ireland, Slovenia, Spain, Greece, Portugal and Estonia, to name but a few.*

In relation to the United States, most Member States still display moderate levels of income inequality, rendering European societies among the most equal in a global comparison. Nevertheless, the global trend in rising income inequality has also become apparent within the EU. Whereas market income inequality, i.e. income before transfers and taxes, as measured by the

Gini coefficient, stood at 0.46 in the United States and 0.41 in the EU in 2007, it reached 0.48 and 0.44 in 2013, respectively<sup>42</sup>. Figure I.2-C.2 displays market income inequality in some Member States, South Korea, Japan and the United States. Whereas market income inequality rose by about 4% in the United States, it increased by 6% in the EU<sup>43</sup>. A fall in market income inequality during this time span is only observed in Poland and the Czech Republic. The highest level of market inequality is seen in Ireland, followed by Greece, Portugal and Spain. These four countries, having been deeply affected by the economic crisis, also experienced the sharpest increases in inequality between 2007 and 2013. The rise in household market inequality is linked, among other determining factors, to a high incidence of unemployment during the crisis years in these countries.

**Figure I.2-C.2 Market income<sup>1</sup> inequality (Gini coefficient)<sup>2</sup>, 2007 and 2013**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD Income Distribution Database

Notes: <sup>1</sup>Labour and capital incomes plus private transfers. <sup>2</sup>0 = perfect equality; 1 = perfect inequality. <sup>3</sup>EU is the unweighted average of the values of the Member States for which data are available.

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42 Source: <https://data.oecd.org/inequality/income-inequality.htm>

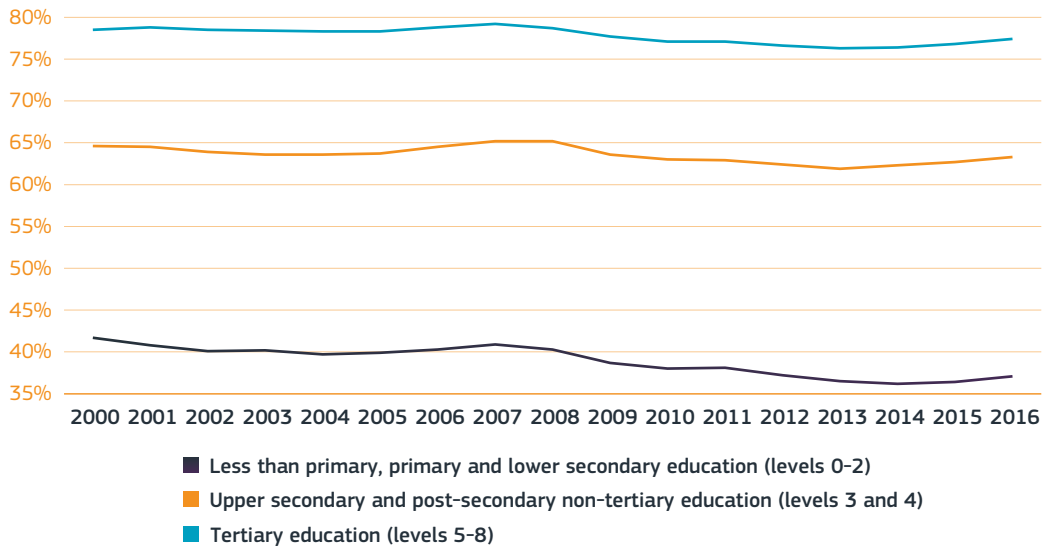
43 Not including Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Malta and Romania (Member States not OECD members) for which data are not available.

*Overall, employment grew in the EU after the Great Recession. It declined in some Member States such as Greece, Spain and Slovenia, although these are also starting to recover, and increased in countries like Sweden or Ireland. This suggests that the rise in inequality in Europe may have different causes in Member States.*

The current recovery is by no means jobless, as the overall employment rate for the EU-28 has reached record high levels of employment

at 71.1%, in 2016, for those aged between 20 and 64. Nevertheless, wage restraints in many economies together with persistently high levels of unemployment in some Member States are among the main symptoms of the changing nature of the economy after the Great Recession. While the employment rate recovered, on average, outcomes differ according to education or skill levels, with the lowest skilled with less than primary, primary and lower secondary education showing the most visible losses (Figure I.2-C.3).

**Figure I.2-C.3** Employment rate<sup>1</sup> in the EU<sup>2</sup> by level of educational attainment (ISCED 2011), 2000-2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (Labour Force Survey)

Notes: <sup>1</sup>Age group 15-74. <sup>2</sup>EU: Croatia is not included for 2000 and 2001.

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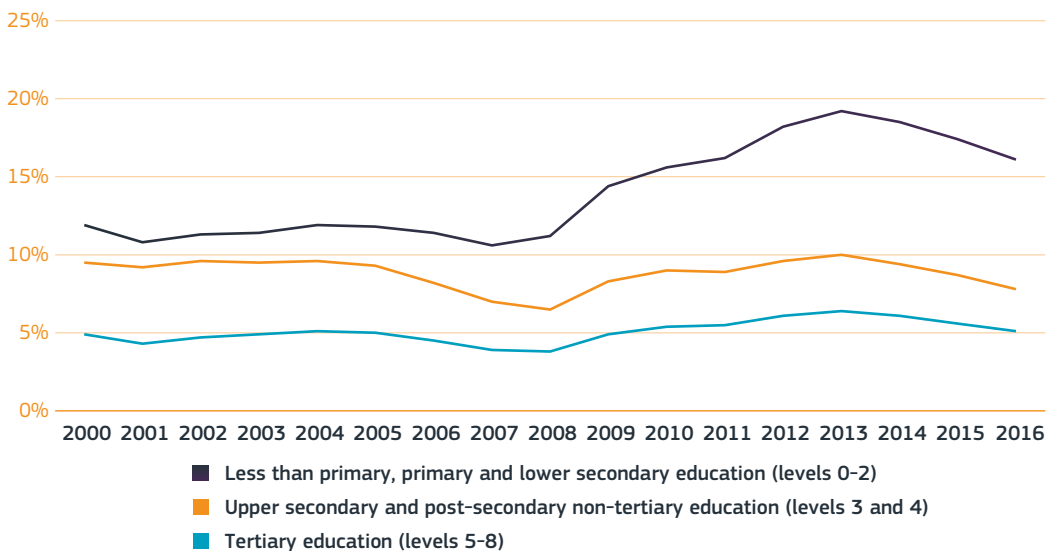
*Unemployment rates have traditionally been higher in those lower-skilled segments that have been disproportionately affected by the economic crisis.*

Figure I.2-C.4 shows that, between 2008 and 2013, the gap in the unemployment rate widening between workers with low skills levels relative to those with middle or high levels of skills. Highly skilled workers benefit from higher demand, hence the benefits of technological progress are not distributed equally across societies. This is in line with the ‘Skill-Biased Technological Change’ hypothesis which postulates a shift in labour demand towards more high-skill labour and a decline in the demand for the low-skilled. Thus, the transformation towards a knowledge-based

economy also entails an increasing employment share for university graduates.

So far, we have only observed a pronounced negative effect for low-skill workers in the European labour market. The problems for people with a low level of education to remain attached to the labour market are likely to become more pronounced over the coming decades as economies adapt to digitalisation and automation in order to remain competitive. These developments potentially put pressure on middle-skilled workers, too<sup>44</sup>. As the low-skilled have, on aggregate, been more affected by the crisis years and display a steeper rise in the incidence of unemployment, the adaptation process requires intensified further education or upskilling for this particular group.

**Figure I.2-C.4 Unemployment rate<sup>1</sup> in the EU<sup>2</sup> by level of educational attainment (ISCED 2011), 2000-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (Labour Force Survey)

Notes: <sup>1</sup>Age group 15-74. <sup>2</sup>EU: Croatia is not included for 2000 and 2001.

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44 According to the Employment and Social Developments in Europe Annual Review, qualifications and skills are becoming more and more important for employment as a result of globalisation and technological change.

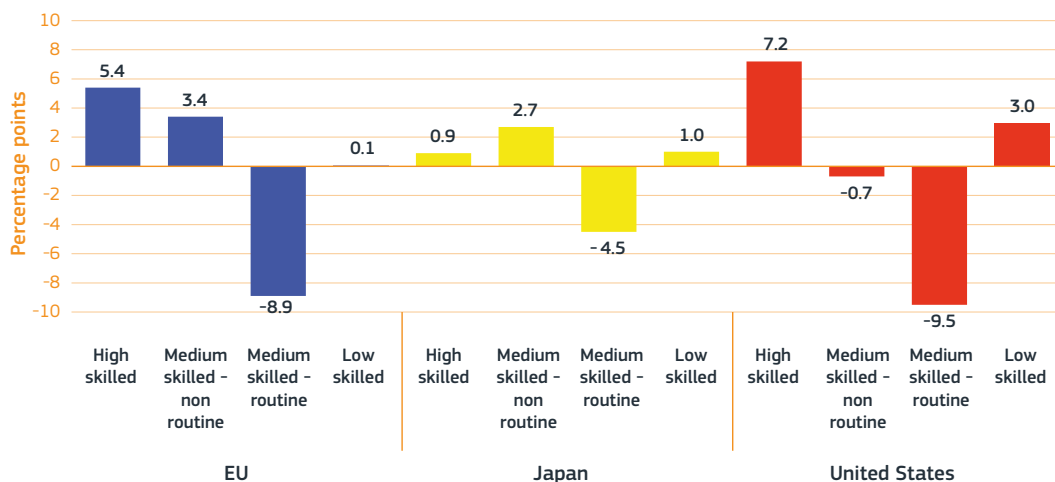
*Despite growing employment trends, job polarisation with a hollowing out of medium-routine jobs has increased in all major economies.*

While employment rates have now recovered to pre-crisis levels in most EU countries, an inequality rift has appeared with respect to the quality of jobs created after the Great Recession, notably in the value of earnings and job security.

When employment shares between 2012 and 2014 are disaggregated by occupation, differentiating between four groups of rou-

tine inherent in the occupation (high, medium non-routine, medium routine and low) it becomes apparent that not all occupations are affected equally by recent changes in the world of work. Figure I.2-C.5 shows a substantial fall of 8.9 percentage points in the employment share of medium-routine occupations in the EU whilst the employment share in the other three occupational categories increased in the time period observed. Albeit at a slower rate, a decline in medium-routine occupations is also evident in Japan and the United States.

**Figure I.2-C.5 Job polarisation - percentage point change in employment shares by skill group, 2012-2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD estimates based on EU-LFS, Japanese Labour Force Survey, BLS Current Population Survey

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***Job polarisation is likely to continue as the risk of automation and computerisation is deeply disrupting or destructing existing jobs: up to 50% of existing jobs are expected to be affected by automation and computerisation in the coming years.***

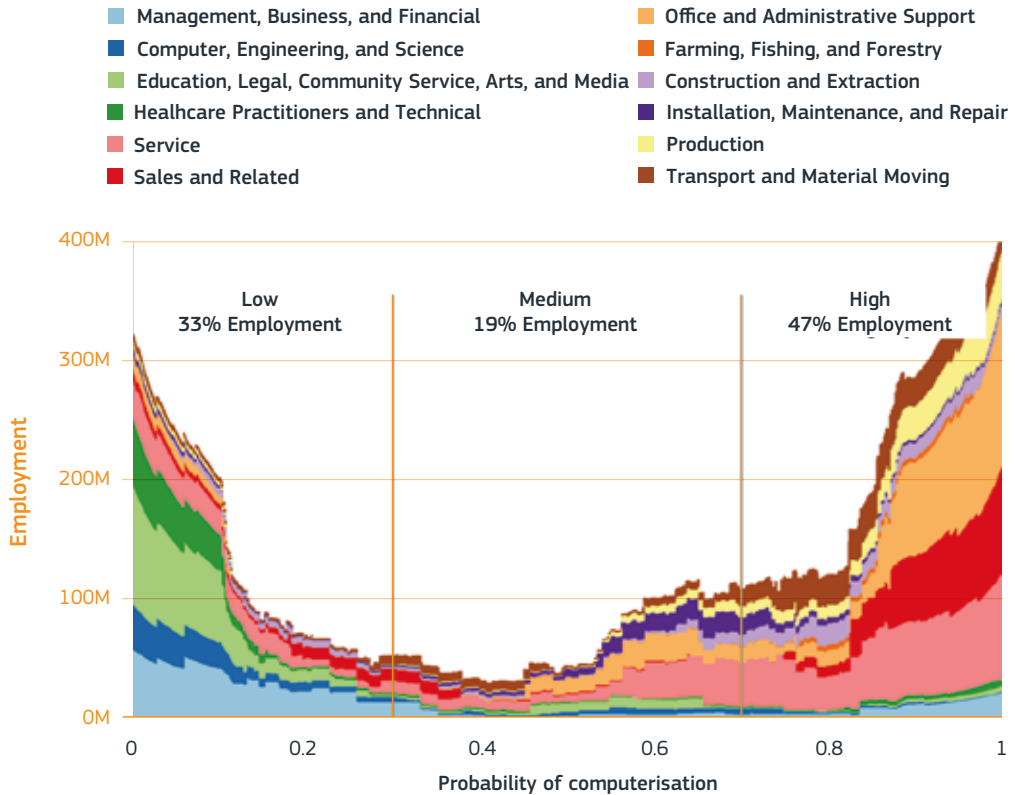
According to an often-cited study, 47% of all American jobs are subject to a high risk of being automated. Their methodology employs occupational classifications related to tasks which are likely to be substituted by robot labour or machine learning within the next 20 years. Predictions of their model also reveal that occupations which are related to perception, manipulation or creativity and social intelligence are associated with a low risk of technological unemployment. Conversely, the high-risk occupations are predicted to be in

transportation and logistics as well as in office work, administrative support and production (see Figure I.2-C.6).

The highly-skilled are more computer-literate and have additional complementary skills, exposing the low-skilled to the risk of the substitution effect.

European estimates of potential employment losses associated with automation lead to similar results varying widely across Member States. The lowest risks are observed in more advanced knowledge-based economies in Northern and Western Europe. On average, the predicted percentage of jobs at high risk of being substituted based on a similar methodology was estimated at 54%, even higher than the 45% estimated for the United States.

**Figure I.2-C.6** Employment in the United States affected by automation / computerisation



Science, Research and Innovation performance of the EU 2018

Source: C. Frey, M. Osborne / Technological Forecasting & Social Change 114 (2017) 254-280<sup>45</sup>

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-c\\_figures/f\\_i\\_2-c\\_6.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_6.xlsx)

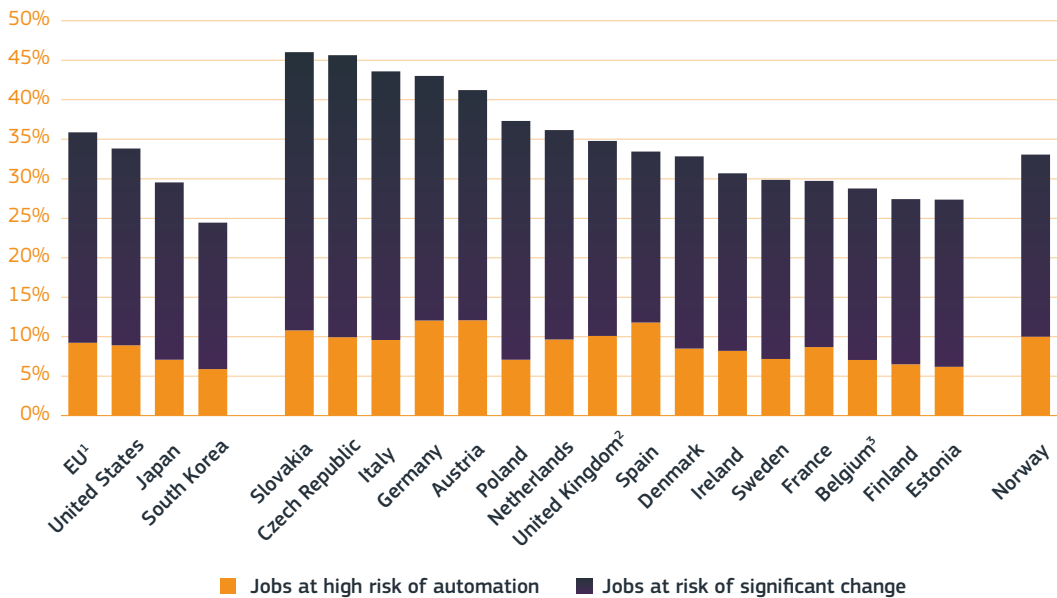
<sup>45</sup> Employment affected by computerisation. The distribution of BLS 2010 occupational employment over the probability of computerisation, along with the share in low-, medium- and high-probability categories. Note that the total area under all curves is equal to total US employment. For ease of visualisation, the plot was produced by smoothing employment over a sliding window of width 0.1 (in probability).

Figure I.2-C.7 shows employment at risk of automation and of significant change as digitalisation and artificial intelligence continue to change the world of work. Countries with a strong manufacturing base, like Slovakia, the Czech Republic, Italy and Germany, for example, display the highest incidence according to OECD estimates, whereas economies which tilt towards an expanding service sector are less affected. The risk

of technological unemployment due to automation is noticeably lower in the United States, Japan and Korea than in many Member States.

However, a more recent study points to a more optimistic outlook for those with a low- and medium-skill level, particularly in occupations in healthcare in which interpersonal skills are valued.

**Figure I.2-C.7** The digital economy - % of workers in jobs at high risk of automation or in jobs facing significant change, 2016



Science, Research and Innovation performance of the EU 2018

Source: OECD (Employment Outlook 2016 - © OECD 2016)

Notes: <sup>1</sup>EU is the unweighted average of the values of the Member States for which data are available. <sup>2</sup>UK: England and Northern Ireland only. <sup>3</sup>BE: Flemish Community only.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-c\\_figures/f\\_i\\_2-c\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_7.xlsx)

***Innovation will also create new jobs, although there is no certainty about the speed and scope of new job creation.***

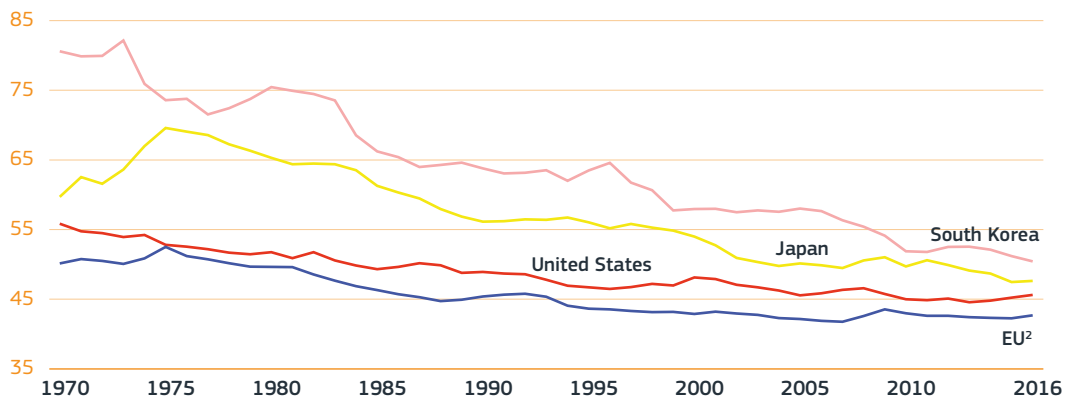
Product innovations are mainly labour-friendly, leading to job creation at the firm level, whereas process or organisational innovations tend to be accompanied by job losses. Empirical research findings suggest that these effects are particularly pronounced in non-high tech sectors of the economy. For high-tech product innovations, the demand for new products and the subsequent increase in job creation offsets the fall in demand for old products and any job losses in laggard firms which operate at lower levels of productivity.

***In addition, innovation also seems to be rapidly changing the distribution parameters between labour and capital.***

Apart from the observed outcomes of the Great Recession on income inequality, it is undisputed

that changes in tasks affected by computerisation have an effect on income distribution and hence also on inequality. A recent scientific paper shows that in the United States technological change and competition drive up market concentration of so-called superstar firms which increase their share of sales. Relative to sales or value added, the share of labour falls as profits rise, leading to a lower aggregate share of labour as market concentration intensifies. Concentration rises most within industries, with an associated sharp decline in the labour share. While the tendency for declining labour shares is observed in for many advanced economies, this is not true for all, and there are stark differences across the EU Member States. These reflect different institutional set-ups, bargaining structures or effects of technological change on countries' economic dynamics. In many instances, the fall in labour share is mainly accounted for by the reallocation of labour towards firms with lower (and declining) shares, as opposed to falling labour shares within firms.

**Figure I.2-C.8 Evolution of labour income share<sup>1</sup>, 1970-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD (Dataset: Economic Outlook No 101 - June 2017)

Notes: <sup>1</sup>Share of wages in total GDP adjusted by the ratio of total-to-dependent employment. <sup>2</sup>EU is estimated as the average of labour income shares weighted by employment for the Member States for which data are available. The number of Member States included in the EU average over time varies depending on the availability of data.

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## BOX 4: Automation, Inequality and the Breaking of our Social Contract

*Prof. Manuel Muñiz Dean, IE School of International Relations*

Since the early 1970s, productivity and labour wages in the United States have diverged markedly, with the former increasing by over 250% and the latter remaining stagnant. Technology and automation have apparently enabled productivity to increase markedly without the need for more or better-paid employment. This seemingly minor development is, in fact, of enormous consequence. So much so that some have referred to it as the breaking of our social contract. The reasons behind its importance are: first, it undoes the at-least-two-century-long belief that everyone benefits from gains in productivity of goods and services. Indeed, if our development models are distilled to their most basic core the following tenet is revealed: productivity gains end up trickling down to wages, producing first a middle class, and ultimately sustained increases in prosperity for workers. In such a scenario, both capital holders and labour providers benefit from increased productivity. This has ceased to happen in the last 40 years.

Second, it is producing wage stagnation in the middle of our income distribution and growing inequality. Today, intergenerational economic mobility in the United States is significantly less likely than six or seven decades ago. An American born in the 1940s had an over 90% chance of earning more than his parents during his lifetime. That figure had dropped to 50% for Americans born in the 1980s. In addition, income and wealth inequality in the United States and the UK are reaching levels not seen since the 1920s and 1850s, respectively. Indeed, the portion of income accruing to capital holders has increased steadily over the last decades. Third, a new eco-

nomic class is emerging within Western societies: the “precariat”. It is composed not just of the unemployed but also of the underemployed, those who are working but who are willing and yet unable to find more work, the sub-employed, people working in jobs below their skill and education level or, most importantly, the working poor, those with full-time jobs who are unable to make ends meet. Fourth, the precariat seems to share a set of common beliefs, two of which stand out: pessimism about the future and anti-elitism. Over 80% of Trump voters believe, for example, that life is worse for them or for people like them than 50 years ago. Over 60% of Europeans are of the opinion that their children will live less-prosperous lives than them. This pessimism is, in turn, driving a generalised questioning of the competency of economic, political and intellectual elites in the West. As one would expect, anti-elitism was strongly correlated with voting for anti-systemic parties and candidates. Data from the 2016 EU membership referendum in the UK showed, for example, strong correlations between low levels of trust in elites and a willingness to support Brexit.

Indeed, if the diagnosis above is correct, we are facing a challenge of a structural nature. Our current economic and political predicament is a consequence of a major change in how wealth is created and distributed within our societies, produced, fundamentally, by technological change and the redundancy of traditional labour. Data on the automation of jobs and evidence on how this process is beginning to affect service-sector employment reinforces the macro data and points to a worsening of the economic and political trends indicated above.

Solutions to these challenges are only just beginning to be explored. These should be the pillars of the new social contract that emerges out of the current convulsion. Four sets of measures stand out: first, a deep and structural reform of our education systems is needed. We are unsure about the nature of future jobs but we do know that they will not look like the current ones. We also know they will combine strong quantitative and social skills, and that the importance of teaching transferable skills will increase. Even if fewer jobs are created than those being automated we should make sure that there is an adequate supply of trained workers for the emerging categories. Second, states around the world will have to review the way they procure their income. The dependency on fiscal traction over labour wages will become increasingly problematic in a world where larger portions of wealth accrue to capital holders. In fact, states might find themselves taxing those who should, in fact, be the beneficiaries of redistributive policies

and not those that finance them. Three, new public redistribution tools should be designed. These should seek to substitute the central role played by labour income in the distribution of wealth from capital holders to the rest. Some form of basic income, conditional transfers, negative income taxes or others are all to be considered and assessed. Unfortunately, this is an exercise that is only in its early stages.

Finally, the private sector should play an essential role in drafting this new social contract. The concept of business sustainability should be expanded to include new stakeholders and, in particular, those not employed by the companies but who are affected by its activities. More philanthropic and social responsibility activities will be required from those companies that are able to grow and bring value to shareholders without creating employment in the places where they operate. Business as usual will produce toxic political and economic environments for companies to operate in.



An increase in the demand for skills in conjunction with an increase in observed skills shortages and mismatches across the EU, as well as advances in technologies is fuelling fears of robots and artificial intelligence substituting human labour. Furthermore, there is a growing trend of higher-educated people taking on jobs requiring lower skills.

An alternative perspective of these developments points towards job opportunities resulting from the strong skill complementarities between the process of automation and human ability to solve problems, leading to productivity gains and higher wages. The link between wage dispersion and innovation and productivity<sup>45</sup> is established via the altered demand for skills: people with skills and human capital, which is complementarity to the process of technological change, will

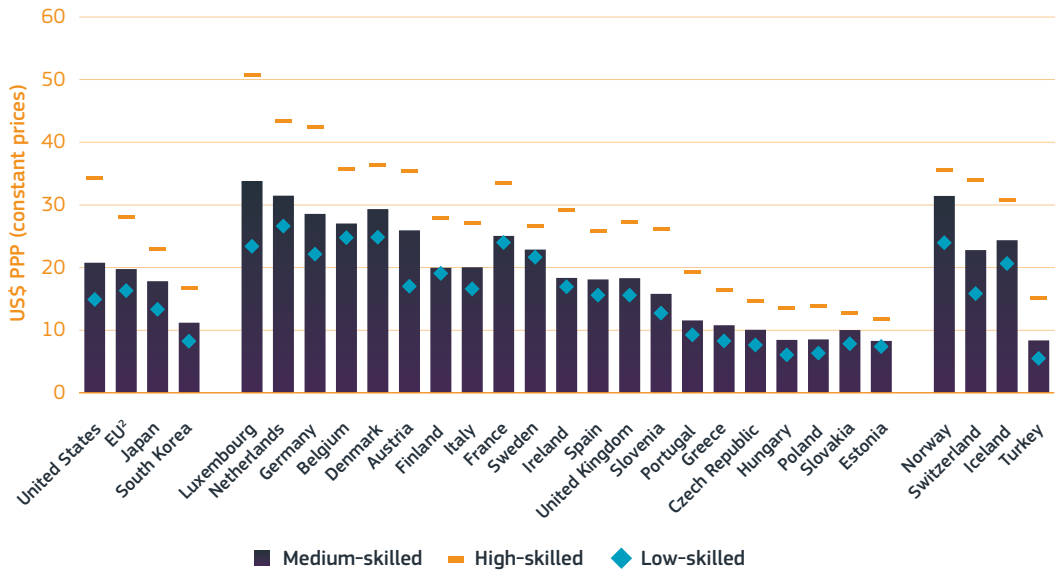
be in high demand and will command higher wages. On the other hand, as mentioned above, low- and medium-routine tasks are likely to be performed more and more by machines. Nevertheless, complex tasks might also be subject to the risk of automation in the future.

'Job polarisation' or the 'hollowing out of the middle' also causes a distributional change leading to greater demand for the highly skilled working in high-wage jobs at one end of the income distribution and the low-skilled working in low-wage jobs at the other end. These shifts observed in the United States in the composition of income distribution due to technological change can squeeze the middle-wage and medium-skill jobs towards the outer ends of the distribution and put pressure on lower-skill jobs and wages.

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45 For a microeconomic analysis on wage dispersion and productivity, please see 'Slow and divided: what policies can lift economies and restart the engines of growth for all?' in Part II of this Report.

**Figure I.2-C.9 Job quality by skill group - average hourly earnings**  
(US\$ PPP at constant prices), 2013<sup>1</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD Job Quality Database

Notes: <sup>1</sup>ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. <sup>2</sup>EU is the unweighted average of the values of the Member States for which data are available.

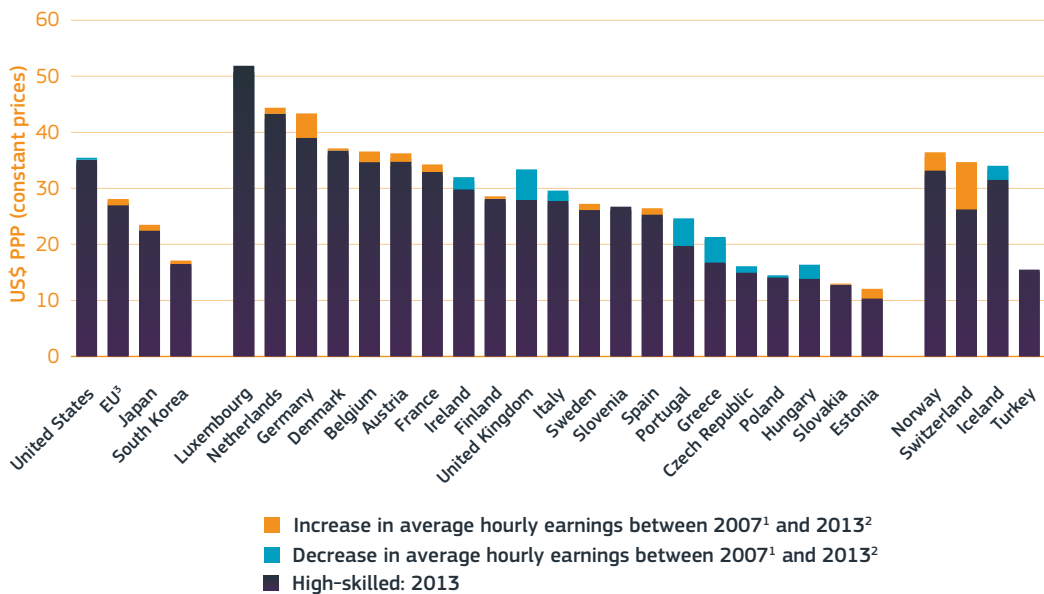
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*In recent years, the increase in the earnings related to high-skills jobs has been particularly significant in countries like Germany, Austria, the Netherlands, Belgium and Sweden.*

Figures on average earning show that during the Great Recession this trend deepened even further in the United States. Whereas the highly skilled still experienced gains in hourly remuneration, the medium- and low-skilled saw their hourly wages fall even further (Figure I.2-C.9). In the EU, no homogenous picture

emerges. In some Member States, the hourly earnings of the highly skilled increased during the observed period, for example in Germany, the Netherlands, Belgium and Austria, whereas in others, the highly skilled were also subjected to substantial wage losses. The highly skilled saw their hourly earnings tumble in the United Kingdom, Ireland, Italy, Portugal and Greece, as well as in the Czech Republic, Poland and Hungary (Figure I.2-C.10). However, on average, the highly skilled made wage gains over the observed period in the EU.

**Figure I.2-C.10 High-skilled workers - average hourly earnings (US\$ PPP constant prices), 2013 compared to 2007**



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: OECD Job Quality Database  
 Notes: <sup>1</sup>EL, NL: 2006; DK, IT: 2008; CH: 2010. <sup>2</sup>ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. <sup>3</sup>EU is the unweighted average of the values of the Member States for which data are available.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-c\\_figures/f\\_i\\_2-c\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_10.xlsx)

On the other hand, on average, medium-skilled job earnings have remained more or less stagnant, with the exception of some strongly performing Member States.

**Figure I.2-C.11 Medium-skilled workers - average hourly earnings (US\$ PPP constant prices), 2013 compared to 2007**



Science, Research and Innovation performance of the EU 2018

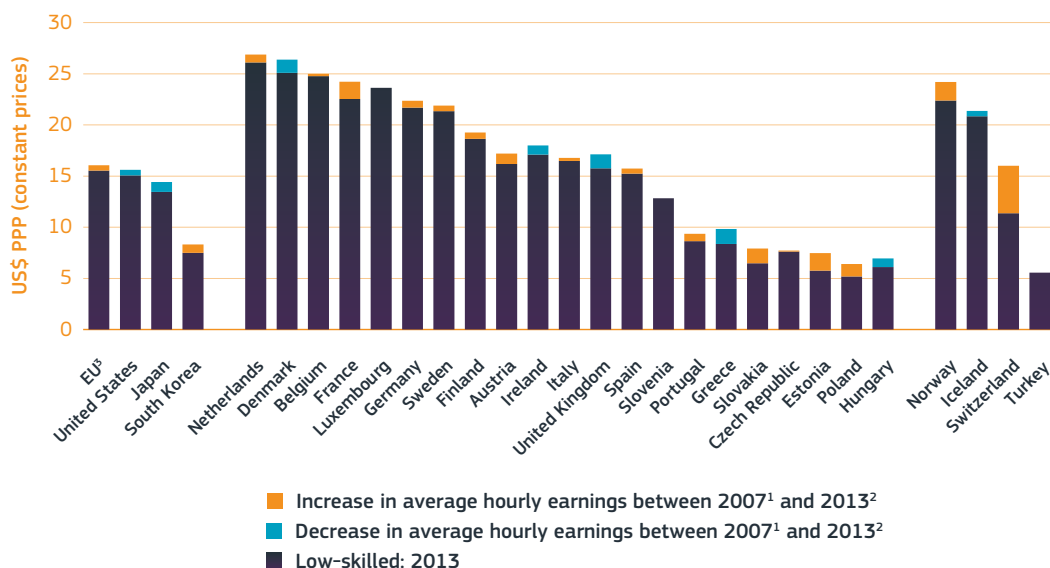
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: OECD Job Quality Database

Notes: <sup>1</sup>EL, NL: 2006; DK, IT: 2008; CH: 2010. <sup>2</sup>ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. <sup>3</sup>EU is the unweighted average of the values of the Member States for which data are available.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-c\\_figures/f\\_i\\_2-c\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_11.xlsx)

*This stagnation, or even decline, is also present for lower-skill jobs, although with some exceptions. The differences between the United States and some Member States are particularly stark.*

**Figure I.2-C.12 Low-skilled workers - average hourly earnings (US\$ PPP constant prices), 2013 compared to 2007**



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: OECD Job Quality Database  
 Notes: <sup>1</sup>EL, NL: 2006; DK, IT: 2008; CH: 2010. <sup>2</sup>ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. <sup>3</sup>EU is the unweighted average of the values of the Member States for which data are available.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_2-c\\_figures/f\\_i\\_2-c\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_12.xlsx)

In conclusion, R&I-enabled technologies do not seem to have destroyed a net number of jobs in Europe yet, although they seem to have had an impact on low- and medium-skills routine jobs. Moreover, a skill bias towards increasing higher earning dynamics for high-skilled jobs seems to be taking place and resulting in a growing market-based income inequality. These new dynamics with respect to declining labour shares and rising income inequality will need to be addressed by policymakers, also in view of raising additional

revenue – through taxation or other forms of redistribution – to safeguard European social security models and overall societal cohesion. Ensuring that new technology-enabled innovations do not generate intolerable levels of inequality will potentially require a combination of social policies that act during transition periods when the economy transforms, with education and skills development strategies that enable a rapid transition and broad segments of the population to contribute to and benefit from these innovations.

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# CHAPTER

## I.3

# INVESTMENT IN R&I AND OTHER INTANGIBLE ASSETS

Financial and human resource investments in research and innovation (R&I) and other intangible assets such as information and communication technologies (ICT); education and skills development; or organisational, management capacity, and marketing are crucial to support knowledge creation and diffusion that can be transformed into higher-value-added innovations. There is an increasing understanding that innovation, and notably reaping the full benefits of innovation, can require investment in different types of intangible assets that are highly complementary. For example, many of the benefits that digitalisation has brought about to increase firms' productivity require investment in R&I and ICT to develop and adopt the enabling technologies, as well as the reorganisation and adjustment of production or distribution activities to benefit from these technological innovations.

Against this background, this chapter assesses investment trends in R&I and other intangible assets in the EU and third countries, highlighting differences between the private and the public sectors. Using this analysis, the chapter aims to knock down persistent silos in the analysis of different sources of innovation, highlighting the complementarity and synergies across innovation-driving assets.

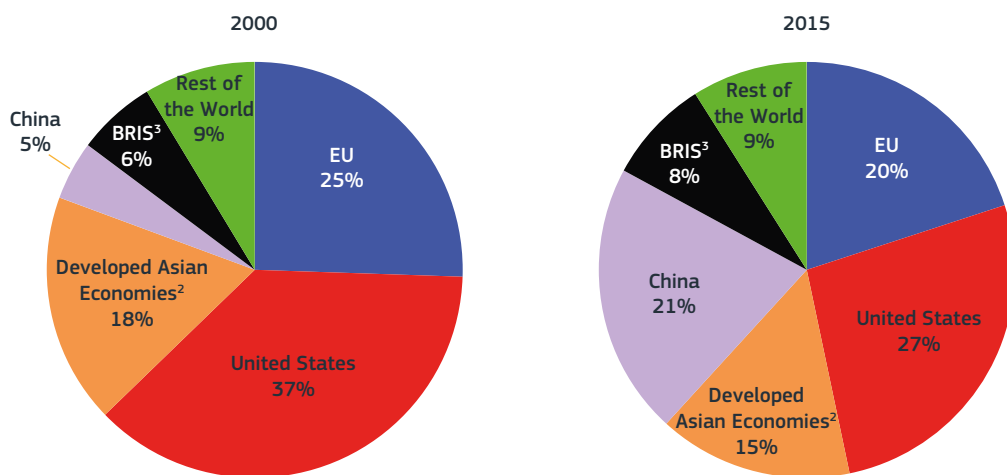
## CHAPTER I.3-A: R&D INVESTMENT

*The EU is a global research powerhouse responsible for one-fifth of all R&D investment worldwide, a share that has nonetheless decreased over time due to the globalisation of research and the rise of China as a major global research competitor.*

China's share of world R&D expenditure increased from 5% in 2000 to 21% in 2015 while over the same period the United States'

share declined by 10 percentage points from 37% to 27% and the EU's share fell from 25% to 20%. These changes reflect a new broader international distribution of R&D investment and show a shift from 'East' to 'West' in the global R&D compass. This is underlined by the fact that, between 2000 and 2015, R&D intensity in South Korea rose from 2.18% to 4.23% of GDP, in China from 0.89% to 2.07% and in Japan from 2.91% to 3.29%.

**Figure I.3-A.1** World expenditure on R&D - % distribution<sup>1</sup>, 2000 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

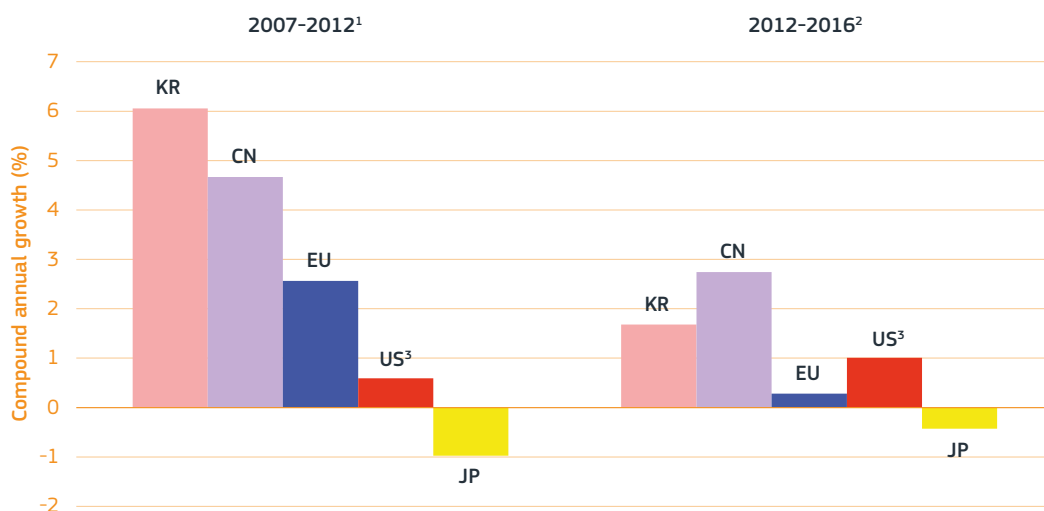
Notes: <sup>1</sup>The % shares were calculated from estimated values for total GERD in current PPSE. <sup>2</sup>Japan+South Korea+Singapore+Chinese Taipei. <sup>3</sup>Brazil+Russian Federation+India+South Africa.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f1\\_world\\_expend\\_on\\_total\\_rd.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f1_world_expend_on_total_rd.xlsx)

*Over the past decade, R&D investment in China has outpaced most other economies, notably the EU, the United States and Japan, all of which experienced much lower growth rates than China for the period 2012-2015.*

In the case of the EU, the compound annual growth of R&D intensity declined from 2.6% for the period 2007-2012 to 0.3% for the period 2012-2016 (Figure I.3-A.2), a significantly lower growth rate than the corresponding one over the period 2012-2015 for China (2.7%), South Korea (1.7%) and the United States (1.0%).

**Figure I.3-A.2** R&D intensity - compound annual growth, 2007-2012 and 2012-2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

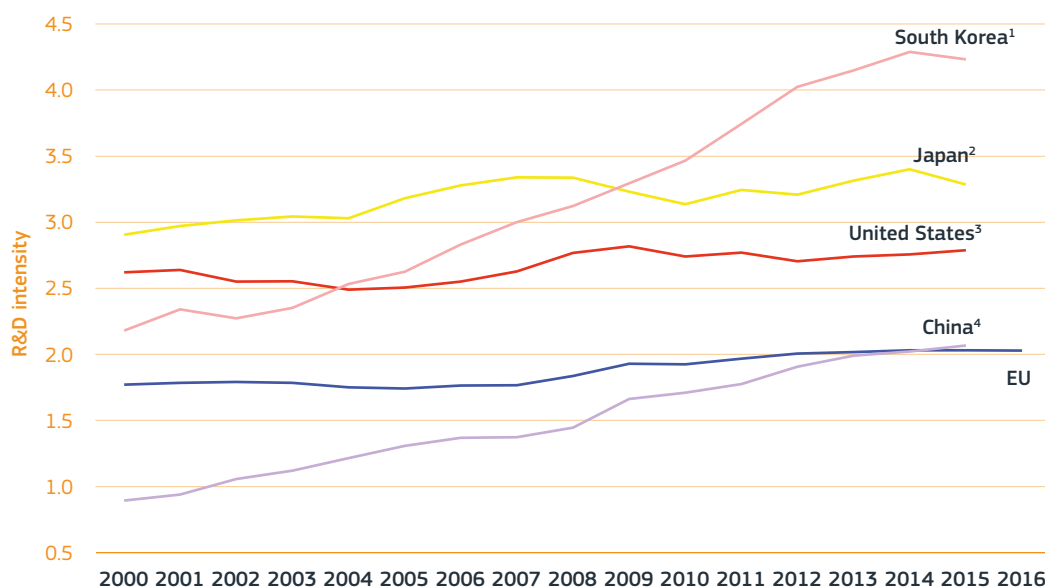
Notes: <sup>1</sup>JP: 2008-2012; CN: 2009-2012. <sup>2</sup>US, CN, KR: 2012-2015; JP: 2013-2015. <sup>3</sup>US: R&D expenditure does not include most or all capital expenditure.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f2\\_rd\\_intensity\\_cagr.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f2_rd_intensity_cagr.xlsx)

*This enabled China to overtake the EU in R&D investment, both in relative and in absolute terms.*

South Korea, Japan and the United States continue to achieve significantly higher R&D intensities than the EU, although the gap between Japan and the EU narrowed slightly between 2014 and 2015.

**Figure I.3-A.3 Evolution of R&D intensity, 2000-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KR: There is a break in series between 2007 and the previous years. <sup>2</sup>JP: There is a break in series between 2008 and the previous years and between 2013 and the previous years. <sup>3</sup>US: (i) R&D expenditure does not include most or all capital expenditure; (ii) There is a break in series between 2003 and the previous years. <sup>4</sup>CN: There is a break in series between 2009 and the previous years.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f3\\_rd\\_intensity.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f3_rd_intensity.xlsx)

*R&D investment in the EU is not growing fast enough to achieve its target of investing 3% of GDP in R&D by 2020, even though some Member States have met or are close to meeting their national R&D intensity targets<sup>1</sup>.*

The R&D intensity target is one of the EU's five headline targets aimed at creating a smarter, greener, more inclusive economy and society. In order to reach the 3% target, R&D intensity in the EU as a whole would have to grow

at a compound annual growth rate of 10.3% per annum between 2016 and 2020. Cyprus has already reached its 2020 R&D intensity target, and Germany and Denmark will almost certainly reach their targets before 2020. Belgium, Greece, Italy, the Netherlands, Austria and Sweden will reach their R&D intensity targets if their R&D intensities grow at a rate of between 4.5% and 5.5% per annum. However, it will be difficult for the other Member States to meet their targets (Figure I.3-A.4).

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1 R&D investment intensity values for BG, CZ, EE, HR, LV, LT, HU, MT, PL, RO, SI and SK refer to 2015 rather than 2016. Provisional R&D expenditure data are available for these Member States for 2016. However, in many cases these data show a relatively important decrease. An investigation into the causes of this decline is under way. Early indications suggest that changes to the programming period of the European Structural and Investment Fund, a main source of funding for R&D in these Member States, may largely explain this situation. These decreases should, therefore, be considered as temporary with the expectation of a full recovery in the coming years. As a result, R&D investment intensities for these Member States in 2016 may not accurately reflect R&D trends.

**Figure I.3-A.4** Situation of each Member State with regard to its R&D intensity target

	R&D intensity 2016 <sup>1</sup>	R&D intensity target 2020	R&D intensity compound annual growth (%) 2000-2016 <sup>2</sup>	R&D intensity compound annual growth (%) 2007-2016 <sup>3</sup>	R&D intensity compound annual growth (%) required to meet the 2020 target 2016-2020 <sup>4</sup>
Belgium	2.49	3.00	+1.6	+3.4	4.8
Bulgaria	0.96	1.50	+4.5	+10.6	9.3
Czech Republic	1.93	. <sup>5</sup>	+3.7	+5.0	:
Denmark	2.87	3.00	+1.5	+1.5	1.1
Germany	2.94	3.00	+1.3	+2.1	0.5
Estonia	1.49	3.00	+6.2	+4.2	15.1
Ireland	1.18	2.00 <sup>6</sup>	+0.5	-0.5	14.2
Greece	0.99	1.21	+3.9	+5.2	5.0
Spain	1.19	2.00	+1.9	-0.4	13.9
France	2.22	3.00	+0.7	+1.6	6.2
Croatia	0.84	1.40	-0.9	+0.8	10.7
Italy	1.29	1.53	+1.5	+1.4	4.4
Cyprus	0.50	0.50	+5.1	+2.6	<i>Target reached</i>
Latvia	0.62	1.50	+2.4	+1.5	19.1
Lithuania	1.04	1.90	+3.9	+3.3	12.8
Luxembourg	1.24	2.30 - 2.60 <sup>7</sup>	-1.1	-1.3	18.5
Hungary	1.36	1.80	+4.5	+4.5	5.7
Malta	0.77	2.00	+4.1	+4.3	21.0
Netherlands	2.03	2.50	+0.01	+1.0	5.3
Austria	3.09	3.76	+3.1	+2.7	5.1
Poland	1.00	1.70	+3.0	+7.5	11.1
Portugal	1.27	2.70 - 3.30 <sup>8</sup>	+2.1	-1.6	24.0
Romania	0.49	2.00	+1.5	-2.1	32.6
Slovenia	2.20	3.00	+1.4	+2.3	6.4
Slovakia	1.18	1.20	+4.1	+12.8	0.4
Finland	2.75	4.00	-1.0	-2.2	9.8
Sweden	3.25	4.00	-0.9	-0.01	5.3
United Kingdom	1.69	:	+0.2	+0.4	:
EU	2.03	3.00	+0.8	+1.5	10.3

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, Member States

Notes: <sup>1</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK: 2015. <sup>2</sup>BG, CZ, EE, FR, LV, LT, HU, PL, RO, SI, SK: 2000-2015; HR: 2002-2015; EL, LU, SE: 2003-2016; MT: 2004-2015. <sup>3</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK: 2007-2015; SI: 2008-2015; EL, PT: 2008-2016. <sup>4</sup>BG, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK: 2015-2020. <sup>5</sup>CZ: a target (of 1%) is available only for the public sector. <sup>6</sup>IE: The national target of 2.5% of GNP has been estimated to equal 2.0% of GDP. <sup>7</sup>LU: a 2020 target of 2.45% was assumed. <sup>8</sup>PT: a 2020 target of 3.0% was assumed. <sup>9</sup>DK, EL, FR, LU, NL, PT, RO, SI, SE, UK: Breaks in series occur between 2000 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>10</sup>Values in italics are estimated or provisional.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f4\\_progress\\_to\\_rd\\_targets.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f4_progress_to_rd_targets.xlsx)

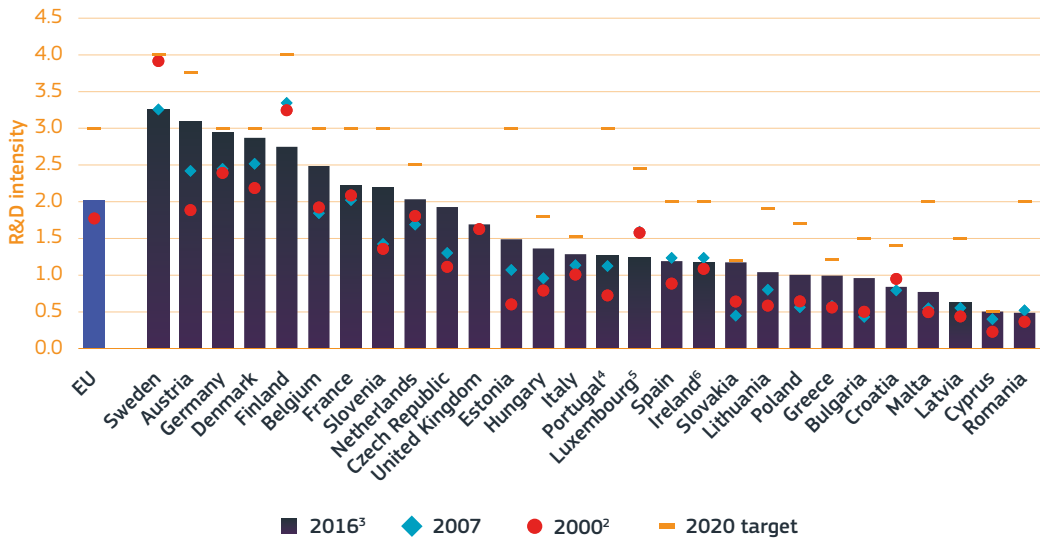


*Undoubtedly, the economic crisis has put an important upper limit on the progress made by many Member States towards their R&D intensity targets. Nevertheless, the R&D intensities of most EU Member States were significantly higher in 2016 than in 2007 (with Finland and Sweden being notable exceptions).*

In some Member States (Bulgaria, the Czech Republic, Poland and Slovakia) R&D intensity

grew at more than 5% per annum between 2007 and 2015. Greece had an R&D intensity growth rate of 5.2% per annum between 2008 and 2016<sup>2</sup>. Belgium, Germany, France, Austria and Slovenia all had R&D intensities higher than the EU average in 2016 and also had R&D intensity growth rates that were higher than the EU average over the period 2007-2016<sup>3</sup>.

**Figure I.3-A.5 R&D intensity 2000, 2007, 2016 and 2020 target<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, Member States

Notes: <sup>1</sup>CZ, UK: R&D intensity targets are not available. <sup>2</sup>EL, SE: 2001; HR: 2002; MT: 2004. <sup>3</sup>BG, CZ, EE, FR, LV, LT, HU, PL, RO, SI, SK: 2015. <sup>4</sup>PT: The R&D intensity target is between 2.70% and 3.30% (3.00% was assumed). <sup>5</sup>LU: The R&D intensity target is between 2.30% and 2.60% (2.45% was assumed). <sup>6</sup>E: The R&D intensity target is 2.5% of GNP which is estimated to be equivalent to 2.0% of GDP. <sup>7</sup>DK, EL, FR, LU, HU, NL, PT, RO, SI, SE, UK: Breaks in series occur between 2000 and 2016.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii\\_3-a\\_figures/f5\\_rd\\_intensities\\_ms.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii_3-a_figures/f5_rd_intensities_ms.xlsx)

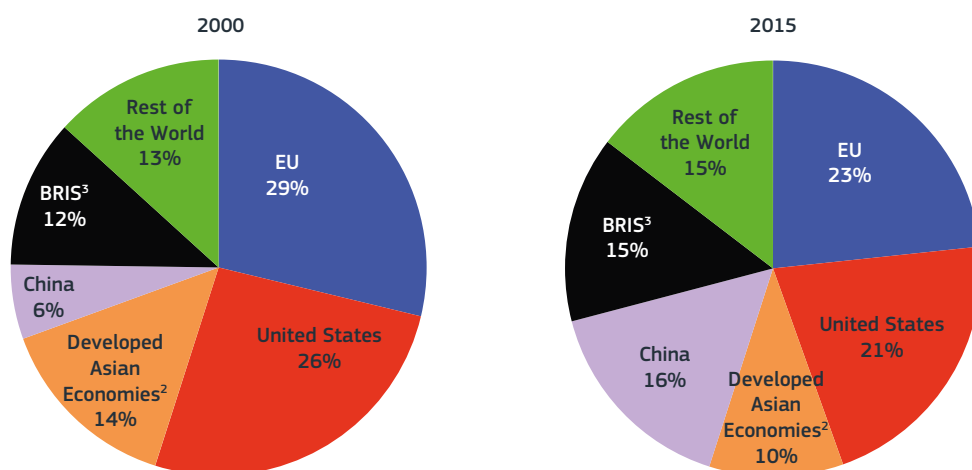
- It should be noted that, during this period, GDP in Greece fell, which affected the denominator of the R&D intensity; therefore, growth rates should be analysed against this general economic backdrop.
- The data for France and Slovenia refer to 2015 and 2007-2015.

*A breakdown of R&D investment by sector shows that the EU remains the major global public investor in R&D.*

Europe's high public sector investment in R&D contributes to nurturing and improving a research capacity that benefits both the public and

private sectors. The United States has the second highest global share of public investment in R&D after the EU. Most public sector R&D in both the EU and the United States is performed by higher education institutions. Higher education expenditure on R&D was around 30% higher in the EU than in the United States in both 2000 and 2015.

**Figure I.3-A.6** World public expenditure on R&D - % distribution<sup>1</sup>, 2000 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

Notes: <sup>1</sup>The % shares were calculated from estimated values for GOVERD+HERD in current PPSE.

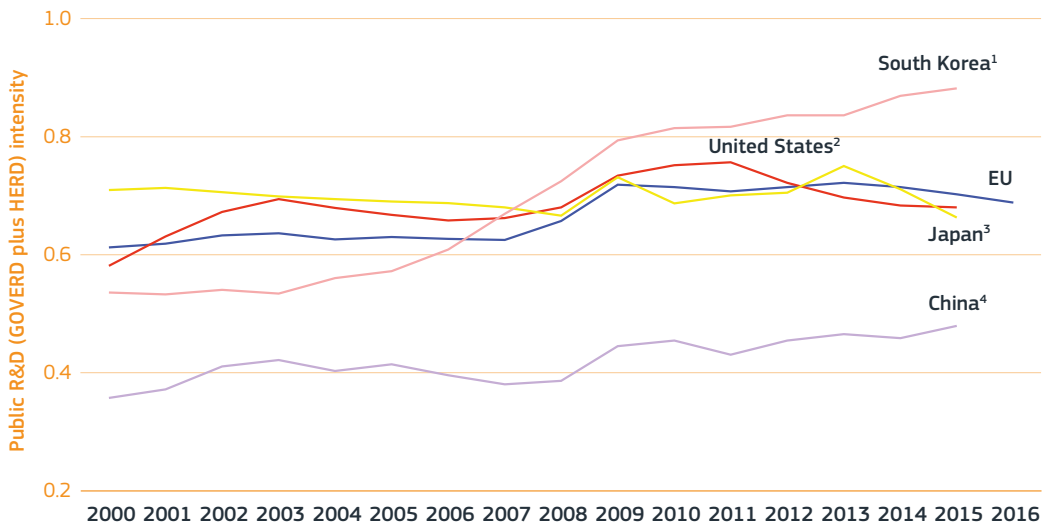
<sup>2</sup>Japan+South Korea+Singapore+Chinese Taipei. <sup>3</sup>Brazil+Russian Federation+India+South Africa.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/ff6\\_world\\_expend\\_on\\_public\\_rd.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/ff6_world_expend_on_public_rd.xlsx)

*The EU has one of the highest public R&D intensities worldwide with a value of 0.69% of GDP in 2016, progressing from 0.61% in 2000.*

Public R&D intensity is now higher in the EU than in the United States, Japan and China.

**Figure I.3-A.7 Evolution of public R&D intensity, 2000-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD

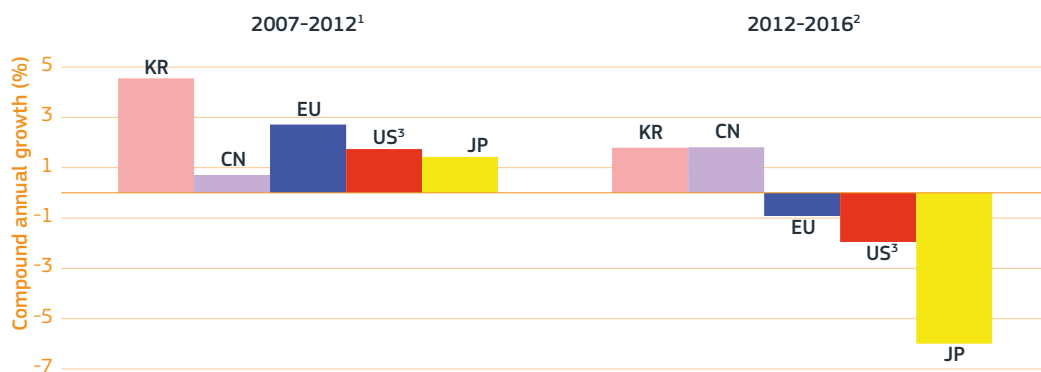
Notes: <sup>1</sup>KR: There is a break in series between 2007 and the previous years. <sup>2</sup>US: (i) Public R&D expenditure does not include most or all capital expenditure; (ii) There is a break in series between 2003 and the previous years. <sup>3</sup>JP: There is a break in series between 2008 and the previous years and between 2013 and the previous years. <sup>4</sup>CN: There is a break in series between 2009 and the previous years.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f7\\_public\\_rd\\_intensity.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f7_public_rd_intensity.xlsx)

*Public R&D intensity growth in the EU, although decreasing over recent years, has not declined to the same extent as in the United States and Japan.*

In fact, total public R&D expenditure in the EU increased every year from 2007 to 2015 and the total of national government budgets for R&D increased every year from 2012 to 2015 (Figure I.3-A.8).

**Figure I.3-A.8 Public R&D intensity - compound annual growth, 2007-2012 and 2012-2016**



## EU million euro

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Public expenditure on R&D (GOVERD plus HERD)	81197	85908	88462	91651	93365	96183	98015	100346	103900	102612
Government budget allocations for R&D (GBARD)	85360	89883	92112	92846	92702	90927	92548	93869	96083	94991

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

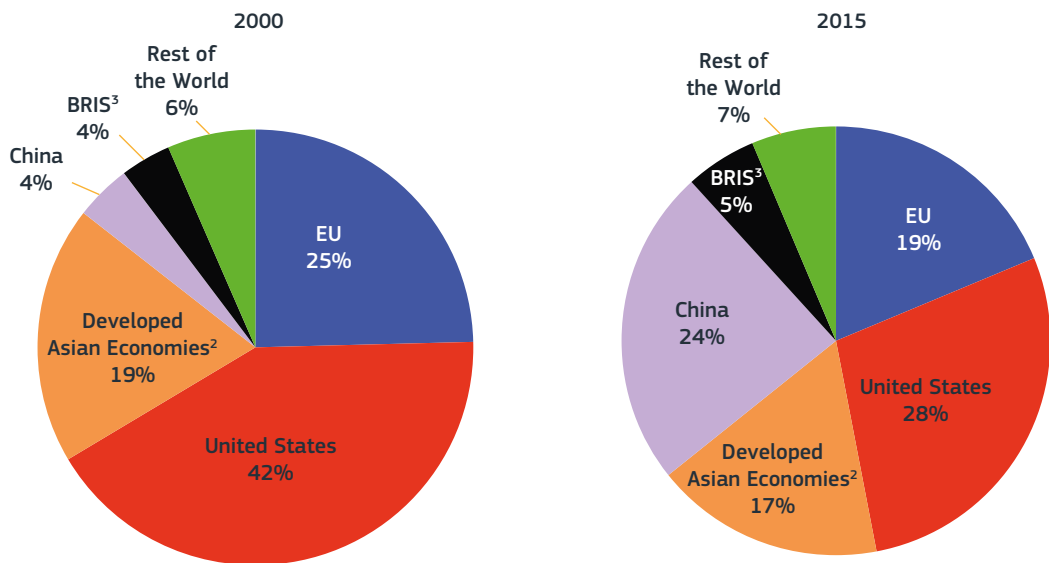
Notes: <sup>1</sup>JP: 2008-2012; CN: 2009-2012. <sup>2</sup>US, CN, KR: 2012-2015; JP: 2013-2015. <sup>3</sup>US: Public R&D expenditure does not include most or all capital expenditure. <sup>4</sup>Values in italics are estimated or provisional.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f8\\_public\\_rd\\_intensity\\_cagr.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f8_public_rd_intensity_cagr.xlsx)

*In terms of business R&D, the EU also maintains a strong position in the global research landscape, accounting for nearly one fifth of all research investment, although this share has declined due to the sharp rise of China which now accounts for almost one quarter of global business R&D expenditure.*

China's share of global business R&D expenditure increased exponentially from 4% in 2000 to 24% in 2015. This increase was mirrored by a decline of 14 percentage points in the United States' share, from 42% to 28%, and by a much less dramatic fall of six percentage points in the EU's share, from 25% to 19%.

**Figure I.3-A.9** World business enterprise expenditure on R&D - % distribution<sup>1</sup>, 2000 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

Notes: <sup>1</sup>The % shares were calculated from estimated values for total BERD in current PPSE.

<sup>2</sup>Japan+South Korea+Singapore+Chinese Taipei. <sup>3</sup>Brazil+Russian Federation+India+South Africa.

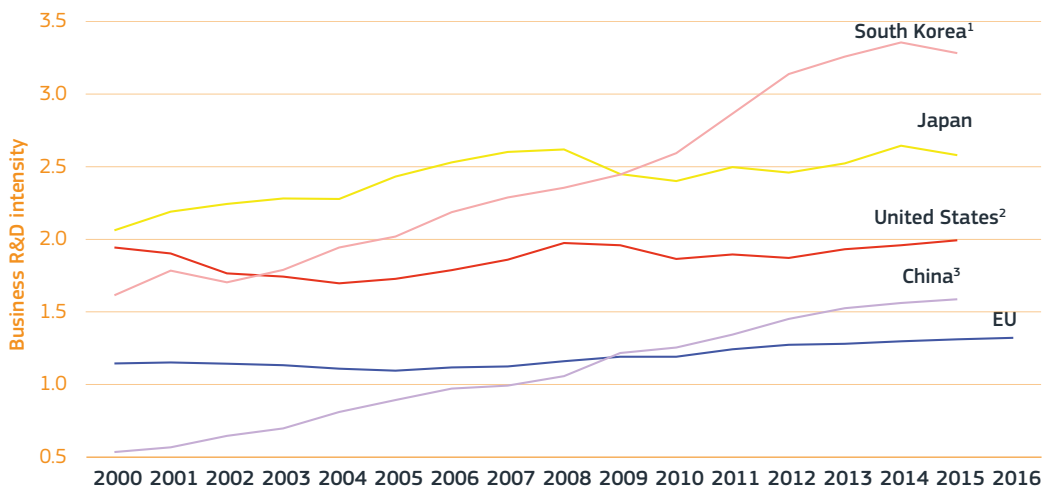
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f9\\_world\\_expend\\_on\\_business\\_rd.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f9_world_expend_on_business_rd.xlsx)

*China has nearly tripled its business R&D intensity since 2000, progress that is rivalled only by South Korea, whose business R&D intensity is approaching 3.5%.*

Business R&D intensity is significantly higher in South Korea (3.28% of GDP) than in Japan (2.58%), the United States (1.99%), China

(1.59%) and the EU (1.32%). The rapid growth of business R&D intensity in South Korea, China and to a lesser extent Japan over the last decade and a half is in sharp contrast to the moderate evolution of business R&D intensity in the EU and the United States and is reflected in the increasing business R&D intensity gap between the EU and its main competitors.

**Figure I.3-A.10 Evolution of business R&D intensity, 2000-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KR: There is a break in series between 2007 and the previous years. <sup>2</sup>US: Business enterprise expenditure on R&D

(BERD) does not contain most or all capital expenditure. <sup>3</sup>CN: There is a break in series between 2009 and the previous years.

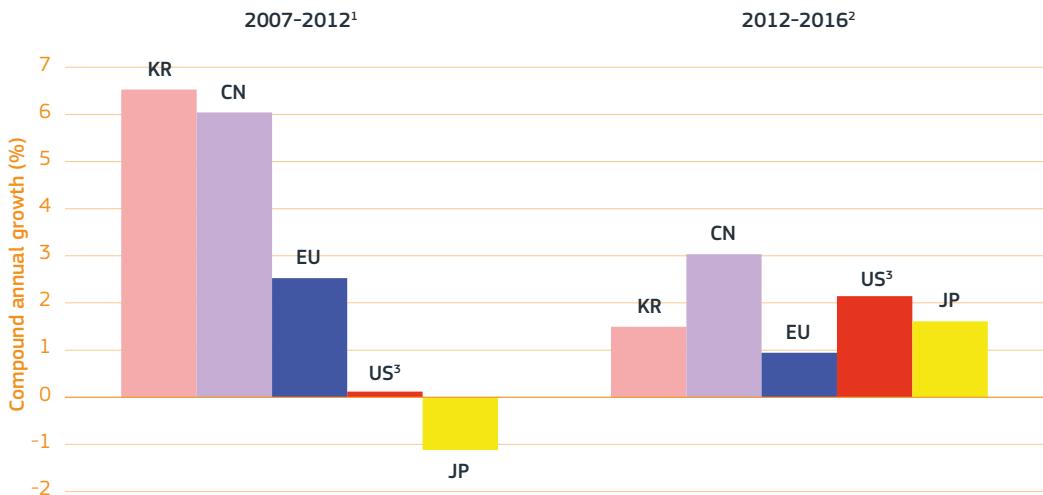
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f10\\_business\\_rd\\_intensity.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f10_business_rd_intensity.xlsx)

*Business R&D intensity in the EU proved to be quite resilient over the first period of the economic crisis and grew at a compound annual growth rate of 2.5% over 2007-2012. This was a much higher level of growth than that experienced in the United States (0.1%) and Japan (-1.1%).*

0.9% per annum, a growth rate that was less than half that of China and the United States, and well below the growth rates of Japan and South Korea (Figure 1.3-A.11). Nevertheless, there are now clear signs of economic recovery in the EU and it is expected that this will lead to increasing business investment in R&D and to higher business R&D intensities.

However, over the period 2012-2016, business R&D intensity growth slowed in the EU to

**Figure I.3-A.11 Business R&D intensity - compound annual growth, 2007-2012 and 2012-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>CN: 2009-2012. <sup>2</sup>US, JP, CN, KR: 2012-2015. <sup>3</sup>US: Business R&D expenditure does not include most or all capital expenditure.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f11\\_berd\\_int\\_cagr.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f11_berd_int_cagr.xlsx)

**The analysis of R&D investment at the aggregate level masks large differences across EU Member States.**

Overall, there is a large dispersion in terms of R&D investment levels, as well as in their dynamics, with some low investors stagnating, some high investors accelerating, and several, but not all, Central and Eastern European countries sharply increasing their R&D levels, thereby initiating a process of upwards convergence (Figure I.3-A.12). The highest EU R&D intensity growth rates over 2007-2015 occurred in Bulgaria, Poland and Slovakia, all of which had

growth rates at least four times higher than the EU average. The Czech Republic, Estonia, Greece, Malta and Hungary also had growth rates that were significantly higher than the EU average. Although the R&D intensities of all of these eight Member States were below the EU average in 2015, the gap with the EU average has narrowed considerably since 2007 for all of them with the exception of Malta. The process of convergence has been facilitated by the increased use of European Structural and Investment Funds available for R&I activities. Greater national efforts will be required to ensure the sustainability of this trend.

**Figure I.3-A.12 R&D intensity, 2016 and compound annual growth, 2007-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

Notes: <sup>1</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, RO, SI, SK, CH, ME, MK, TR, BA, MD, UA, TN, IL, US, JP, CN, KR: 2015. <sup>2</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SK, MK, TR, MD, UA, TN, IL, US, CN, KR: 2007-2015; SI, CH, JP: 2008-2015; EL, PT, SI: 2008-2016; RS: 2009-2016; ME: 2011-2015; BA: 2012-2015; IS: 2013-2016. <sup>3</sup>US: R&D expenditure does not include most or all capital expenditure. <sup>4</sup>FR, LU, NL, RO, SI, UK, JP, CN: Breaks in series occur between 2007 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series.

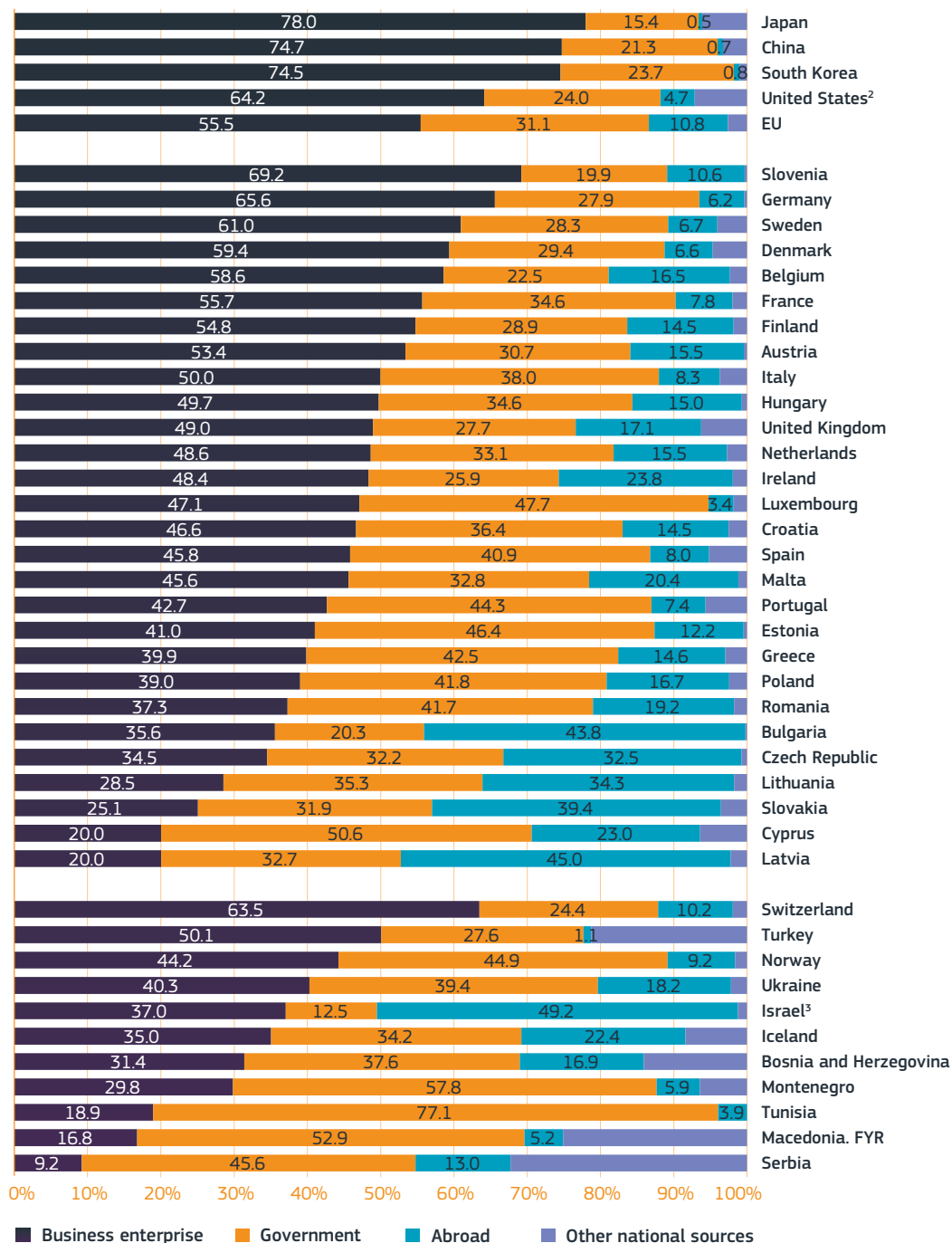
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f12\\_rd\\_intensity\\_2007-2015.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f12_rd_intensity_2007-2015.xlsx)



***In the EU as a whole, 31.1 % of R&D is financed by government.***

This share is much higher than the corresponding shares for the United States (24.0%), South Korea (23.7%), China (21.3%) and Japan (15.4%). This reflects the higher reliance and stronger role of public research in many EU Member States. In fact, there are only nine Member States where the share of R&D financed by government is lower than 30%. These are: Denmark (29.4%), Finland (28.9%),

Sweden (28.3%), Germany (27.9%), the UK (27.7%), Ireland (25.9%), Belgium (22.5%), Bulgaria (20.3%) and Slovenia (19.9%). Eight Member States have shares that are higher than 40%. In the EU, 55.5% of R&D is financed by domestic business enterprise, and an additional 7% of R&D is financed by business enterprise abroad. This still leaves the EU's share of R&D financed by business enterprise behind the United States (64.2%), South Korea (74.5%), China (74.7%) and Japan (78.0%), all of which have higher R&D intensities than the EU.

Figure I.3-A.13 GERD financed by sector (%), 2015<sup>1</sup>

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

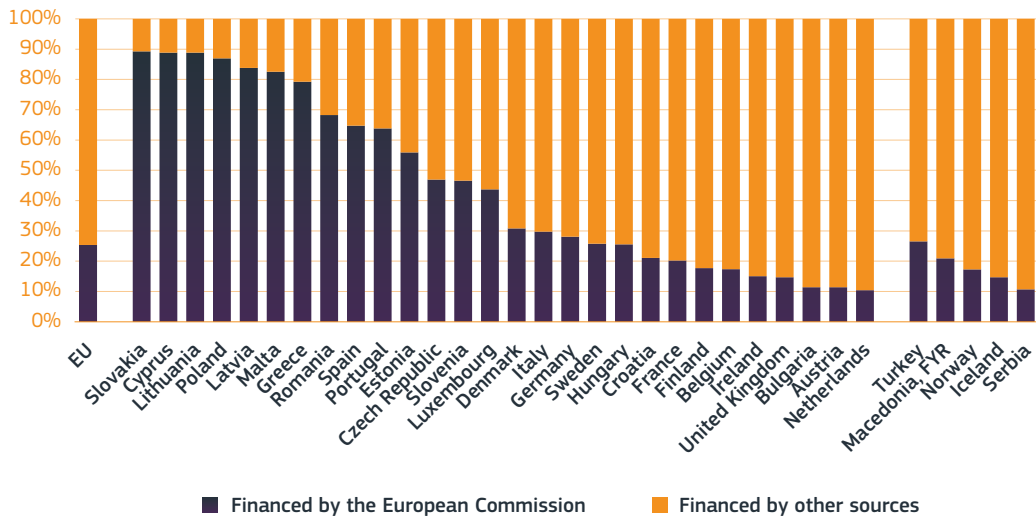
Notes: <sup>1</sup>SE, IL: 2013; FR: 2014; EL, AT, IS, RS: 2016. <sup>2</sup>US: R&D expenditure does not include most or all capital expenditure.<sup>3</sup>IL: Defence (all or mostly) is not included.Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f13\\_gerd\\_fin\\_by\\_sect.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f13_gerd_fin_by_sect.xlsx)

*R&D financing from abroad plays an important role in many countries.*

R&D financing from abroad originates from public and private sources. The main public source of financing from abroad for EU Mem-

ber States is the European Commission which funds R&D projects under the Horizon 2020 programme and the European Structural and Investment Funds. In 11 Member States, more than 50% of total R&D funding from abroad comes from the European Commission.

**Figure I.3-A.14 R&D expenditure financed from abroad, 2015<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Note: <sup>1</sup>SE: 2013; FR: 2014; IS: 2016.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f14\\_financing\\_from\\_abroad.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f14_financing_from_abroad.xlsx)

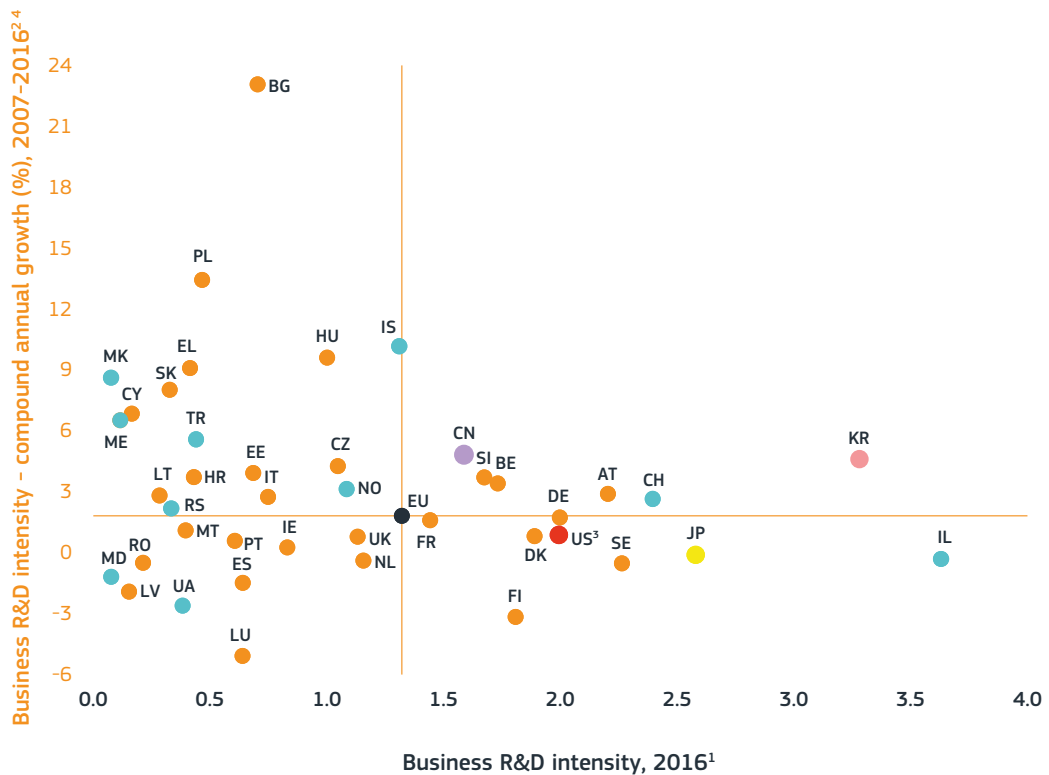


**Business R&D intensity growth rates have been more modest.**

Seven of the more R&D intensive EU Member States (Denmark, Germany, France, the Netherlands, Finland, Sweden and the UK) reported business R&D intensity growth rates lower than the EU average over the period 2007-2016. Of the other EU Member States,

Bulgaria, Hungary, Poland and Slovakia had very high business R&D intensity growth rates (above 8%) over the period 2007-2015, and in Bulgaria and Hungary the business R&D intensity gap with the EU average narrowed considerably between 2007 and 2015. Business R&D intensity in Slovenia has grown significantly since 2007 and is now much higher than the EU average (Figure 1.3-A.16).

**Figure 1.3-A.16 Business R&D intensity, 2016 and compound annual growth, 2007-2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

Notes: <sup>1</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK, CH, ME, MK, TR, MD, UA, IL, US, JP, CN, KR: 2015. <sup>2</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SK, MK, TR, MD, UA, IL, US, JP, CN, KR: 2007-2015; SI, CH: 2008-2015; EL, ES: 2008-2016; RS: 2009-2016; ME: 2011-2015; IS: 2013-2016. <sup>3</sup>US: Business enterprise expenditure on R&D (BERD) does not contain most or all capital expenditure. <sup>4</sup>LU, NL, RO, SI, UK, RS, CN: Breaks in series occur between 2007 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series.

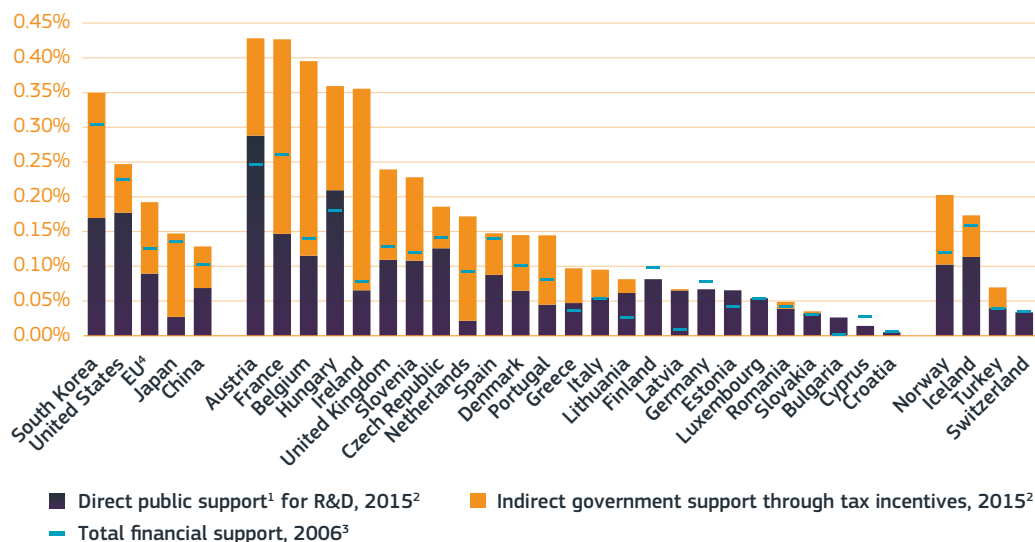
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f16\\_berd\\_intensity.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f16_berd_intensity.xlsx)

*In recent years, business R&D intensity has stagnated at the EU level. Public support for business R&D increased substantially from 0.13% of GDP in 2006 to 0.19% of GDP in 2015. While R&D tax incentives are effective in stimulating R&D investments, there is a lag between the introduction of an R&D tax incentive and an increase in R&D spending.*

Public support for business R&D as a percentage of GDP increased in 21 Member States between 2006 and 2015, with a rise of more than 100% in six of these countries. Much of this support came through the provision of tax incentives for R&D. In the EU as a whole, tax incentives for R&D now account for 53%

of all public support for business R&D. This share is greater than 50% in the Netherlands (87%), Ireland (82%), Belgium (71%), Portugal (69%), France (66%), Denmark (55%), the UK (54%), Slovenia (53%) and Greece (51%). Two of these economies, Denmark and Ireland, are the most high-tech-intensive economies in the EU. Germany and Finland, both of which have high business R&D intensities, either have no tax incentives for R&D. It should be noted that there is a lag between the introduction of an R&D tax incentive and an increase in R&D investment that would be contingent on how the incentive is designed and implemented, as well as on the structure of the economy in which it is implemented.

**Figure I.3-A.17 Public support for business R&D as % of GDP, 2006 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD, Eurostat

Notes: <sup>1</sup>Estimated direct public support for business R&D includes direct government funding, funding by higher education and public sector funding from abroad. Public sector funding from abroad is not included for DE, NL, IS, CH. <sup>2</sup>US, CN: 2013; BE, BG, FR, IE, EL, UK, IS, TR: 2014. <sup>3</sup>BE, DK, LU, SI, KR: 2007; CH, TR: 2008; RO, CN: 2009; SK: 2010; IS: 2011. <sup>4</sup>EU was estimated by DG Research and Innovation and does not include MT, PL, SE. Data on tax incentives for R&D are not available for MT, PL, SE. The following countries have no tax incentives for R&D: BG, DE, EE, HR, CY, LU, FI. <sup>5</sup>Elements of estimation were involved in the compilation of the data.

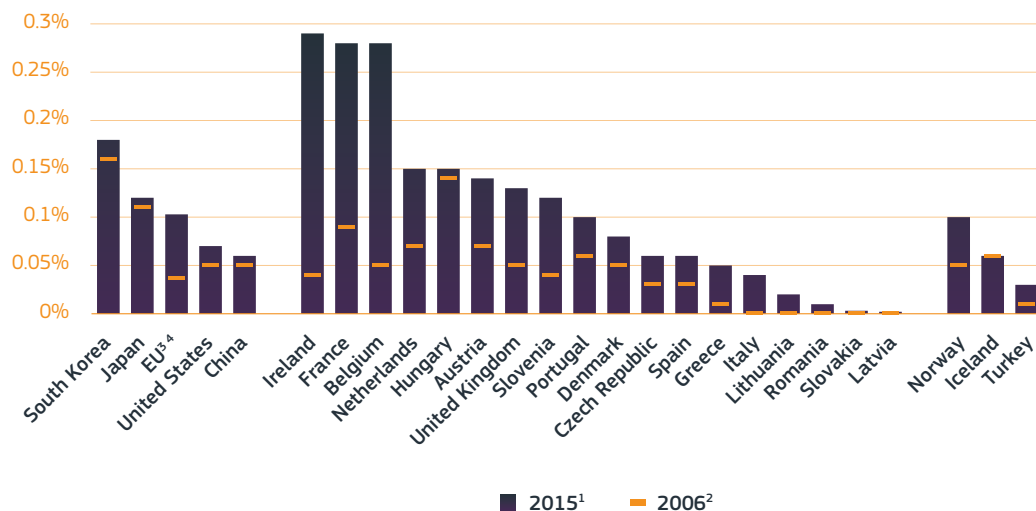
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f17\\_public\\_support\\_for\\_berd.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f17_public_support_for_berd.xlsx)

*Tax incentives are now part of the R&D landscape in most EU Member States; in the EU as a whole, they increased from 0.04% of GDP in 2006 to 0.1% of GDP in 2015.*

There is a much higher rate of increase in the use of tax incentives for R&D in Europe than in the United States, Japan, China and South Korea. Over the same period, tax incentives as a percentage of GDP increased by more than 100% in Belgium, Ireland, Greece,

France, the Netherlands, Slovenia, the UK and Turkey. Although tax incentives for R&D are now higher than they have ever been, business R&D intensity in the EU did not increase very significantly between 2012 and 2016. The development of more effective public sector measures to stimulate business investment in R&D will depend on each EU Member State finding the right balance between direct public support for business R&D and tax incentives for R&D.

**Figure I.3-A.18** Tax incentives for R&D as % of GDP, 2006 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD, Eurostat

Notes: <sup>1</sup>US, CN: 2013; BE, IE, EL, FR, UK, IS, TR: 2014. <sup>2</sup>BE, DK, SI, KR: 2007; TR: 2008; RO, CN: 2009; SK: 2010; IS: 2011.

<sup>3</sup>EU was estimated by DG Research and Innovation and does not include MT, PL, SE. Data on tax incentives for R&D are not available for MT, PL, SE. <sup>4</sup>BG, DE, EE, HR, CY, LU, FI, CH have no tax incentives for R&D.

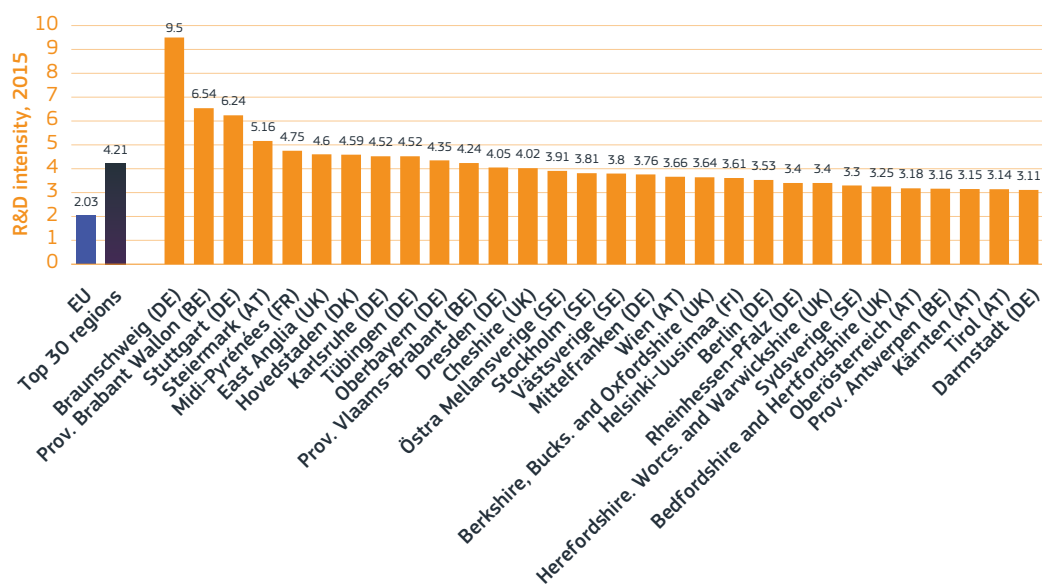
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/f18\\_tax\\_incentives.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f18_tax_incentives.xlsx)

*A regional analysis of R&D investment shows that research is heavily concentrated in particular regions of the EU, notably in core Member States such as Germany, Sweden, Austria, Belgium and Finland.*

The top 30 most R&D-intensive regions in the EU (out of a total of 272) accounted for 36% of all EU R&D expenditure and had an average

R&D intensity of 4.21% of GDP in 2015. This is significantly higher than the EU R&D intensity of 2.03%. The highest regional R&D intensity of 9.5% in Braunschweig (DE) was more than four times higher than the EU average. The top 10 regions all had R&D intensities that were at least double the EU average and were also higher than the R&D intensities for the United States, Japan, China and South Korea.

**Figure I.3-A.19** The 30 most R&D intensive regions<sup>1</sup> in the EU - R&D intensity, 2015<sup>2</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: <sup>1</sup>NUTS Level 2 regions. <sup>2</sup>FR: 2013.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/figure\\_19\\_top\\_30\\_regions.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/figure_19_top_30_regions.xlsx)



*The concentration of research activity in the most R&D intensive regions has not increased in recent years.*

In 2007, the top 30 most R&D intensive regions at that time accounted for an estimated 42% of all EU R&D expenditure and had an estimated R&D intensity of 3.65% of GDP. There is some evidence to suggest that a regional ‘catching-up’ process may be taking place (Figure I.3-A.20). In 2015, the 30 regions ranked 31 to 60 in terms of R&D intensity had an aggregate R&D intensity of 2.60% and accounted for 24% of all EU R&D expenditure compared to an aggregate R&D intensity of 2.23% and a 17% share of total EU R&D expenditure in 2007. In 2015, the narrowing of the R&D expenditure gap between the top 30 regions and the regions ranked 31 to 60 is an indication of more widespread regional R&D activity, although a change in the Île-

de-France’s ranking from 28 in 2007 to 33 in 2015 had a big impact in this regard. It is noticeable that R&D intensities for the three categories of regions increased significantly between 2007 and 2015, with the highest rise of 17.3% occurring in the least R&D intensive category of regions. The funding of R&D projects under the European Commission Framework and Horizon 2020 Programmes and the Structural Funds is a catalyst for this process. The Smart Specialisation Strategies approach, which was integrated into the reformed Cohesion Policy for 2014-2020, and which was designed to maximise the positive impact on growth and jobs, is already helping over 120 regions to identify their strengths and competitive advantages as a basis for prioritising R&I investment. Exploiting the full R&D potential of individual regions will lead to higher regional and national R&D intensities and reduce regional R&D intensive disparities.

**Figure I.3-A.20** R&D intensity and % share of R&D expenditure by category of region<sup>1</sup>, 2007 and 2015<sup>2</sup>

	R&D intensity			% share of total R&D expenditure	
	2007	2015	% change 2007-2015	2007	2015
Top 30 R&D intensive regions	3.65	4.21	15.3	42	36
Regions ranked 31 to 60 in terms of R&D intensity	2.23	2.60	16.7	17	24
Regions ranked higher than 60 in terms of R&D intensity	1.09	1.28	17.3	41	40
EU	1.77	2.03	15.0	100	100

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: <sup>1</sup>NUTS Level 2 regions. <sup>2</sup>FR: 2013. <sup>3</sup>Some figures were estimated when the data were compiled.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-a\\_figures/figure\\_20\\_regional\\_table.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/figure_20_regional_table.xlsx)

## CHAPTER I.3-B: INVESTMENT IN INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

*ICT is the driving force of the digital era and has the potential to spur innovation, job creation, productivity and economic growth<sup>4</sup>.*

ICT has profoundly shaped (and changed) the way businesses operate across all sectors of the economy and how individuals communicate and interact with each other. By creating opportunities to buy products and services online, engage in long-distance video calls, and store, exchange and share data, ICTs have also contributed to enhancing well-being. Investments in technologies, such as big data, high performance computing, the Internet-of-Things (IoT), artificial intelligence (AI) and cloud computing are also enabling productivity-enhancing processes and systems and contributing to ICT-driven innovation. In addition, ICTs are becoming increasingly relevant to create new and 'better' jobs. However, due to the disruptive nature of these technologies, it is important to ensure that the digital transition follows an inclusive approach whereby the access, adoption and uptake of digital technologies is widespread across individuals and firms. If not, the lack of ICT diffusion from frontier to laggard firms and among individuals could contribute to widening the digital divide and jeopardising the potential of ICTs to elevate living standards and generate inclusive and resilient growth in Europe. Investments in ICT coupled with investments in knowledge-based capital (see Section I.3-D) hold part of the solution to meet this ambition<sup>5</sup>.

*The contribution of ICT capital to economic growth has slowed down since the crisis.*

The economic and financial crisis that followed the burst of the dot.com bubble had a negative impact on the contribution of ICT investments to economic growth (OECD, 2016b), which has slowed down substantially when comparing the period 2000-2007 with 2008-2015. Of the EU Member States with available data, the contribution of ICT investments declined the most in percentage points (-0.41) between both periods in Sweden, followed by Denmark (-0.31 percentage points) and Portugal (-0.28 percentage points). In South Korea, Japan and the United States, the contribution of ICT investments to GDP growth also slowed down significantly, with a fall of 0.33, 0.31 and 0.29 percentage points, respectively, between the two periods under consideration, despite the recent rise in digital technologies. When focusing only on the period 2008-2015, Belgium, the Netherlands and Austria were the EU Member States where ICT capital contributed the most to GDP growth (with increases of 0.28, 0.26 and 0.25 percentage points, respectively). While understanding the full reasons for this decline is complex, lower investment levels and returns on these investments may be behind this trend.

4 See, for instance, OECD (2016a) and Cardona, M., Kretschmer, T. and Strobel, T. (2013).

5 For example, IT is more effective when paired with good management. Bloom et al. (2012) found that "US IT-related productivity advantage is primarily due to its tougher people management practices". Haskel and Westlake (2017) also emphasise the growing dominance of the intangible economy to explain a firm's success.

**Figure I.3-B.1** Contribution of ICT capital<sup>1</sup> to GDP growth (percentage points), average over 2000-2007 and 2008-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD Productivity Database

Note: <sup>1</sup>ICT capital: computer hardware, telecommunications equipment, and computer software and databases.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_1.xlsx)

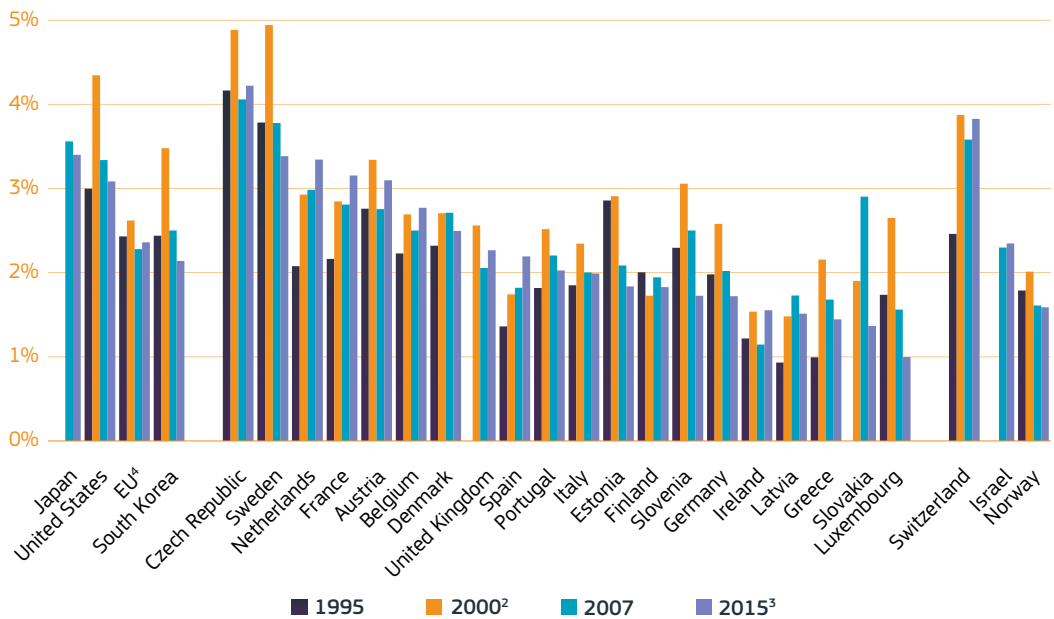
**The EU still invests less in ICT than other third countries such as Japan and the United States.**

ICT investments have an important role to play as catalysts of economic growth, through both the supply and the demand side (OECD, 2016a). On the supply side, investing in ICT fosters upwards convergence towards higher-value-added and productive activities. The widespread access and use of ICTs on the demand side can also contribute to efficiency gains across all sectors of the economy and to societal welfare. Through the “ICT dividend”<sup>6</sup>, ICT investments generate a higher return on productivity growth than other types of capital investment.

After a generalised increase in ICT investments between 1995 and 2000, overall, investments con-

tracted to a lower level in 2015 (in some countries even slipping back to 1995 levels). From 2000 to 2015, the share of ICT investments declined significantly in the United States and South Korea. Despite the recent increase of ICT investment in Europe, the EU continues to lag behind Japan and the United States, as investment rose slightly above 2% in 2015 against values above 3% in the United States and Japan. Some EU Member States, such as the Czech Republic, Sweden and the Netherlands, stand out as top investors in ICT as a percentage of GDP with shares equivalent to or even higher than those of the United States and Japan. Luxembourg, Slovakia and Greece were the EU Member States that registered the lowest shares of ICT investments relative to GDP in 2015, showing a decline since 2007.

**Figure I.3-B.2 Investment in ICT<sup>1</sup> as % of GDP, 1995, 2000, 2007 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: OECD Compendium of Productivity Indicators 2016, OECD National Accounts at a Glance, Eurostat

Notes: <sup>1</sup>For those countries for which data on total investment in ICT were not available, investment in ICT as % of GDP was derived from the ICT share in gross fixed capital formation (GFCF) and the share of GFCF in GDP. <sup>2</sup>DE, CH, KR: 2001. <sup>3</sup>SI: 2013; DE, DK, EE, IE, ES, LV, PT, SK, SE: 2014. <sup>4</sup>EU is the average of the available data for Member States weighted by GDP.

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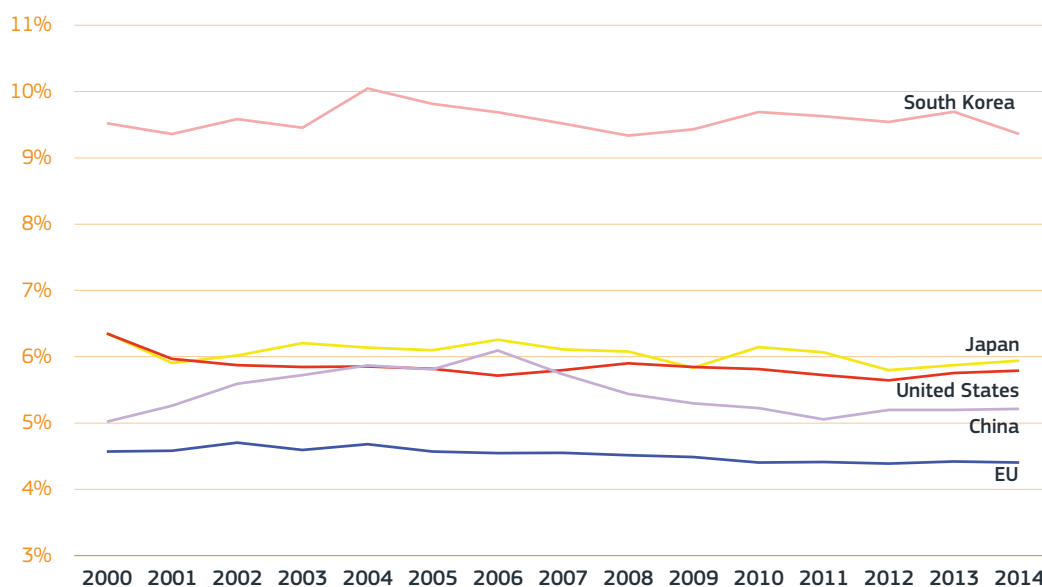
6 See, for example, Oxford Economics (2012).

*This is reflected in a lesser role for the ICT sector in the European economy than among other international players.*

The value added of the ICT sector in the EU stagnated at around 4.5% of GDP between 2000 and 2014. Hence, the contribution of

the ICT sector to the European economy in 2014 was still below that of South Korea (8.9%), Japan (5.4%), the United States (5.29%) and China (4.71%). Differences in investment trends between the EU and some of these third countries may partly explain this gap in the role of ICT.

**Figure I.3-B.3 Value added in ICT<sup>1</sup> as % of GDP, 2000-2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT Project (DG JRC)

Note: <sup>1</sup>The operational definition of ICT, as defined in the PREDICT project, was used. The operational definition of ICT allows for international comparison with non-EU countries.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_3.xlsx)

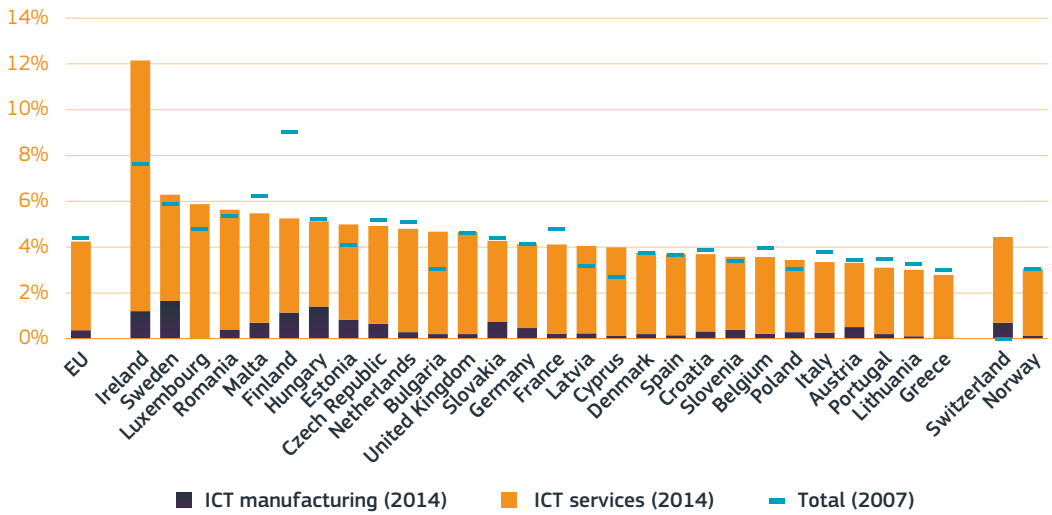
*There has been little progress in raising the share of ICT in the value added of most Member States, although there are some notable exceptions.*

The value added of the ICT sector was highest in Ireland in 2014, with marked increases in the importance of the sector from 7.6% in 2007 to 12.2% of GDP in 2014. In Greece, the sector accounted for less than 3% of GDP in 2014, and in Finland there was a substantial

decline in this share from 9% to 5.3% of GDP between 2007 and 2014.

On average, ICT services represented 91.2% of the ICT sector in 2014. In fact, in some countries, like Luxembourg, the contribution of ICT manufacturing industries to ICT value added is almost non-existent, while in others, such as Sweden and Hungary, this sector still contributes to a little more than one-quarter of the sector's value added.

**Figure I.3-B.4** Value added in ICT<sup>1</sup> as % of GDP broken down by manufacturing and services, 2014 (and for 2007 without breakdown)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT project (DG JRC)

Note: <sup>1</sup>The comprehensive definition of ICT, as defined in the PREDICT project, was used.

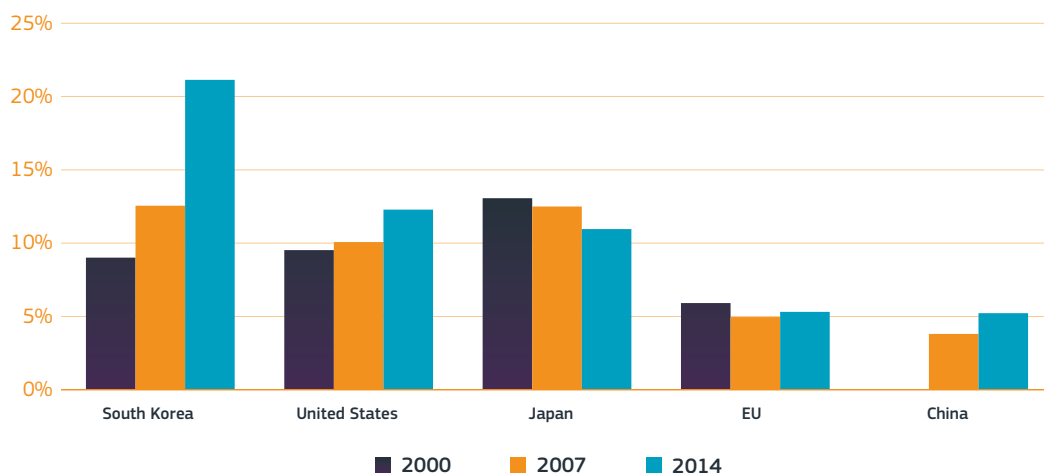
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**Europe's investment in R&D in the ICT sector also lags behind.**

Private R&D intensity in the European ICT sector lags behind that of other major international players (see Figure I.3-B.5 below). Overall, in the period 2000-2014, the business R&D

intensity in ICT of companies located in the EU was around half that of those based in the United States, Japan and South Korea. This illustrates that the EU ICT sector not only lags behind in terms of its size in the economy but is also not focused on R&D-intensive activities.

**Figure I.3-B.5 R&D intensity of ICT<sup>1</sup>, 2000, 2007 and 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: PREDICT Project (DG JRC)

Note: <sup>1</sup>Business enterprise expenditure on R&D as % of value added. The operational definition of ICT, as defined in the PREDICT project, was used. The operational definition of ICT allows for international comparison with non-EU countries.

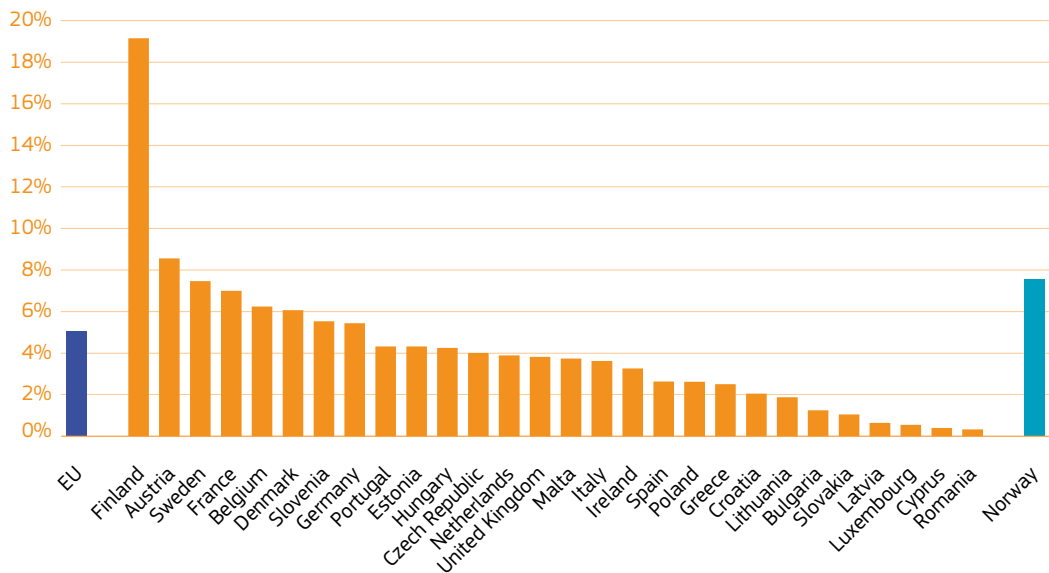
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However, some Member States stand out in ICT, due to their R&D investment in this sector.

Figure I.3-B.6 shows that, in 2014, Business Enterprise R&D expenditure (BERD) in the ICT sector was notably high in Finland (19.2% of total value added), followed by Austria (8.6%) and Sweden (7.5%). On the contrary, BERD in-

tensity in Luxembourg, Cyprus and Romania was significantly lower, with values of 0.5%, 0.4% and 0.3%, respectively. This reveals the considerable variation across EU Member States in efforts by the private sector devoted to investing in R&D in the ICT sector, and explains why the EU lags behind other advanced economies, as mentioned above.

Figure I.3-B.6 R&D intensity of ICT<sup>1</sup>, 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT project (DG JRC)

Note: <sup>1</sup>Business enterprise expenditure on R&D as % of value added. The comprehensive definition of ICT, as defined in the PREDICT project, was used.

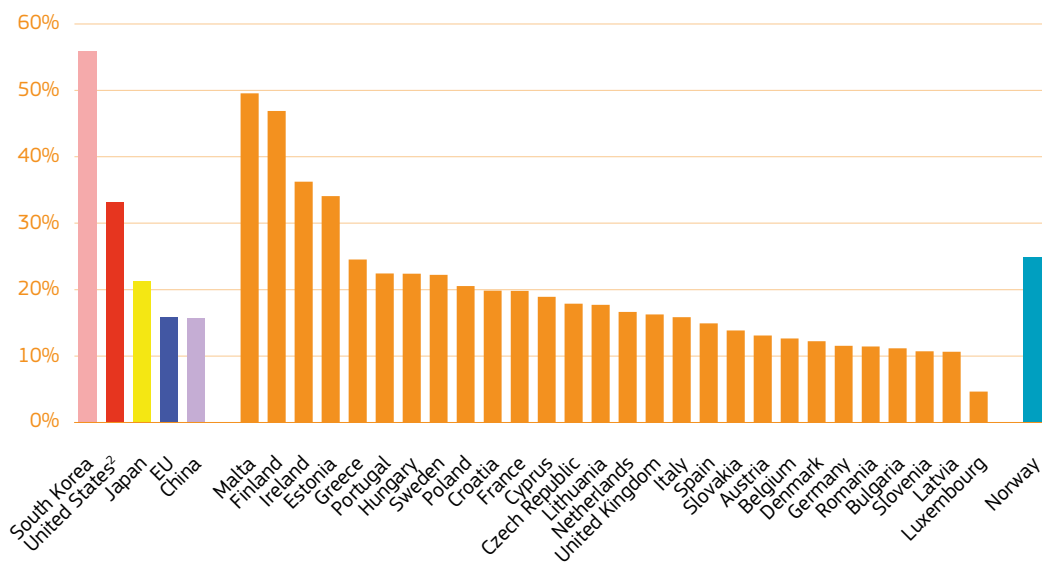
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Different patterns also emerge when assessing the representativeness of business R&D expenditures on ICT in total BERD. South Korea is an outstanding example of a country where private investments in R&D are remarkably channelled to the ICT sector (more than half of the total BERD). This is correlated with the fact that the country has the highest ICT value-added contribution to GDP. In the United States, 33.1% of private R&D investments

are allocated to the ICT sector versus 16.4% in Europe. Malta and Finland (and also Ireland) have the highest shares of BERD in ICT relative to total private R&D investments since the ICT sector has a strong role in these economies. The most striking case is that of Luxembourg which despite relying heavily on the ICT sector, has the lowest share of BERD devoted to ICT which is probably due to higher private R&D investments in the financial sector.

**Figure I.3-B.7 Business R&D expenditure on ICT<sup>1</sup> as % of total business R&D expenditure (BERD), 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: DG JRC, Eurostat, OECD

Notes: <sup>1</sup>The comprehensive definition of ICT, as defined in the PREDICT project, was used for all countries with the exception of EU, US, JP, CN and KR in respect of which the operational definition was used. <sup>2</sup>US: Business R&D expenditure (BERD) does not include most or all capital expenditure.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_7.xlsx)

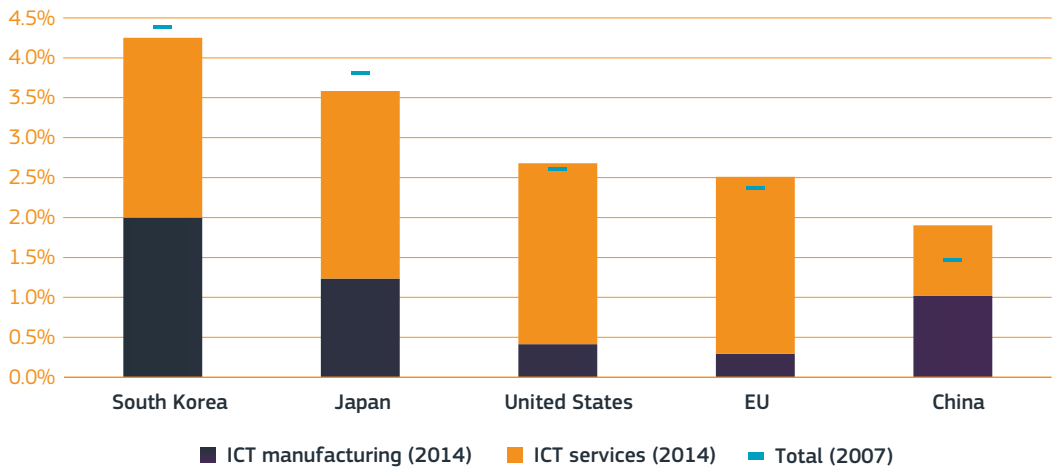
*The share of jobs in the ICT sector in Europe is lower than in South Korea, Japan or the United States, even though more new jobs come from this sector.*

the economic crisis. Nevertheless, the EU still lags behind South Korea (4.2%), Japan (3.6%) and the United States (2.7%) with China catching up (from 1.5% in 2007 to 1.9% in 2014).

Due to its dynamic and innovative nature, the ICT sector is a key source of new jobs in the economy. The importance of this sector for employment in the EU rose slightly between 2007 (2.4%) and 2014 (2.5%)<sup>7</sup> with ICT services representing almost 90% of total ICT employment. In fact, the ICT sector proved resilient to expanding its share of employment between 2007 and 2014, despite

Most EU Member States also increased the weight of the ICT sector in total employment over 2007-2014. Luxembourg (4.28%), Malta (4.26%) and Ireland (4.16%) emerge as the Member States with the highest shares, even outperforming other third countries such as Switzerland (3.39%) and Norway (2.84%) in 2014, as illustrated by Figure I.3-B.9.

**Figure I.3-B.8** Employment in ICT<sup>1</sup> as % of total employment broken down by manufacturing and services, 2014 (and for 2007 without breakdown)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

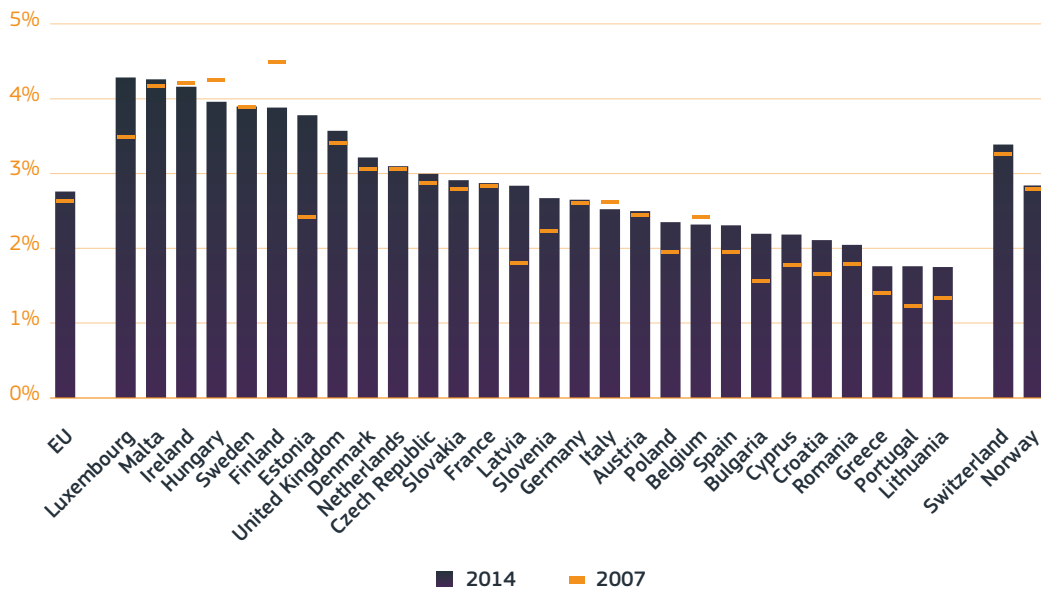
Data: PREDICT project (DG JRC)

Note: <sup>1</sup>The operational definition of ICT, as defined in the PREDICT project, was used. The operational definition of ICT allows for international comparison with non-EU countries.

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7 This follows the 'operational definition' of the JRC's PREDICT project which allows for comparisons between the EU and other international players. For this reason, the shares presented for the EU in this figure and in Fig.I.3-B.9 (which follows a more comprehensive definition of the sector) will be slightly different.

**Figure I.3-B.9** Employment in ICT as % of total employment, 2007 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT project (DG JRC)

Note: <sup>1</sup>The comprehensive definition of ICT, as defined in the PREDICT project, was used.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_9.xlsx)

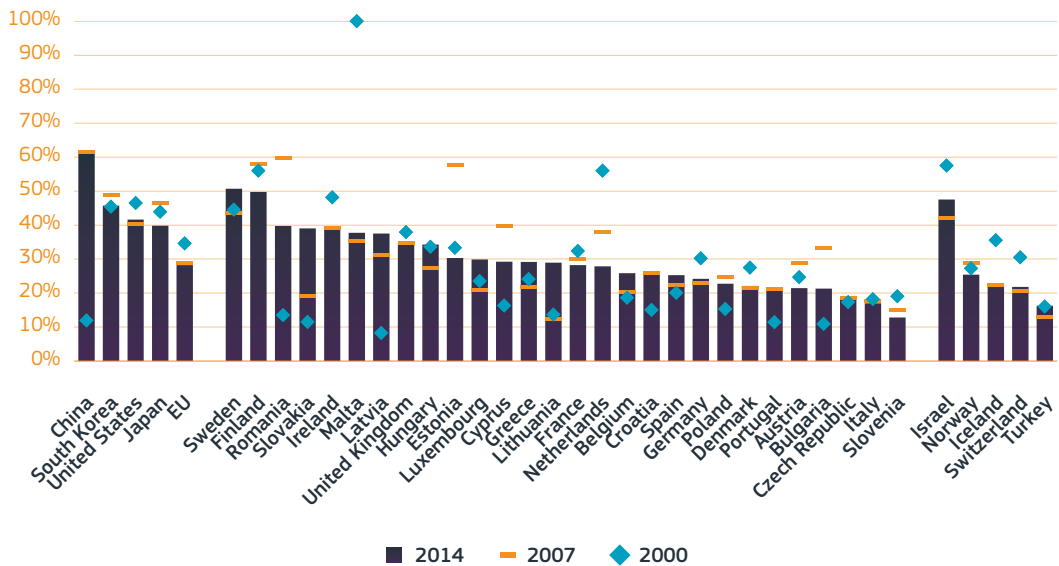
**Underinvestment in ICT research in Europe has translated into a lower degree of innovativeness in the sector.**

ICT-related patents as a share of total patents in Europe have declined since 2000, from 34.6% to 28.3% in 2014. This compares with significantly higher shares of patenting in ICTs in Japan (39.8%), United States (41.7%), South Korea (45.7%) and China (61.2%) in 2014. In particular, in 2014, China registered a spectacular growth in ICT patenting since 2000 of almost 50 percentage points. Israel also appears as a top innova-

tor in ICT with ICT-related patents accounting for nearly 48% of total patent applications in 2014.

Sweden, Finland and Romania are the EU Member States with the highest shares of ICT patenting relative to total patenting, with shares of 50.7%, 49.8% and 39.8% in 2014, respectively. On the contrary, Slovenia (12.8%), Italy (17%) and the Czech Republic (18.5%) are the countries with the lowest representation of ICT patenting in total patenting. Considerable differences are also found in the evolution pattern of ICT innovation across EU Member States.

**Figure I.3-B.10 ICT-related<sup>1</sup> PCT patent applications as % of total PCT patent applications<sup>2</sup>, 2000, 2007 and 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: OECD

Notes: <sup>1</sup>Domains covered are: telecommunications, consumer electronics, computers, office machinery and other ICT.

<sup>2</sup>Patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO). Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

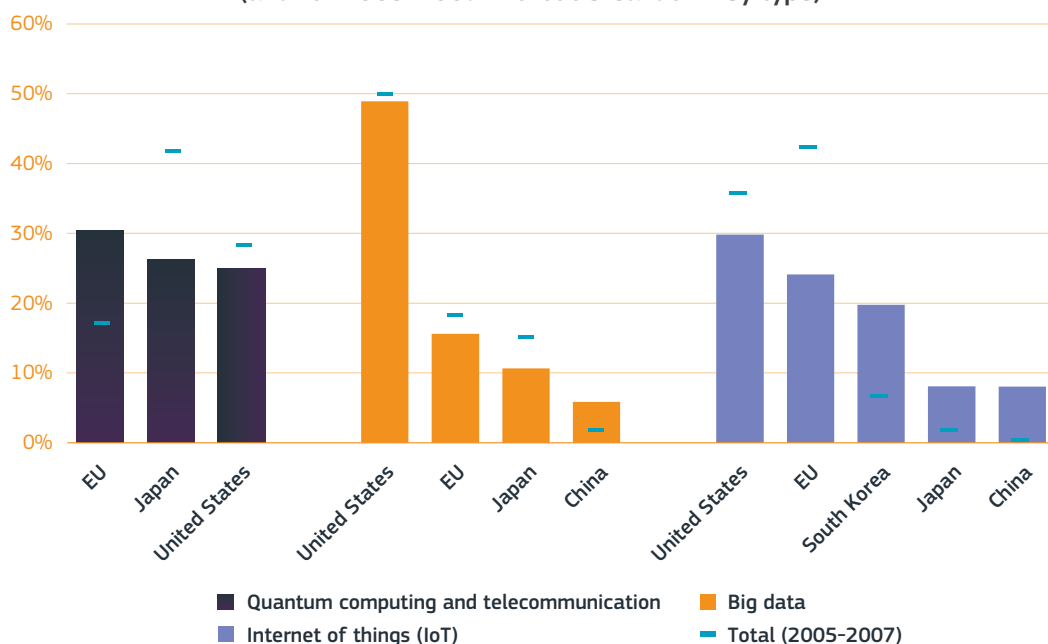
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*Europe lags behind the United States in particular with regard to some of the ‘new-generation ICT technologies’, including AI.*

Some ICT technologies – ‘New generation ICT technologies’ – have an inherent disruptive capacity to shape new business processes, models and organisation and to set the path towards enhanced innovation in the ICT sector. While the EU was leading in ‘quantum computing and telecommunication’ with a share of around 30% of the patent families in this field, nevertheless, it has lost its positioning as the leader in inventive IoT patenting to the United States, and lags substantially behind the latter in big data patenting. More recently, South Korea has increased its share in IoT patenting to the detriment of a lower share for the United States and the EU, as well as China, which has improved its position significantly as big data and IoT innovator from an initial relatively low share over the period 2005-2007.

Figure I.3-B.12 shows the evolution of the worldwide distribution of AI patenting between two different periods: 2000-2005 and 2010-2015. Japan emerges as the world’s top inventor economy in AI in both periods under consideration, although its leadership weakened in 2010-2015 as South Korea and China increased their relevance significantly in the most recent period. The United States’ share declined from 23.2% to 17.2% between both periods. The EU’s share fell from 19.1% in 2000-2005 to only 11.9% over 2010-2015, which may indicate that the EU may be ‘missing the train’ when it comes to the creation of new AI technologies. Within the EU, Germany stands out as the most active Member State in AI patenting in both periods, but its weight declined from 6.3% in 2000-2005 to 3.7% over 2010-2015. France and the UK also stand out in the EU context with a contribution of 2.1% and 1.9% to the world’s AI patenting over 2010-2015.

**Figure I.3-B.11 New-generation technologies – % share of IP5<sup>1</sup> patent families filed at EPO and USPTO by type of ICT technology, 2010-2012 (and for 2005-2007 without breakdown by type)**



Science, Research and Innovation performance of the EU 2018

Source: OECD Science, Technology and Industry Scoreboard 2015

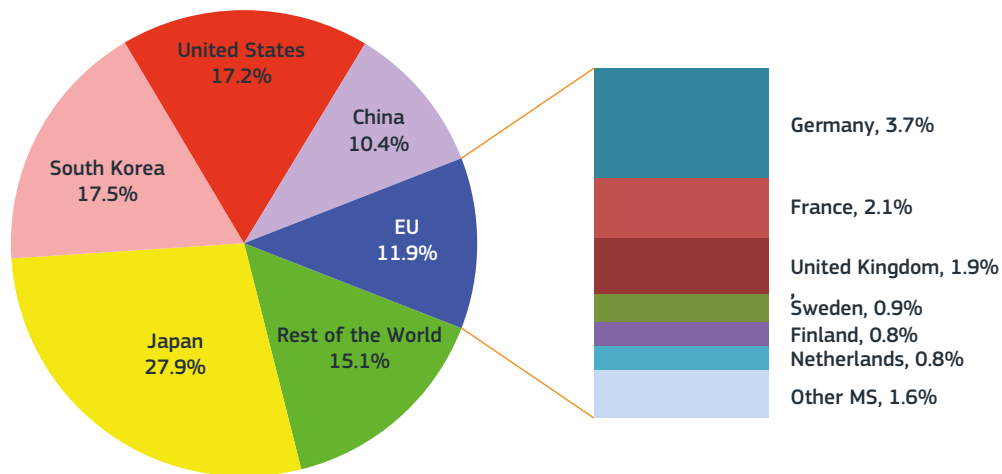
Note: <sup>1</sup>The five IP offices (IP5) is a forum of the five largest intellectual property offices in the world (EPO, USPTO, JPO, SIPO, KIPO). They account for 90% of all patent applications filed worldwide.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_11.xlsx)

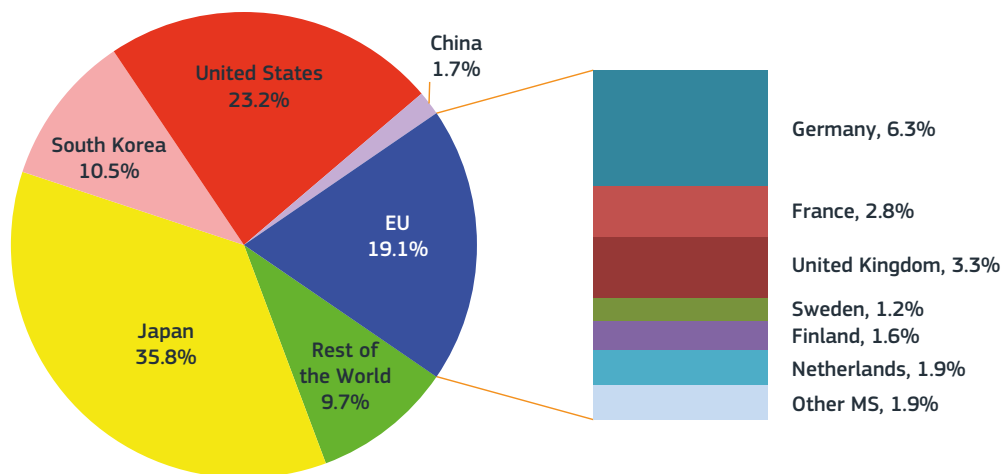
**Figure I.3-B.12 Top inventors' economies in terms of AI patents**

Distribution of AI-related IP5 patent families by economy, %

2010-2015



2000-2005



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD (STI Scoreboard 2017)

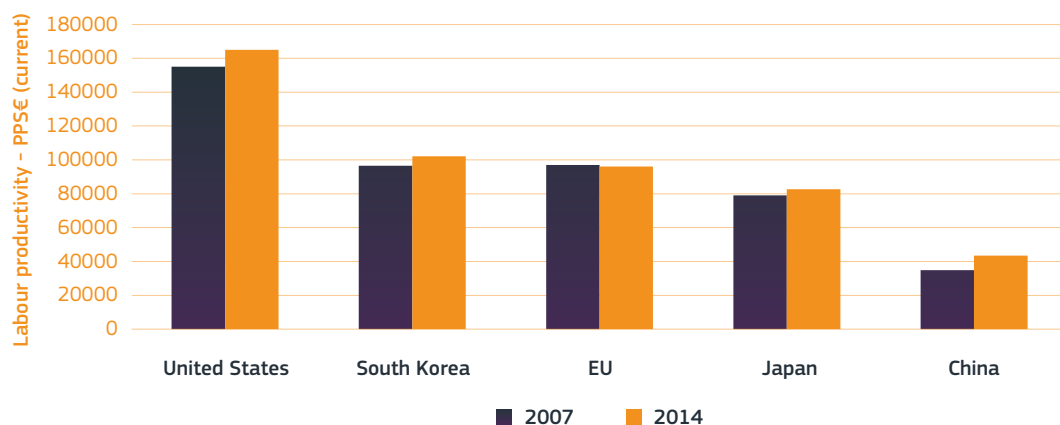
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*In Europe, the ICT sector's productivity is lower than in the United States or South Korea.*

According to Figure I.2-B.13, labour productivity in ICT stabilised in the EU at around 96 000 PPSE per person employed in 2014. This compares

with a lower productivity of 83 000 PPSE in Japan and 44 000 PPSE in China in the same year. Nevertheless, the EU labour productivity figure in the ICT sector is significantly lower than that of the United States (165 000 PPSE) and South Korea (102 000 PPSE).

**Figure I.3-B.13** Labour productivity (GDP per person employed)<sup>1</sup> in ICT<sup>2</sup>, 2007 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT project (DG JRC)

Notes: <sup>1</sup>GDP per person employed in current PPSE. <sup>2</sup>The operational definition of ICT, as defined in the PREDICT project, was used.

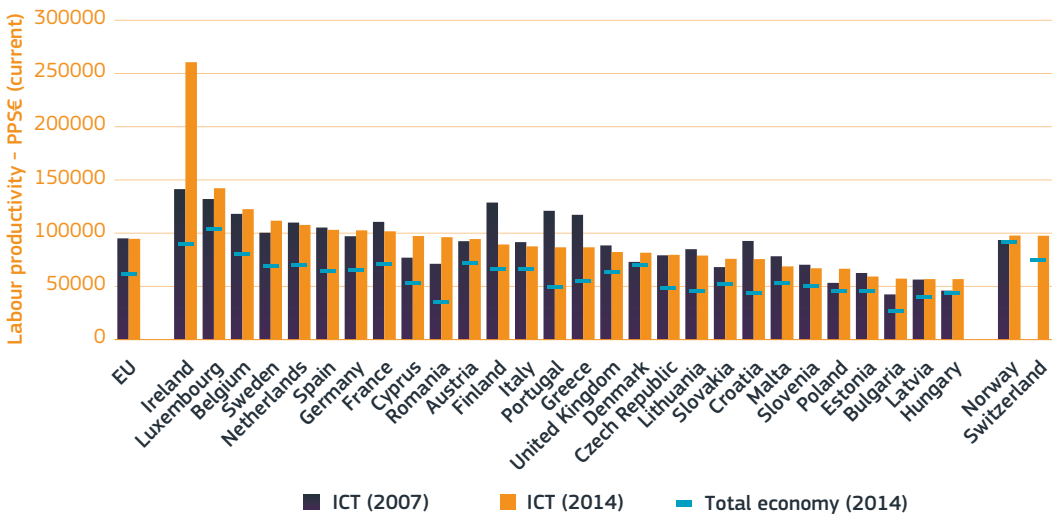
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However, the ICT sector is one of the most productive in the European economy.

As shown by Figure I.3-B.14, the ICT sector is typically more productive than the overall economy due to its intrinsic innovative and productivity-enhancing nature. Overall, ICT labour productivity increased in the medium term

(2007-2014) in around half of the EU Member States, while the other half saw a decline in ICT productivity. This decline was particularly apparent in Portugal, Greece and Finland. In 2014, Ireland, Luxembourg and Belgium registered the highest ICT productivity levels in Europe, with Ireland in the lead after a remarkable increase in ICT productivity between 2007 and 2014.

**Figure I.3-B.14** Labour productivity (GDP per person employed)<sup>1</sup> in ICT<sup>2</sup>, 2007 and 2014 (and total economy for 2014)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT project (DG JRC. Directorate B)

Notes: <sup>1</sup>GDP per person employed in current PPSE. <sup>2</sup>The operational definition of ICT, as defined in the PREDICT project, was used.

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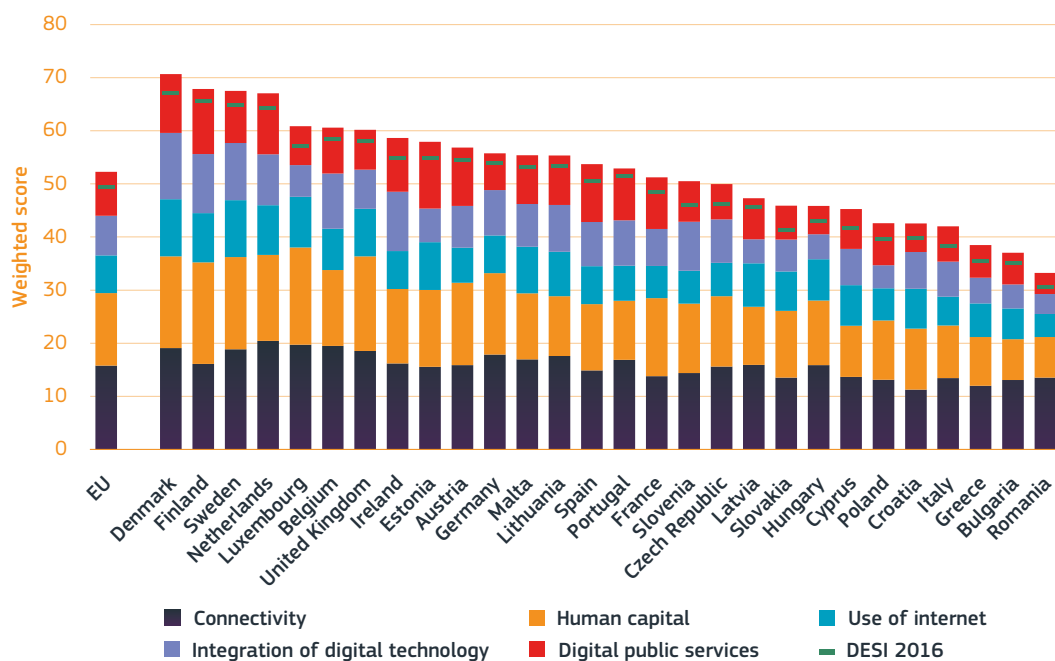


*Despite this European lag in the ICT sector's productivity, overall the EU Member States are making progress in improving their digital capacity.*

The European Commission's Digital Economy and Society Index (DESI) is a composite index which weighs relevant indicators on Europe's digital performance and tracks the evolution of digital

competitiveness in EU Member States. In 2017, all EU Member States improved their overall digital capacity as measured by the DESI. Scandinavian countries – Denmark, Sweden and Finland – were the top digital players, followed by Luxembourg, Belgium and the UK. The lowest overall digital performances were in Romania, Bulgaria, Greece and Italy. In the EU, Slovakia and Slovenia have progressed most in relation to 2016.

**Figure I.3-B.15 Digital Economy and Society Index (DESI)<sup>1</sup> by main dimension, 2017 (and total for 2016)**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission, Digital Scoreboard 2017

Note: <sup>1</sup>The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The index is the weighted average of the five main dimensions: connectivity, human capital, uses of internet, integration of digital technology and digital public services.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_15.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_15.xlsx)

***The digital divide between the most-advanced and least-advanced digital players still persists.***

The *connectivity* dimension of the DESI indicator (Figure I.3-B.16) examines the coverage and uptake of fixed and mobile broadband infrastructure and networks, including the speed and affordability of such connections. In 2017, the Netherlands, Luxembourg and Belgium were in the lead in this dimension with scores above 75, while Croatia, Greece and Bulgaria were the lowest performers with weighted scores below (or slightly above) 50. This differential in the scores between the top and bottom ranking shows there is still room to improve the quality of connectivity throughout Europe to boost ICT diffusion.

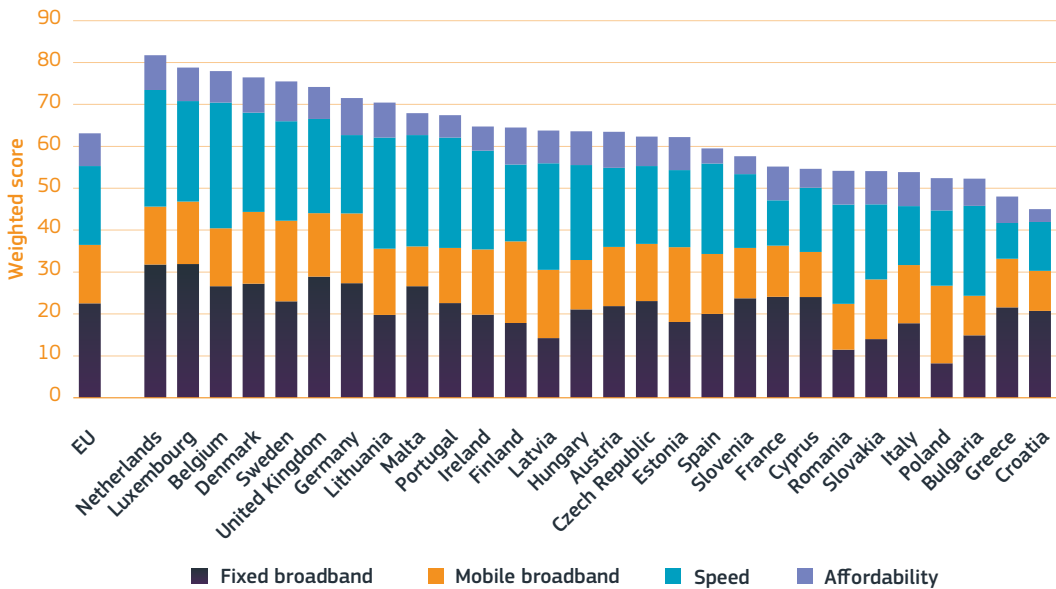
The *human capital* dimension (Figure I.3-B.17) assesses the level of digital skills in European economies, including basic skills such as internet access and more advanced workforce skills such as STEM competences. Here, Finland, Luxembourg and the UK registered the highest scores (above 70) while Greece, Bulgaria

and Romania had the lowest scores (below 40). Again, efforts must be made to foster the widespread use of these skills to ensure that all European citizens can exploit and fully grasp the opportunities offered by digitalisation.

The dimension *integration of digital technology by businesses* (Figure I.3-B.18) analyses practices linked to business digitisation, such as the use of electronic invoices and cloud technologies, and also includes an e-commerce sub-dimension. Businesses are the most advanced in this respect in Denmark, Ireland and Finland (scores above 55), and the least developed in Romania, Poland and Bulgaria (scores below 22.5) with e-commerce practices still far behind their full potential for use.

As for the *digital public services* dimension (Figure I.3-B.19) which focuses on e-government aspects such as pre-filled forms, the top scores (above 77) were in Estonia, Finland and the Netherlands while the lowest scores (below 36) were in Romania, Hungary and Croatia.

**Figure I.3-B.16** ‘Connectivity’ dimension of the Digital Economy and Society Index (DESI)<sup>1</sup>, 2017



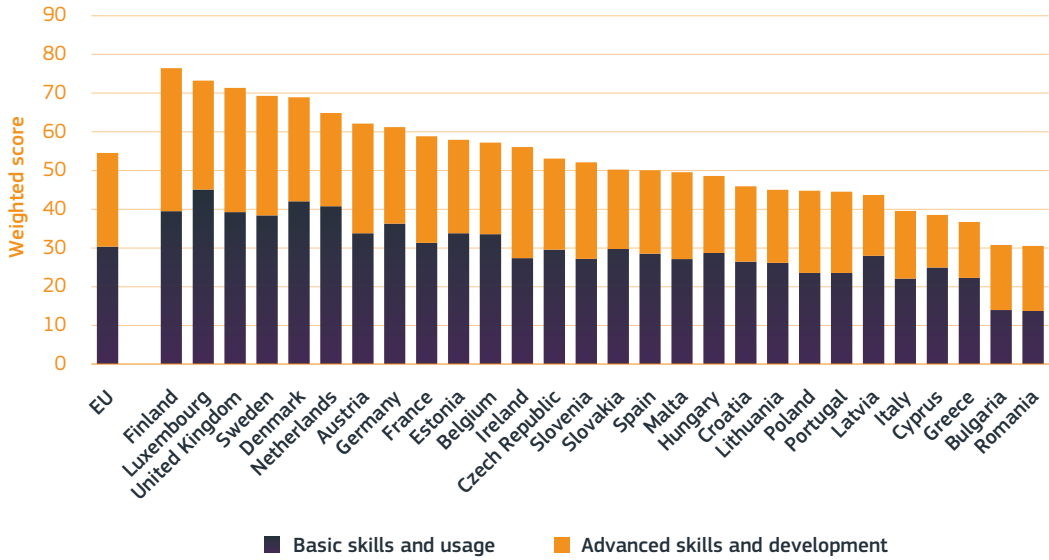
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: European Commission - DG CONNECT, Digital Scoreboard 2017

Note: <sup>1</sup>The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The connectivity dimension index is the weighted average of the four sub-dimensions: fixed broadband, mobile broadband, speed, and affordability.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_16.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_16.xlsx)

**Figure I.3-B.17** ‘Human capital’ dimension of the Digital Economy and Society Index (DESI)<sup>1</sup>, 2017



Science, Research and Innovation performance of the EU 2018

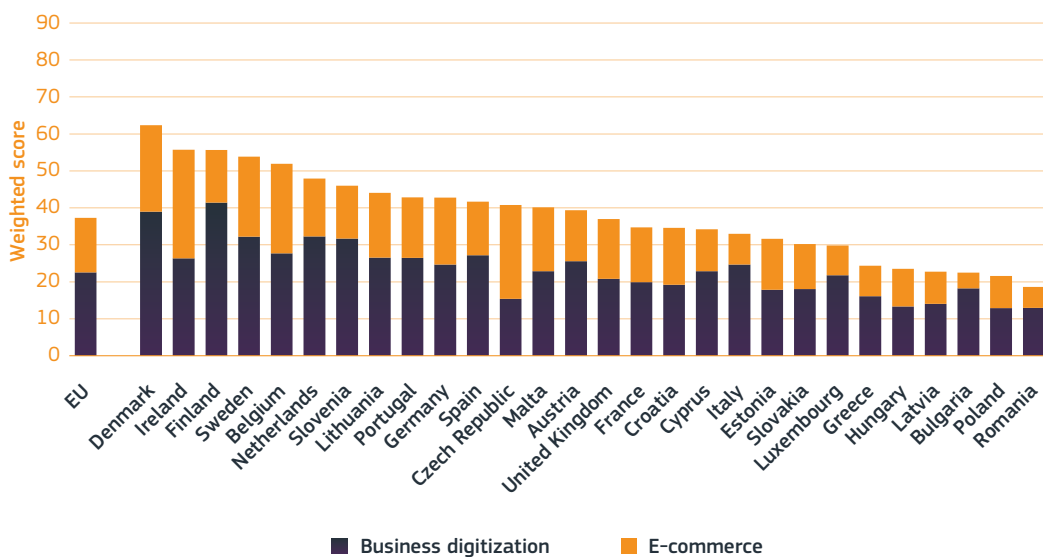
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG CONNECT, Digital Scoreboard 2017

Note: <sup>1</sup>The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The human capital dimension index is the weighted average of the two sub-dimensions: basic skills and usage, and advanced skills and development.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/part/i\\_3-b\\_figures/f\\_i\\_3-b\\_17.xlsx](https://ec.europa.eu/info/sites/info/files/srip/part/i_3-b_figures/f_i_3-b_17.xlsx)

**Figure I.3-B.18** ‘Integration of digital technology’ dimension of the Digital Economy and Society Index (DESI)<sup>1</sup>, 2017



Science, Research and Innovation performance of the EU 2018

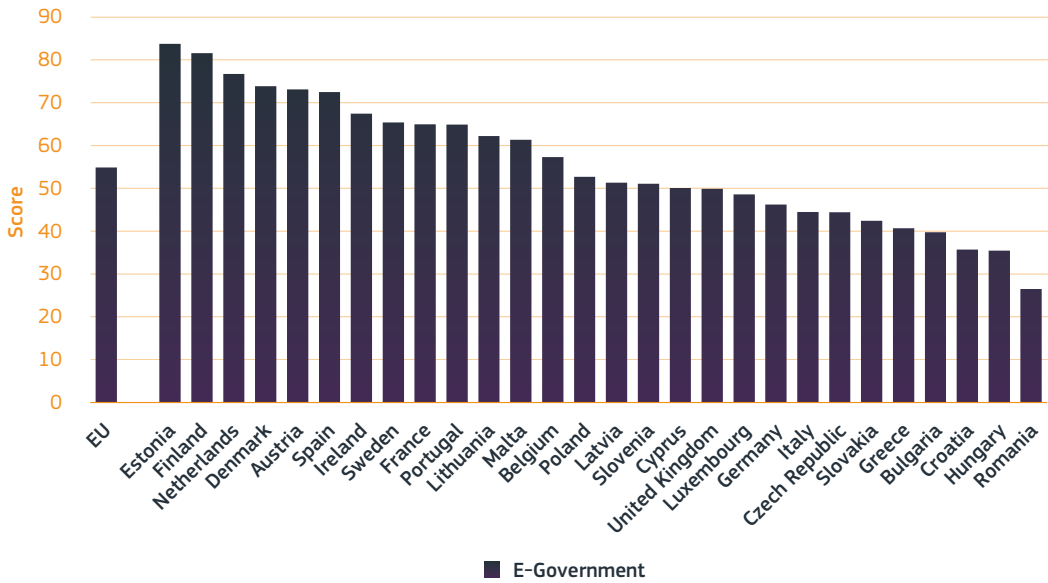
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG CONNECT, Digital Scoreboard 2017

Note: <sup>1</sup>The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The integration of digital technology dimension index is the weighted average of the two sub-dimensions: business digitisation and e-commerce.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/part/i\\_3-b\\_figures/f\\_i\\_3-b\\_18.xlsx](https://ec.europa.eu/info/sites/info/files/srip/part/i_3-b_figures/f_i_3-b_18.xlsx)

Figure I.3-B.19 ‘Digital public services’ dimension of the Digital Economy and Society Index (DESI)<sup>1</sup>, 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG CONNECT, Digital Scoreboard 2017

Note: <sup>1</sup>The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The integration of the digital public services dimension index comprises one sub-dimension: e-government.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-b\\_figures/f\\_i\\_3-b\\_19.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_19.xlsx)

**Different barriers appear to be undermining ICT diffusion and hence full exploitation of the benefits of ICTs which requires adequate policy responses.**

Bridging and closing the digital divide between more advanced and less digitally advanced countries requires a set of policy responses aimed at overcoming the main barriers to ICT diffusion within and across Member States. Indeed, many of those are associated with the completion of the Digital Single Market, as highlighted in the European Commission’s ‘Single Market integration and competitiveness report’ (2016)<sup>8</sup>. One of the main issues concerns the need to improve system interoperability together with the definition and use of well-established

standards. Without unified standards and full interoperability, the efficiency of ICT investments declines and can also generate hesitations over the so-called ‘vendor lock-in’ effect – i.e. not being able to change supplier (OECD, 2017).

In addition, there are legal and regulatory barriers to the creation and roll-out of new business models, especially when these rely substantially on digital technologies. The sharing economy and the spread of online platforms have challenged existing regulations and it is now clear that the regulatory environment will need to be flexible enough to accommodate these new innovation channels while at the same time ensuring that competition in the market, consumer protection and data security are all in place.

8 See also World Bank (2016).

## CHAPTER 1.3-C: SKILLS AND HUMAN RESOURCES

*The growing knowledge orientation of the economy and society, together with current demographic trends in Europe, make investment in skills and their lifelong upgrading increasingly important.*

Skilled human capital for research, innovation and economic development is crucial to sustain the needs of a knowledge economy. The EU is facing an increasing demand for skilled labour, including researchers, whilst at the same time it appears that labour related to routine activities is being replaced more and more by machines.

An additional challenge comes from ongoing demographic developments, such as the falling number of young people entering the labour market, which is expected in the future in many Member States, while the baby-boomer generation is set to retire within the next decade. The EU's working age population (20-64) peaked in 2010 at 307 million and has been declining ever since, with Southern, Central and Eastern European countries most affected by the shrinking labour force. At the same time, life expectancy continues to rise by about two years each decade. In the EU, the population of 65 years and older has grown by about 2 million per year, from 90 million in 2012 to 98 million in 2016,

and the old-age dependency ratio is also growing, directly affecting employment in the health and care sectors and indirectly (longer working life) the labour market.

Another factor is migration. In 2015, while the natural population change in the EU (births minus deaths) was, for the first time, negative, at -0.1 million, this was compensated for by a record net migration to the EU of 1.8 million. In 2016, while the natural change was again slightly negative, net migration totalled 1.5 million.

The demographic shift towards lower shares of young people and larger shares of elderly people is confronting Europe with important challenges. Given a global massification in tertiary education, a more favourable demography outside Europe, and strong investment in excellence (United States, China) in other world regions, the EU is facing growing competitive challenges as regards the quality and quantity of its human capital. This could endanger its traditional comparative advantage as regards skilled labour. Further investment in skills and their lifelong upgrading will also be necessary to bridge the productivity growth gap between the EU and the United States and South Korea.

***A strong growth in employment requiring a high level of qualifications is expected in the coming decade – at the same time, the number of jobs at medium- and low-qualification levels is likely to shrink.***

According to the 2016 Cedefop skills forecast (see Figure I.3-C.1) the economically active population (employed and disposable unemployed, aged 15 and over) will stagnate between 2015 and 2025. However, trends will differ significantly between Member States, with the economically active population, for mainly demographic reasons, shrinking strongly in Lithuania (-19.7%), Latvia (-11.3%) and Estonia (-7.6%). Germany, the EU's largest Member State, will face a decline of 3.8%. At the same time, the economically active population will continue to increase in most Western and Northern European Member States (UK +3.7%, France +5.7%), with Luxembourg (+22.9%) expected to show the highest growth rate.

In the same period, employment in the EU is expected to increase by 3%. The gap between employment growth and growth in the active population implies a decline in unemployment, both in absolute and relative terms. While employment is expected to increase in most EU Member States, with Cyprus (+15.3%), Ireland (+14.3%) and Luxembourg (+9.3%) expected

to show the highest growth, it is forecast to decline in five Member States: Estonia (-4.1%), Romania (-2.2%), Germany (-1.9%), Bulgaria (-1.6%) and Latvia (-1.2%), in most cases because of a shrinking labour force.

Furthermore, the EU is facing a shift to employment at higher qualification levels. While employment at high qualification levels is expected to increase by 22.6% in the period 2015–25, employment at medium qualification levels is forecast to fall slightly (-2.1%) and employment at low qualification levels to decline significantly (-17.6%).

In the EU, employment growth plus the need to replace people leaving workplaces (retirement, migration and other reasons) will lead to 97 million job opportunities in the next decade, of which over 40 million will be in jobs requiring high qualifications.

The trends shown might contribute to sustaining the gap in unemployment rates between different qualification levels. In 2016, according to Eurostat data, while the overall unemployment rate in the EU stood at 8.6%, it was nearly twice as high for those with a low level of qualifications (lower secondary education or less), reaching 16.1%, while the unemployment rate for highly skilled people (with at least tertiary education) in the EU was only 5.1%.



**Figure I.3-C.1** Key results of the 2016 Cedefop skills forecast

	Qualification level	2015-2025
Labour Force (econ. active population, aged 15+), change	All	+0.2%
Employment, change	All	+3%
	High	+22.6%
	Medium	-2.1%
	Low	-17.6%
Job opportunities	All	97.1 million
	High	40.4 million
	Medium	13.7 million
	Low	42.9 million

Science, Research and Innovation performance of the EU 2018

Source: Cedefop, 2016 skills forecast

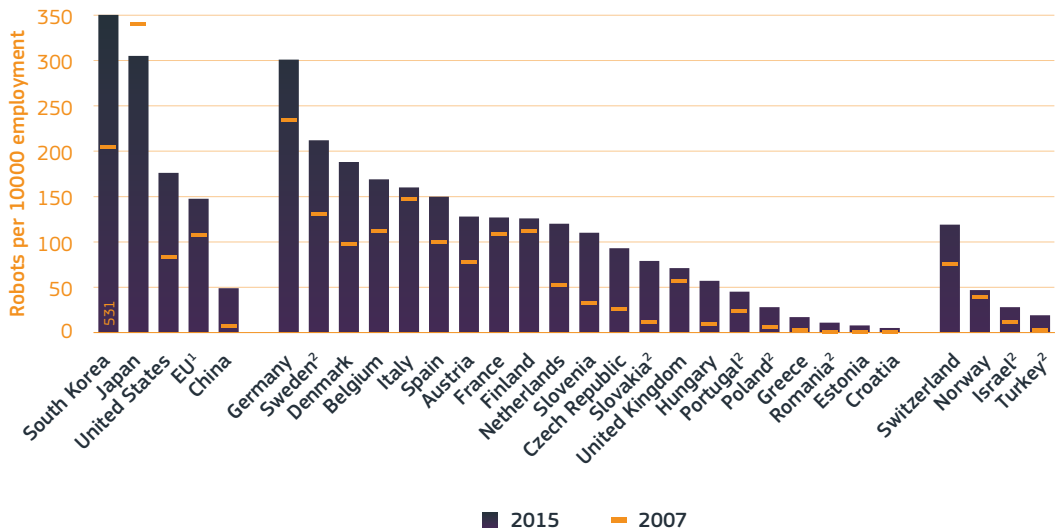
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*The manufacturing sector is characterised by a growing use of industrial robots. Countries with a large car industry tend to have high numbers of industrial robots per persons employed.*

There is an ongoing debate on the impact of technical progress on employment. Currently, the manufacturing sector is still more affected by automation and rationalisation than services. Replacing workers by machines is ongoing with even more complex manual tasks being taken over increasingly by robots. In the future, AI might replace skilled people even in the service sector.

Currently, 0.3 million industrial robots (out of a worldwide stock of 1.6 million) are deployed in EU Member States. The number is increasing by about 40 000 per year. Germany, with its large car industry (about half of the robots are deployed in the automotive industry) has the highest number of industrial robots per 10 000 persons employed in the EU's manufacturing industry, followed by Sweden and Denmark. The EU has a similar density as the United States, but lags behind Japan and South Korea. China is catching up quickly, but still has a much lower density than the EU.

**Figure I.3-C.2** Estimated number of multi-purpose industrial robots per ten thousand persons employed in manufacturing industry, 2007 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, International Federation of Robotics (IFR), World Robotics Report 2016

Notes: ¹EU was estimated as the average of the available data for the Member States weighted by employment. ²PT, RO, SK, SE, TR, IL: revised employment data according to ILO employment by economic activity 2015.

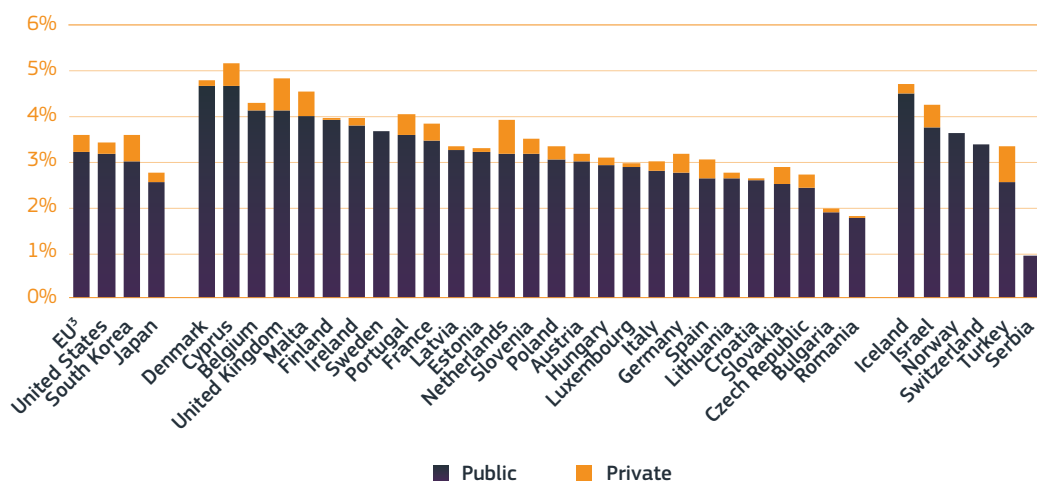
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*In the EU, investment in tertiary education lags behind that of the United States and South Korea, despite significant public efforts. Private investment in the EU is much lower than in these countries and public spending has fallen slightly in recent years. In the EU, there are large differences in spending on tertiary education, with the UK, the Netherlands, the Nordic countries and Cyprus in the lead.*

Total investment in education in the EU is at a similar level as in the United States and South Korea and higher than in Japan. However, there are large differences in spending levels between EU Member States, reflected both in primary/secondary education and in tertiary education.

As regards non-tertiary education (mostly pre-primary, primary and secondary) very low levels of spending, as the figures available show for Bulgaria and Romania, are somewhat reflected in educational outputs, as evidenced by international skills tests in compulsory education, although non-financial factors play an important role, too. However, while high levels of spending per pupil do not necessarily translate into corresponding educational outcomes, there is a consensus that investment in higher participation rates (a higher number of learners) has both social and economic benefits.

**Figure I.3-C.3** Total educational expenditure on non-tertiary education<sup>1</sup> from public and private sources as % of GDP, 2014<sup>2</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>ISCED 2011 levels 1-4. <sup>2</sup>IL, US, JP, KR: 2013. <sup>3</sup>EU was estimated and does not include EL.

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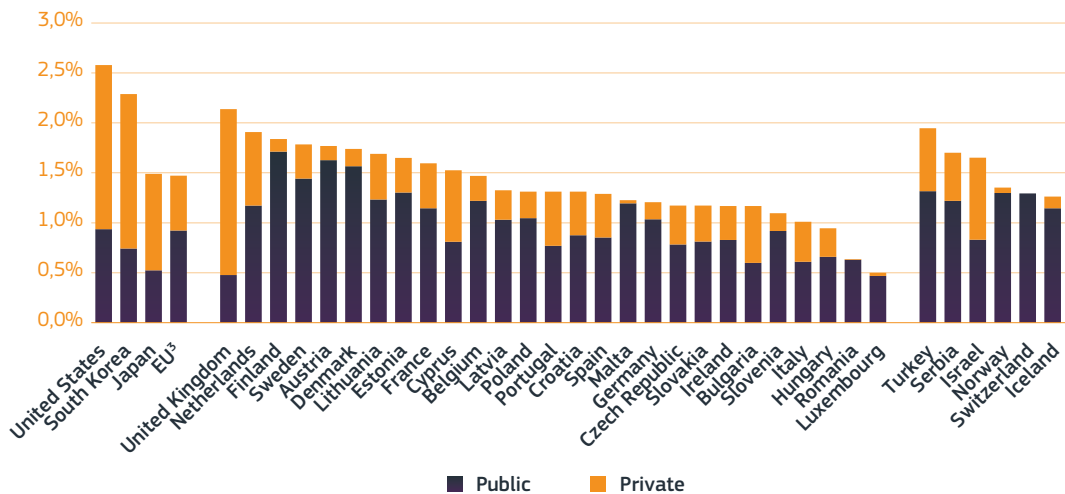
There is a general consensus among education economists that early investment in education gives the highest returns, since the outcomes of earlier stages of education also determine results at later stages. For example, high levels of numeracy at lower secondary level are important for the outcomes of learning at the upper secondary level and have an impact on the take-up of science and technology studies at tertiary level, fields of study where there is a potential gap in the future supply of graduates.

While spending on primary and secondary education in the EU is comparable to the levels found in North America or East Asia, there is a marked gap in tertiary education (see Figure I.3-C.4), caused mainly by lower levels of private spending in Europe. Public and private spending on tertiary education as

a % of GDP is about 1 percentage point lower in the EU, compared to the United States.

The spending gap per tertiary student currently amounts to nearly EUR 10 000 per year (or about EUR 200 billion for tertiary education as a whole). The Nordic countries, the Netherlands, the UK and Cyprus (where a high share of tertiary students study abroad) show relatively high levels of tertiary spending. On the other hand, tertiary spending levels are relatively low in Bulgaria and Romania (and also in Luxembourg, although this has to be seen in the context of a high GDP per capita and many students studying abroad). There is a high correlation between tertiary education spending levels and participation and attainment rates, as well as scientific excellence, important factors for R&I systems.

**Figure I.3-C.4 Total educational expenditure on tertiary education<sup>1</sup> from public and private sources as % of GDP, 2014<sup>2</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>ISCED 2011 levels 5-8. <sup>2</sup>IL, US, JP, KR: 2013. <sup>3</sup>EU was estimated and does not include EL.

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*Since 2013, the absolute number of EU tertiary students has been in decline for demographic reasons (the age group 20-24 dropped from 31.4 million in 2010 to 29.8 million in 2015) and as a result of an approaching saturation rate. This anticipates a possible decline in the number of tertiary graduates in the medium term, especially for Central and Eastern European countries.*

As tertiary participation rates approach saturation in many Member States, and because of the shrinking cohort size, the number of tertiary students in the EU started to decline in 2014 – for demographic reasons, this decline will continue in the near future. In 2000, the EU had 16% of the world's tertiary student population. In 2015, the share was down to 9%, while China's share increased in the same period from 7% to 20% and India's share rose from 9% to 15%.

The decline in tertiary students is strongest in Central and Eastern European countries, where the small cohorts of the post-1990 demographic crisis are now at the tertiary student age. In the period 2013-2015, the number shrank by more than 10% in Estonia (-14.8%), Hungary (-14.3%), Poland (-12.5%), Romania (-12.4%), Slovenia (-12.4%), Slovakia (-12.0%) and

Lithuania (-11.9%). In the EU-15, the decline since 2013 was strongest in Portugal (-9.0%). The number of tertiary students is still rising in some EU-15 Member States, in Cyprus (+16.3%) and in Malta (+5.1%). (In both these countries, the relatively new higher education systems are still in the expansion phase.) Despite an unfavourable demography, student numbers are still increasing in Germany (+7.1%) as a result of a growing number of foreign students and an ongoing rise in participation rates (which, as a result of an orientation towards vocational education, have traditionally been relatively low). Denmark (+7.8%) and Ireland (+7.6%) show similar growth rates. The number is also still increasing, although at a slower pace, in France (+3.7%), Belgium (+3.3%) and Austria (+0.8%).

At the same time, the European student population is becoming more international. The number of mobile students from abroad rose in the EU from 1.43 million in 2013 to 1.54 million in 2015 (+8.2%), of whom 0.88 million came from outside Europe. In 2013, women outnumbered men by about 1 million, representing 54% of the EU tertiary student population, with the share of male students catching up a little in recent years.

**Figure I.3-C.5** Number of tertiary students (million), 2000-2015

	2000	2010	2013	2014	2015
<b>World</b>	<b>99.7</b>	<b>181.4</b>	<b>199.0</b>	<b>210.7</b>	<b>212.7</b>
EU	16.0	20.0	19.8	19.7	19.5
China	7.4	31.0	34.1	41.9	43.4
India	9.4	20.7	28.2	30.3	32.1
United States	13.2	20.4	20.0	19.7	19.5
Brazil	2.8	6.6	7.5	8.1	8.3
Russian Federation	6.3	9.3	7.5	7.0	6.6
Japan	4.0	3.8	3.9	3.9	3.9

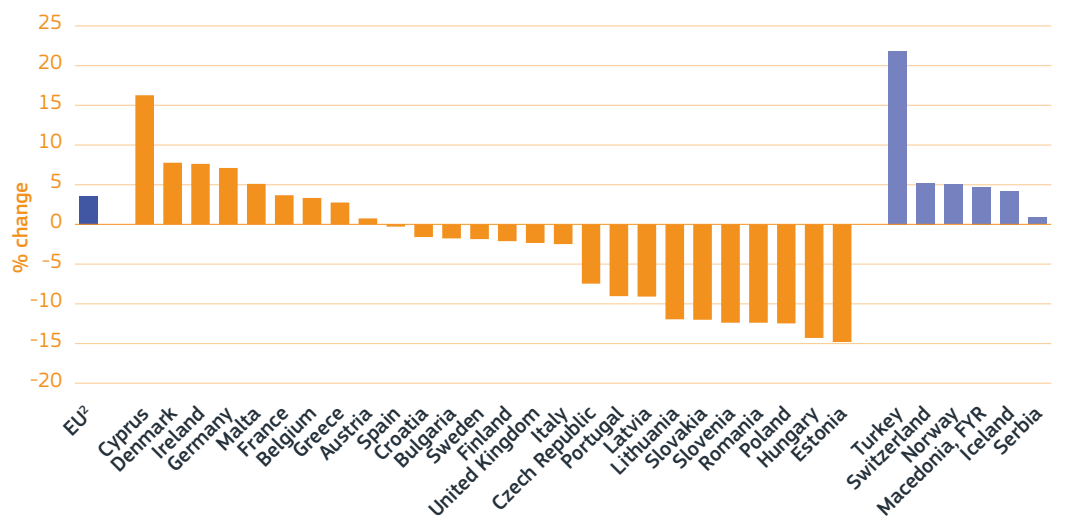
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, UNESCO

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_5.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_5.xlsx)

**Figure I.3-C.6** % change in the number of tertiary students between 2013 and 2015<sup>1</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: <sup>1</sup>IS: 2013-2014; <sup>2</sup>EU: 2014-15. <sup>2</sup>EU was estimated and does not include LU and NL.

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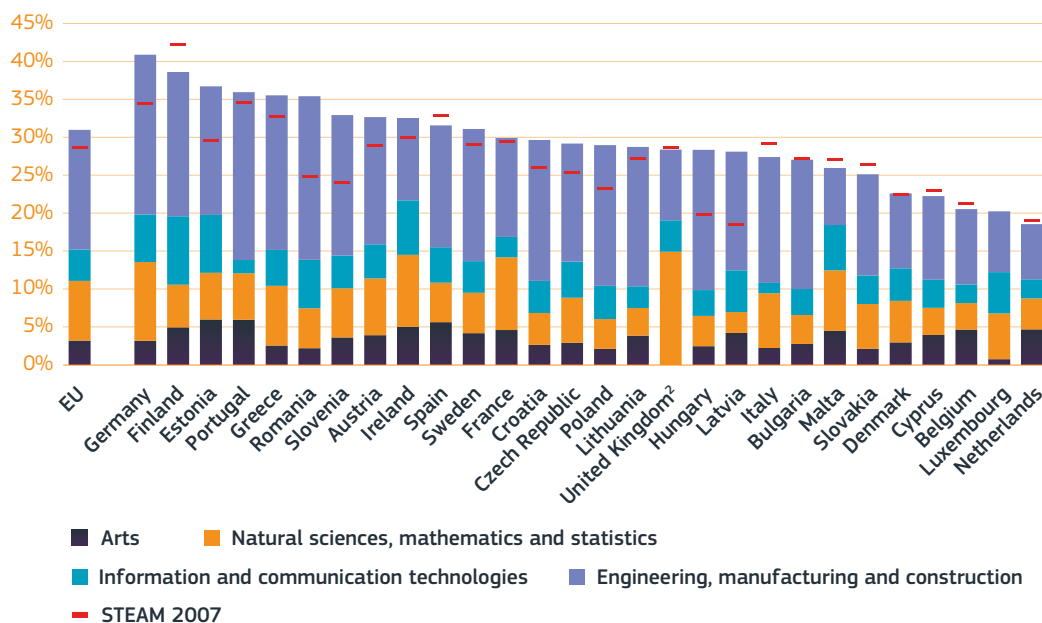
*The share of STEM students (science, technology, engineering, mathematics) has increased since 2007, with strong improvements in many Central and Eastern European countries.*

The share of STEM students increased since 2007 from 24.6% to 27.8%. Countries with a high share include Germany, Finland, Estonia and Portugal. Countries that progressed most include Estonia, Romania, Slovenia, Hungary and Latvia. Countries with limited university systems, like Malta, Cyprus and Luxembourg, tend to have low STEM shares, since many have to go abroad to study or graduate in these fields. Shares are also relatively low in Belgium and the Netherlands. The importance of design for product marketing and innovation is increasingly recognised. Therefore, art/design students are seen increasingly as an important asset – contributing to ‘creative industries’ – in

modern economies. Correspondingly, STEM is sometimes extended to STEAM. The share of STEAM students increased from 28.6% in 2007 to 31.0% in 2015 (thus, the share of arts students declined from 4.0% in 2007 to 3.2% in 2015). However, the inclusion of the arts does not change the order of leading countries.

While there is still a scientific debate about the optimal number and share of university graduates in the population and their relevance for balanced R&I systems, available statistical data show that returns on tertiary education in terms of average earnings and the risk of unemployment are high, suggesting that there has yet to be an oversupply of tertiary graduates. However, manufacturing-oriented economies, like Germany and Austria, traditionally also rely on a strong supply of graduates from vocational education and training, most of them at an upper-secondary level.

**Figure I.3-C.7 Tertiary students in science, technology, engineering, the arts and mathematics (STEM) as % of total tertiary students, 2015<sup>1</sup> (and for 2007 without breakdown)**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: <sup>1</sup>IE, EL, IT: 2014. <sup>2</sup>UK: Data are not available for the arts for 2015.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_7.xlsx)

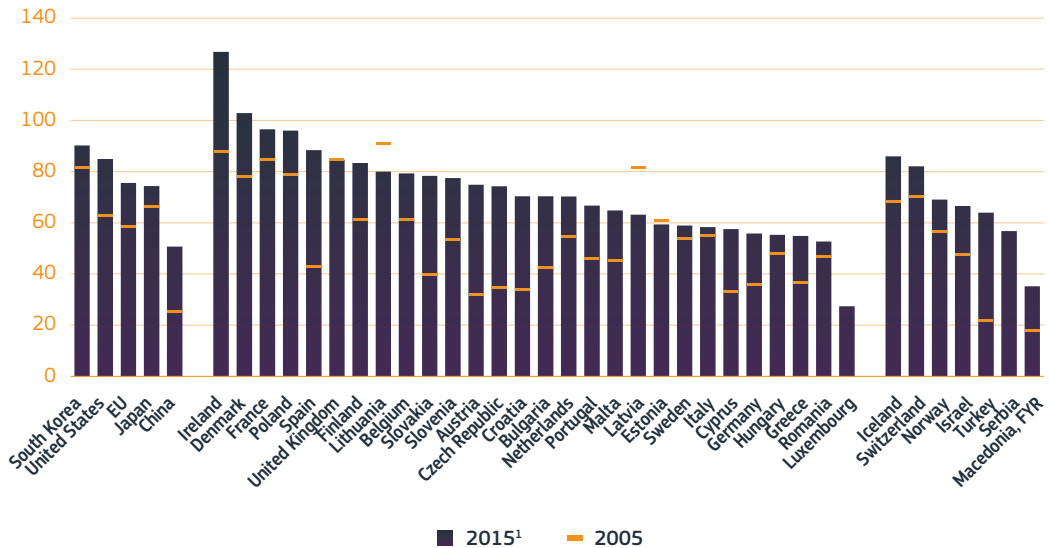
Although the EU still lags behind the United States and South Korea, the number of tertiary graduates per 1000 population in the EU has stopped growing and is even expected to fall in the future.

As regards new tertiary graduates per thousand population (see Figure I.3-C.8), the EU performs at a similar level as Japan, but below the United States and South Korea. While figures in China and the United States continue to grow, the number of new tertiary graduates per population has hardly grown in the last decade in the EU and has fallen in South Korea and Japan. Differences between Member States are large, with Ireland leading and several Eastern European countries

(Poland, Lithuania and Slovakia) showing high numbers of new graduates and thus the latter catching up on tertiary attainment. While Central and Eastern European countries experienced high growth rates in the past, the number of graduates in these countries is expected to fall in the future as cohort size declines.

Gender imbalances are larger than for the number of students. In 2013, women represented 58.3% of tertiary graduates in the EU. In the EU, Germany has the best gender balance (male share of tertiary graduates 49.9%), while men represent less than 40% of tertiary graduates in many Central and Eastern European countries, notably in the Baltic States.

**Figure I.3-C.8** New graduates from tertiary education per thousand population aged 20-29, 2005 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO (UIS)

Note: <sup>1</sup>IS: 2013; EL, IT, RS, IL, US, JP, KR: 2014.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_8.xlsx)

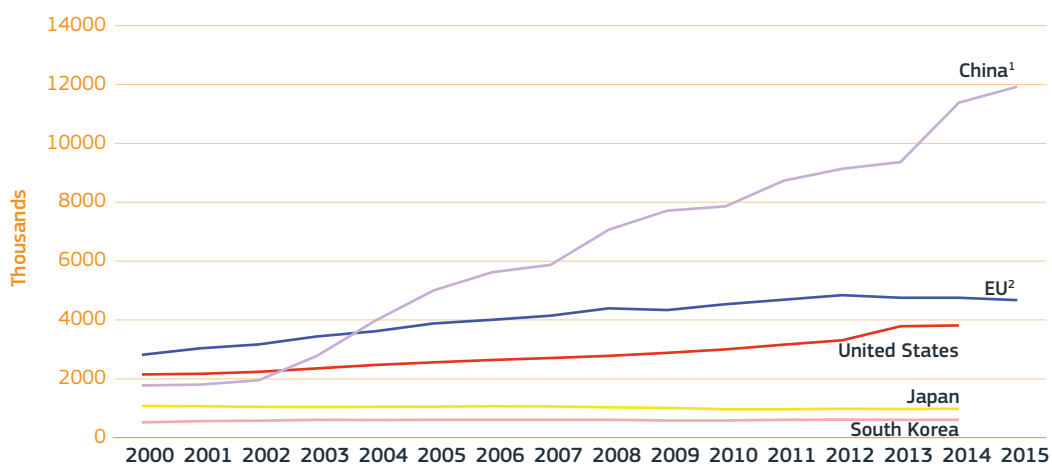


*In terms of the absolute number of tertiary graduates, the EU still scores above the United States but has been overtaken by China, which is now by far the world's largest producer of tertiary graduates.*

In 2004, China (whose population is 2.7 times the EU total) overtook the EU in terms of the absolute number of tertiary graduates

(see Figure I.3-C.9). The number of tertiary graduates has grown six-fold in China since 2000 to reach about 12 million in 2015, more than double the EU figure. At the same time, the number of tertiary graduates in Japan and South Korea stagnated, as tertiary participation rates in these countries are reaching saturation and demographic factors come into play.

**Figure I.3-C.9** Total number of tertiary graduates, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO (UIS)

Notes: <sup>1</sup>CN: the value for 2003 was estimated. <sup>2</sup>EU: the value for 2011 was estimated.

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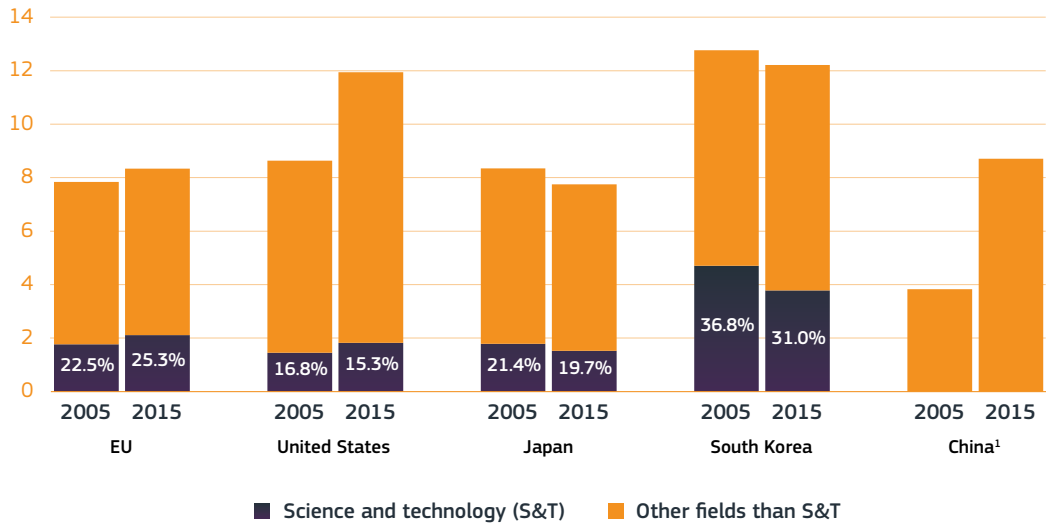
*Since 2005, the EU has made progress in the share of science and technology graduates, while this share has declined in South Korea, Japan and the United States. Women represent only one-third of all science and technology graduates.*

As regards science and technology graduates (see Figure I.3-C.10) the EU countries have progressed more since 2005 in terms of graduates per 1000 population than Japan and South Korea (partially a result of the Bologna effect of more degree levels and hence more double-counting). It is also doing better in the science and technology share among graduates (increasing from 22.5% to 25.3%) than

Japan (declining from 21.4% to 19.7%) and the United States (decreasing from 16.8% to 15.3%). However, South Korea still has a much higher share (2005: 36.8%, 2015: 31.0%) of science and technology graduates in all tertiary graduates and more graduates relative to population.

Women represent only about 34% of all science and technology graduates in the EU. The share of female science and technology graduates is relatively high in Estonia (45%), Poland (45%), Romania (44%), Cyprus (42%) and Italy (41%). It is lowest in Austria (25%) and the Netherlands (26%).

**Figure I.3-C.10 Tertiary graduates per thousand population broken down by science and technology and other fields, 2005 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO (UIS)

Note: <sup>1</sup>CN: the data refer to total graduates (a breakdown between S&T and non-S&T is not available).

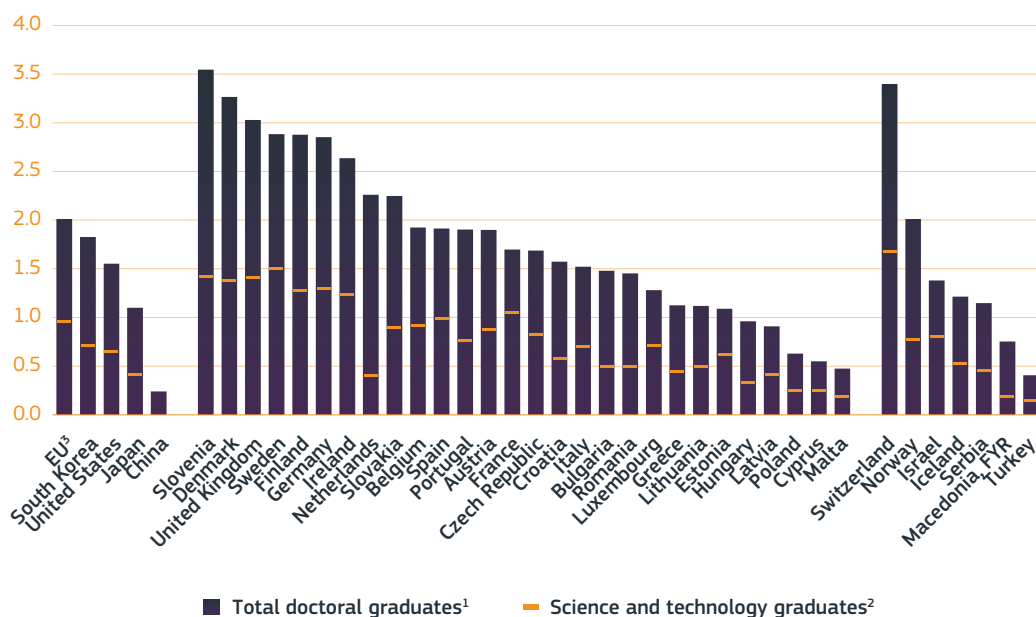
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_10.xlsx)

*The EU performs well in the production of new doctoral graduates, including in the field of science and technology. Some EU countries are among the best performers worldwide.*

When it comes to new graduates at the doctoral level (see Figure I.3-C.11), the EU performs at the same level as South Korea, but outperforms the United States and Japan.

Slovenia, the Nordic countries, the UK and Germany perform well, while in smaller countries, where a high share of doctoral students attain their degree abroad, the data available understate performance. Many Eastern and Southern European countries have a relatively low production of doctoral graduates, partially a result of a perceived lower attraction of academic careers.

**Figure I.3-C.11** New doctoral graduates per thousand population aged 25-34, 2015



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD, UNESCO (UIS)

Notes: <sup>1</sup>IS: 2013; EL, IL, US, JP, KR: 2014. <sup>2</sup>NL, IS: 2013; EL, IL, US, JP, KR: 2014. <sup>3</sup>EU was estimated. The estimated EU value for science and technology graduates per thousand population does not include EL and NL.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_11.xlsx)

***The EU has made good progress as regards the headline target on tertiary attainment – some countries have already reached it, but differences between EU Member States are still large.***

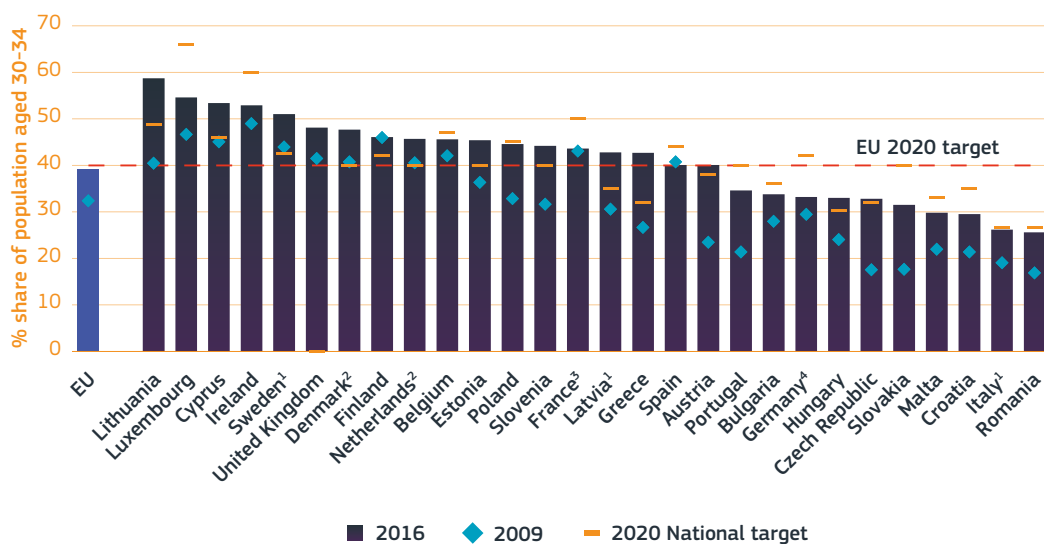
Progress in the number of tertiary graduates is (with some time lags) also reflected in the evolution of the EU headline target on tertiary attainment (of 30-34-year-olds). With a tertiary attainment level of 39.1% in 2016 (see Figure I.3-C.12), the EU is on track to reach the headline target of 40% by 2020 and will probably even surpass it. There is a notable gender gap with females' tertiary attainment already reaching 43.9%, 9.5% above the level for men. Latvia (female attainment rate 26 percentage point higher than that of men), Slovenia (21.7%) and Lithuania (20.7%) show the biggest gender gap, while Germany (-0.4%) shows the smallest.

Lithuania, Luxembourg, Cyprus, Ireland and Sweden already have attainment rates of over 50%. Malta, Croatia, Italy and Romania still

show relatively low tertiary attainment rates. After Mexico, Italy has the lowest tertiary attainment rate among OECD countries. Despite the progress achieved, the EU still lags behind tertiary attainment levels (data for 25-34-year-olds and relating to 2015) of the United States (47%), Japan (60%) and Korea (69%).

However, tertiary attainment is only a proxy for the skills levels acquired. Studies, such as the OECD PIAAC survey, show big differences between the skills levels of tertiary graduates in EU countries and hence the need to focus more on the quality of education in some countries. As educational attainment rates in tertiary education reach saturation in many Member States, attention must shift to the quality of education and the acquisition of skills relevant for the labour market. The demographic dividend, the declining cohort size in many countries, could help to provide the resources for that.

**Figure I.3-C.12** EU headline target on the tertiary attainment of population aged 30-34



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat

Notes: <sup>1</sup>LV, IT, SE: the 2020 national targets are set as averages between the values provided by the Member States (LV: 34-36%, IT: 26-27%, SE: 40-45%). <sup>2</sup>DK, NL: the 2020 national targets are set at over 40%. <sup>3</sup>FR: the 2020 national target includes persons aged between 17 and 33 years. <sup>4</sup>DE: the 2020 national target includes ISCED11 level 4 attainment.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_12.xlsx)

## BOX 5: Transferable skills to tackle education obsolescence and foster innovation

*Prof. Diego Rubio, IE School of International Relations*

The world of work is changing faster and more drastically than in any other time in recent history. By 2030, it is expected that nearly half of today's jobs will be automated or outsourced, 65% of today's schoolchildren will be employed in jobs that currently do not exist, and more than a third of what are now considered 'core skills' will be different (U.S. Department of Labor, 1999; Benedikt and Osborne, 2013; WEF, 2016).

Technological and socio-economic disruptions are transforming the employment landscape at an unprecedented rate. This is challenging our educational systems, which seem increasingly unable to supply the new set of competencies demanded by the labour market to meet society's changing needs. Since 2008, mismatches between skills and jobs have grown by 29% in Europe (Manpower, 2017), creating substantial problems for recruiting, productivity losses, and missed opportunities for improving the EU's R&I performance.

There are at least two ways to address these problems of a growing skills gap and increased education obsolescence. One is to use developing foresight methods and big data analysis to anticipate which skills will be required in the coming years, so that they can be included in national vocational education and training (VET) curricula and lifelong learning education programmes. The other way is to expand the traditional talent pipeline of formal disciplines and 'hard skills', to place transferable skills at the heart of our educational models.

Transferable skills (often referred to as soft, transversal, key, or behavioural skills) can be described as those non-job-specific competences that are central to occupational proficiency across a wide range of sectors and levels, since they enable employees to navigate their environment and work effectively either alone or with others. Tax-

onomies vary greatly, but typically they include communication and interpersonal skills, as well as attributes such as creativity, critical thinking, time-management, decision-making, adaptability and problem-solving, among many others.

The technification and automation of developed economies has increased the demand for such skills to the point of becoming some of the most demanded competences by employers in Europe (Deming, 2015; GMAC, 2014). In fact, there is growing evidence that shows these competences rival technical skills in their ability to predict employment and earnings, among other outcomes, and that their demand is likely to increase over the coming years (Balcar, 2014; Carnevale, 2013; Kautz, et al., 2014). This is due to a number of factors:

1. Transferable skills are more versatile and durable than technical ones, enhancing workers' adaptability and occupational mobility, and enabling greater levels of business renewal and societal resilience during economic downturns (EC, 2011; Keep and Payne, 2004).
2. They are not easily automatised, since they cannot be performed by most AI and robots.
3. They promote better R&I outputs by facilitating knowledge and technology transfer, fostering creativity, and enabling researchers to work more effectively in the increasingly mobile and multidisciplinary research environment (Herrmann and Peine, 2011; KIRD, 2010; OECD, 2012 and 2015). a study conducted by the Australian government concluded that the combination of technical capabilities with transferable skills had enabled researchers "to contribute to some of the most transformative innovations developed in recent times" (Commonwealth of Australia, 2011).

4. They are centrally important for human capital development, making a significant contribution to developed economies (Cedefop 2010; International Labour Organization, 2008) which, in the case of the UK, has been estimated to be worth around 6.5% of its annual GDP (Development Economics, 2015).
5. They have major positive effects beyond the labour market, enhancing individuals' social well-being and academic performance (Durlak et al., 2011; Padhi, 2014; Weedon, 2013).

Yet, despite their importance, transferable skills still occupy second place in European policy agendas. Some countries (Finland, Norway, France, Germany and the UK) are taking important steps by increasing resources and setting up pioneering programmes for learning and skills training in educational and working environments. However, the overall results are still insufficient. According to Cedefop's European skills and jobs survey, 26% of European workers acknowledge that they do not have the transferable skills needed to carry out their work properly, while 48% of the employers interviewed indicate that a lack of skills is one of the key reasons they could not hire the necessary employees (Cedefop, 2014). In the UK, for instance, recent surveys indicate that soft skills are associated with between 33% – 40% of all reported skills-shortage vacancies, and suggest that the problem will increase in the future (Development Economics, 2015; UKCES, 2014).

This shortage of transferable skills is causing major problems in European countries by fueling unemployment, adversely affecting workers' well-being, diminishing economies' productivity, and lowering business capacity to innovate and adapt to changing circumstances (Clarke, 2016; McKinsey, 2014; Mourshed et al., 2016;). To address these issues, EU Member States should:

1. Develop concrete education and training policies aimed at fostering the acquisition, de-

velopment, and certification of transferable skills at all levels, following the good practices and models developed by pilot projects such as NESSIE, HISS, GRASS and VALEW, among others. Some measures should include: adopting problem-based learning methodologies, increasing teacher training and support, introducing more inter-disciplinarity into curricula, promoting the 'environmental factor' and extra-curricular activities, and introducing new digital technologies and gamification systems designed to develop transferable skills, such as eLene4work, ModEs and S-Cube, to mention but a few.

2. Create a European standardised taxonomy for the description and measurement of transferable skills at a regional level, following the example of other internationally comparable datasets on cognitive skills which already exist (e. g. PISA, PIAAC).
3. Introduce transferable skills as part of European forecast tools (e. g. CEDEFOP and EUCLID) to develop a comprehensive, consistent and detailed view of future skills needs and vacancies across the EU.
4. Promote awareness of the importance of transferable skills among all stakeholders, including public institutions, civil society and private business, which should increase their support to the acquisition and valuation of transferable skills in all HR processes – from recruitment and employee training to performance assessments (Martinez Lucio, 2007; Thelen, 2004).

If implemented correctly and in a timely manner, these measures should help the EU to raise labour productivity and create a more innovative and versatile workforce, public institutions, and private sector, which will be better prepared to cope with the uncertainties and fast-changing nature of the economy and society in the 21st century.

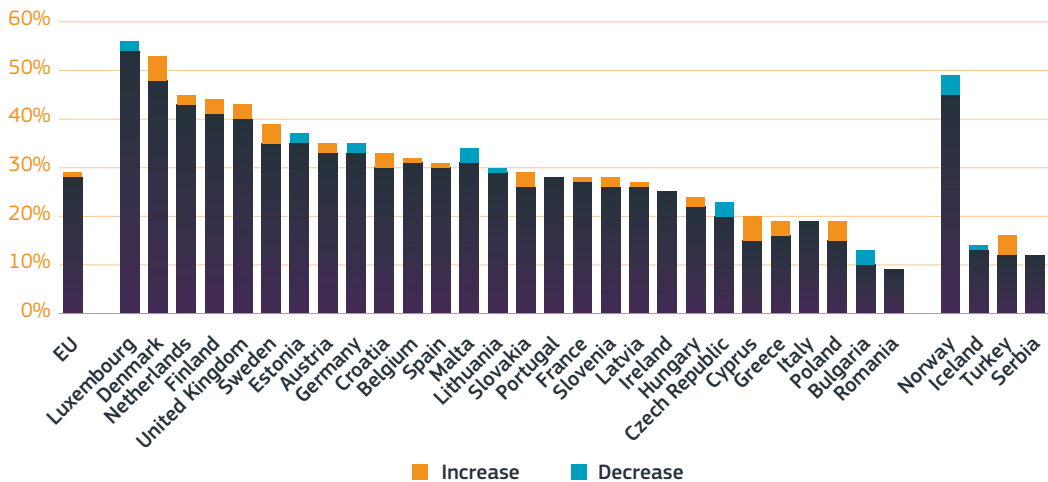
*As regards the increasingly important digital skills, the EU is making progress, but there is a considerable digital divide between Member States, linked to income levels.*

EU populations as regards digital skills are Romania and Bulgaria, countries where low per-capita incomes lead to a relatively low household penetration of digital equipment.

With reference to the increasingly important digital skills, the Eurostat ICT household survey (See Figure I.3-C.13) for 2016 shows significant differences between Member States in the share of the population aged 15-74 with above-average digital skills. The Nordic countries, Luxembourg, Netherlands and the UK perform best in this area. They also tend to have relatively high shares of ICT start-ups. The lowest performers in

The share of individuals with digital skills in the EU population seems to be increasing. As regards high computer skills, it rose from 23% in 2007 to 25% in 2012 to 29% in 2014. With reference to above-average digital skills, it increased from 29% in 2015 to about 30% in 2016. In 2016, the countries that made most progress include Denmark, Sweden, Cyprus and Poland.

**Figure I.3-C.13** Individuals with above average digital skills as % of total population, 2016 (with the change compared to 2015)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_13.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_13.xlsx)



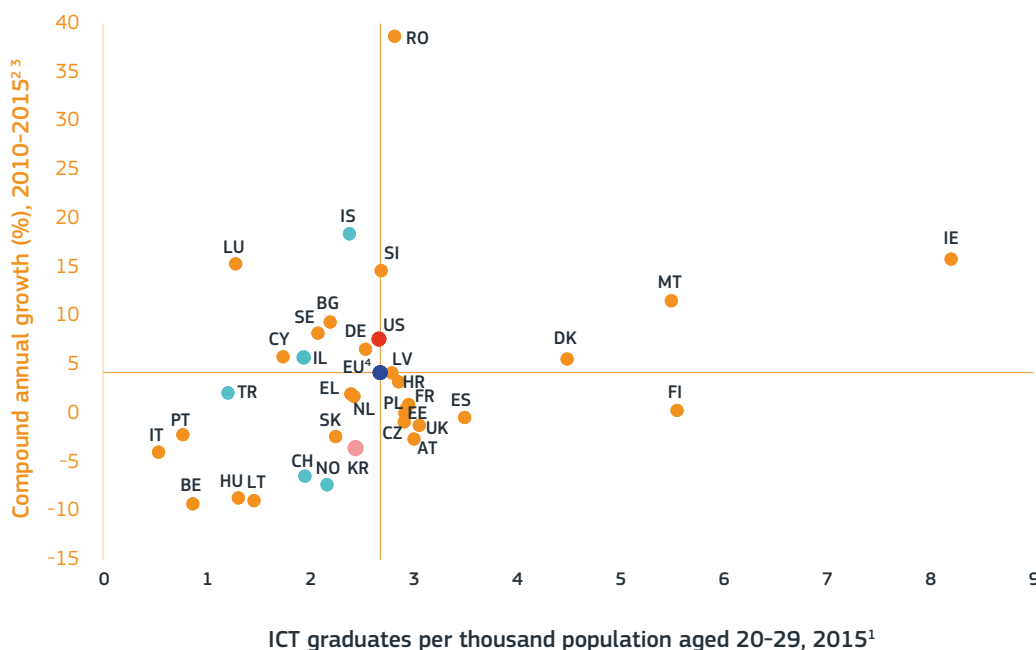
*Although the number of computing graduates has increased recently by about 5% per year, there are still not enough graduates to fill the available vacancies.*

While ICT skills are improving, there is still a growing need for IT professionals. Recently, the number of ICT practitioners has been growing by about 4% annually. Growth is fuelled by new developments such as big data, the IoT, the cloud and the growth of the app economy.

In the period 2010-2015, the number of computing graduates in the EU increased on average by over 5% per year. However, in several Member States it declined. As a result, there are not enough graduates to fill the vacancies available in this sector. According to a Commission esti-

mate in the context of the digital skills initiative, there could be up to 500 000 vacancies for ICT professionals in the EU by 2020. Member States with a high number of computing graduates per 1000 population aged 25-34 include Ireland (where many American ICT companies have their European headquarter), Malta (where an online gaming cluster has developed), Finland (with its important video-game sector) and Denmark, while figures are relatively low in Italy, Portugal and Belgium. However, in some countries, including Romania, the figures available tend to understate performance since computing is often integrated into subject areas like mathematics. Nevertheless, of concern is the fact that, since 2007, the number of graduates from computing studies has fallen by over 10% in countries like Italy and Belgium (see Figure I.3-C.14).

**Figure I.3-C.14** Graduates in the field of ICT per thousand population aged 20-29, 2015 and compound annual growth, 2010-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD

Notes: <sup>1</sup>NL: 2012; IS: 2013; EL, IT, IL, US, KR: 2014. <sup>2</sup>EU: 2009-2015; NL, IS: 2010-2012; IT, IL, US, KR: 2010-2014; LU: 2011-2015; FR, HR: 2013-2015. <sup>3</sup>Break in series between 2013 and the previous years due to change of classification (ISCED97/11 replaced by ISCED-F 2013). IL, US, KR: data based on ISCED97. <sup>4</sup>EU was estimated from the available data for the Member States and does not include EL, IT and NL.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_14.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_14.xlsx)

***Employment in science and technology has been resilient during the crisis. The number of researchers and R&D personnel has expanded considerably since 2008.***

An adequate supply of skilled human resources is vital for the functioning of R&I systems and for the development of science and technology-intensive economic sectors. The EU is facing growing demographic challenges in the coming decades with small young cohorts entering the labour market combined with a retiring baby-boomer generation and a potential risk of sectoral and regional bottlenecks in the supply of skilled workers. However, rapid technological progress and change in workplace requirements, growing interdisciplinarity and the resulting low predictability of future skills needs combined with fluctuating migration levels make planning and foresight difficult. A certain surplus of skilled people can stimulate economic development and innovation, as these people move into non-traditional job areas or become entrepreneurs, while the growing internationalisation of labour markets is making regional or national skills gaps less severe. On the other hand, there is growing international and intersectoral competition for highly skilled people.

In 2016, the EU's active population (referring to the total labour force, which includes both employed and unemployed people) amounted to about 245 million, of whom 224 million were employed and 21 million were unem-

ployed (see Figure I.3-C.15). Human resources in science and technology (HRST) accounted for 126 million people in the EU, or 56.3% of total employment, a share that has been increasing constantly in the past. Those who have successfully completed tertiary-level education (HRSTE) accounted for 43.8% of total employment, with Ireland, Cyprus and Luxembourg showing the highest shares. Those who have both completed tertiary-level education and are currently employed in an S&T occupation (HRSTC) accounted for 22.6% of total employment. This implies that 50% of tertiary education graduates are employed in S&T occupations.

In the past, human resources in science and technology have grown faster than total employment and jobs in this area proved more resilient during the crisis. Whilst total employment increased on average by 0.2% per year between 2007 and 2016, HRST grew by 2.4% annually, or by nearly 20 million, over the whole period, research personnel by 2.3% and the number of researchers by 2.8%. This reflects the labour force's rising educational attainment, as well as the shift towards skill-intensive jobs and a knowledge-intensive economy. In absolute terms, the stock of human resources in science and technology is still growing, partly because of increasing attainment rates. Overall, there is no evidence yet of a skills gap, but the situation might change in the future and there are already bottlenecks in certain regions and sectors, such as ICT.

**Figure I.3-C.15** Key data on human resources in science and technology in the EU

	Total (000s) 2016 <sup>1</sup>	As % of total employment 2016	Compound annual growth (%) 2007-2016 <sup>2</sup>
Active population	244594	109	0.36
Total employment (LFS)	223681	100	0.19
HRST - Human Resources in Science and Technology	103802	46.4	2.00
HRSTE - Human Resources in Science and Technology - Education	75771	33.9	3.14
HRSTO - Human Resources in Science and Technology - Occupation	78628	35.2	1.51
HRSTC - Human Resources in Science and Technology - Core	50596	22.6	2.90
SE - Scientists and Engineers	17189	7.7	2.26
Total R&D personnel (FTE)	2849	1.3	2.33
Researchers (FTE)	1818	0.8	2.79

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: <sup>1</sup>Total R&D personnel (FTE), Researchers (FTE): 2015. <sup>2</sup>Total R&D personnel (FTE), Researchers (FTE): 2007-2015; breaks in series occur between 2014 and the previous years and between 2011 and the previous years for HRST data.

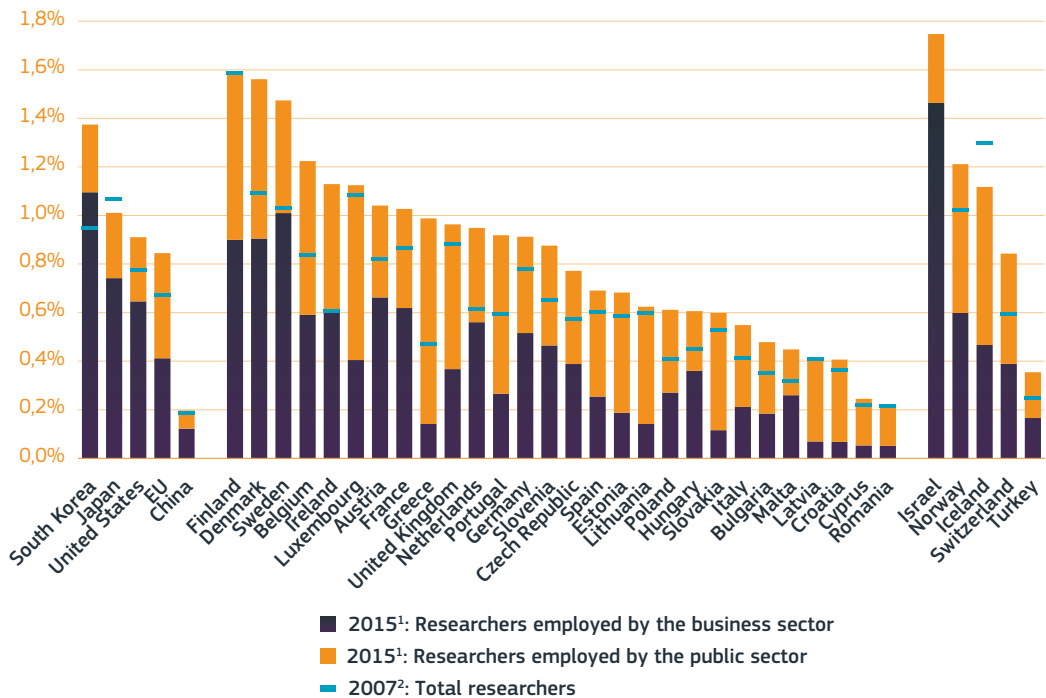
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_15.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_15.xlsx)

*The share of researchers in the workforce reflects economic structures and development levels and is strongly correlated with countries' innovation outputs. Countries with high shares of researchers in total employment tend to be innovation leaders.*

In terms of researchers, as a percentage of total employment, the EU lags behind the United States, Japan and especially South Korea, notably when it comes to researchers employed in the business sector (see Figure I.3-C.16). However, compared to the United States and especially to Japan, where the number of researchers is stagnating, the EU is catching up, while South Korea is pulling further ahead.

China shows even stronger growth. It already has the largest number of business researchers in absolute terms and might soon overtake the EU, too, in terms of the total number of researchers. In the EU, the Nordic countries (Finland, Denmark and Sweden) show the highest share of researchers in total employment and also perform well as regards researchers employed by the business sector. The south-eastern European countries – Croatia, Bulgaria, Cyprus, Romania and Latvia – show relatively low levels, particularly for researchers in the business sector. On the other hand, many Central and Eastern European countries (notably Bulgaria, Hungary and Poland) plus Malta are catching up in terms of researchers and business enterprise researchers. There is a high correlation between the employment share of researchers in the business sector and innovation outputs.

**Figure I.3-C.16 Total researchers (FTE) as % of total employment, 2007 and 2015**



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat, OECD  
 Notes: <sup>1</sup>CH, IL: 2012; FR, TR, US: 2014. <sup>2</sup>CH: 2008.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_3-c\\_figures/f\\_i\\_3-c\\_16.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_16.xlsx)

*Although females represent almost half of the graduates at doctoral level, women still represent less than one-quarter of all researchers and only one-sixth of researchers in the business sector.*

The share of female researchers is still far from a gender balance. In 2015, women represent-

ed only 23.7% of researchers in the EU, with marked differences between European countries. The Baltic States (Latvia 50.5%, Lithuania 46.5% and Estonia 43.1%), and south-eastern European countries (Croatia 51.0%, Bulgaria 49.8% and Romania 45.0%) have the highest shares, probably partly as a result of comparatively less-attractive salaries but greater job safety.

Figure I.3-C.17 Researchers (FTE) – total and business enterprise, 2015

	Total researchers (FTE)			
	2015 <sup>1</sup> (thousands)	% of female researchers <sup>2</sup>	Compound annual growth (%) 2007-2015 <sup>3</sup>	As % of total employment <sup>4</sup>
EU	1817.7	23.7	2.8	0.8
Belgium	55.1	:	5.3	1.2
Bulgaria	14.2	49.8	3.0	0.5
Czech Republic	38.1	24.1	4.0	0.8
Denmark	41.8	32.9	4.2	1.6
Germany	357.5	22.7	2.6	0.9
Estonia	4.2	43.1	1.6	0.7
Ireland	21.5	29.3	6.8	1.1
Greece	35.1	38.9	9.2	1.0
Spain	122.4	38.6	0.0	0.7
France	268.4	26.1	2.6	1.0
Croatia	6.4	51.0	0.5	0.4
Italy	120.7	36.1	3.3	0.5
Cyprus	0.9	38.6	0.9	0.2
Latvia	3.6	50.5	-1.7	0.4
Lithuania	8.1	46.5	-0.5	0.6
Luxembourg	2.9	27.3	6.9	1.1
Hungary	25.3	26.4	4.8	0.6
Malta	0.8	29.4	6.5	0.4
Netherlands	77.0	25.6	1.7	0.9
Austria	42.3	23.0	3.7	1.0
Poland	96.7	35.3	5.8	0.6
Portugal	39.6	43.7	1.6	0.9
Romania	17.5	45.0	1.9	0.2
Slovenia	7.9	34.7	-0.2	0.9
Slovakia	14.4	41.3	1.9	0.6
Finland	37.5	:	-0.1	1.6
Sweden	68.7	28.0	2.0	1.5
United Kingdom	289.3	:	1.7	1.0
Iceland	1.9	36.0	6.5	1.1
Norway	30.8	:	3.0	1.2
Switzerland	36.0	:	9.4	0.8
Turkey	89.7	32.6	8.8	0.4
Israel	63.5	:	15.1	1.7
United States	1351.9	:	2.5	0.9
Japan	662.1	15.3	-0.2	1.0
China	1619.0	:	6.7	0.2
South Korea	356.4	18.9	6.1	1.4

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>CH, IL: 2012; FR, TR, US: 2014. <sup>2</sup>The values refer to 2014 or to the latest available year (JP, KR: 2015). EU refers to 2013 and does not include BE, FI and UK. <sup>3</sup>CH: 2008-2012; PT, SI, JP: 2008-2015; IL: 2011-2012; EL: 2011-2015. <sup>4</sup>CH: 2012; FR, TR, IL, US, CN: 2014. <sup>5</sup>CH: 2012; FR, TR, IL, US: 2014. <sup>6</sup>CH: 2008-2012; SI: 2008-2015; IL: 2010-2014; EL: 2011-2015. <sup>7</sup>CH: 2012; FR, TR, IL, US, CN: 2014.

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Figure I.3-C.17 (contd.) Researchers (FTE) - total and business enterprise, 2015

	Business enterprise researchers (FTE)				
	2015 <sup>5</sup> (thousands)	% of female researchers <sup>2</sup>	Compound annual growth (%) 2007-2015 <sup>5</sup>	As % of total employment <sup>7</sup>	As % of total researchers (FTE)
EU	885.7	16.3	3.6	0.4	48.7
Belgium	26.6	:	5.0	0.6	48.3
Bulgaria	5.5	40.1	19.5	0.2	38.6
Czech Republic	19.2	14.6	5.8	0.4	50.3
Denmark	24.2	27.7	3.0	0.9	58.0
Germany	202.0	13.7	1.9	0.5	56.5
Estonia	1.2	29.5	2.3	0.2	27.5
Ireland	11.5	22.9	6.0	0.6	53.8
Greece	5.0	27.6	5.7	0.1	14.3
Spain	45.2	30.9	0.9	0.3	36.9
France	161.8	20.5	3.8	0.6	60.3
Croatia	1.1	44.4	2.4	0.1	16.7
Italy	46.6	22.2	4.5	0.2	38.6
Cyprus	0.2	35.2	0.2	0.1	21.5
Latvia	0.6	45.8	5.4	0.1	16.7
Lithuania	1.8	30.7	4.4	0.1	22.7
Luxembourg	1.0	11.1	1.5	0.4	36.0
Hungary	15.0	17.8	10.0	0.4	59.4
Malta	0.5	23.4	8.8	0.3	58.0
Netherlands	45.5	17.2	1.1	0.6	59.1
Austria	27.0	15.7	3.8	0.7	63.7
Poland	42.8	19.3	20.2	0.3	44.3
Portugal	11.5	28.6	7.0	0.3	29.0
Romania	4.2	39.3	-1.4	0.1	24.3
Slovenia	4.2	25.7	0.5	0.5	53.1
Slovakia	2.8	18.0	7.2	0.1	19.4
Finland	21.3	:	-0.4	0.9	56.8
Sweden	47.1	22.5	2.0	1.0	68.6
United Kingdom	110.4	:	2.6	0.4	38.2
Iceland	0.8	:	-8.2	0.5	41.8
Norway	15.2	:	3.0	0.6	49.4
Switzerland	16.6	:	12.6	0.4	46.2
Turkey	41.8	23.8	15.5	0.2	46.7
Israel	56.5	:	7.6	1.5	:
United States	960.0	:	2.4	0.6	71.0
Japan	486.2	8.6	0.1	0.7	73.4
China	1014.6	:	7.5	0.1	62.7
South Korea	284.1	14.8	6.9	1.1	79.7

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>CH, IL: 2012; FR, TR, US: 2014. <sup>2</sup>The values refer to 2014 or to the latest available year (JP, KR: 2015). EU refers to 2013 and does not include BE, FI and UK. <sup>3</sup>CH: 2008-2012; PT, SI, JP: 2008-2015; IL: 2011-2012; EL: 2011-2015. <sup>4</sup>CH: 2012; FR, TR, IL, US, CN: 2014. <sup>5</sup>CH: 2012; FR, TR, IL, US: 2014. <sup>6</sup>CH: 2008-2012; SI: 2008-2015; IL: 2010-2014; EL: 2011-2015. <sup>7</sup>CH: 2012; FR, TR, IL, US, CN: 2014.

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## CHAPTER I.3-D: INVESTMENT IN ECONOMIC COMPETENCES

*Synergies and complementarities between 'economic competences' and other intangible and tangible assets have significant potential to enhance productivity and economic growth in Europe.*

Economic competences are an increasingly relevant category of intangible assets which include investments in brand equity, firm-specific human capital, organisational capital and market research<sup>9</sup>, and which lead to productivity growth. In fact, the impact of a given investment increases when some of these economic competences, such as training and effective organisational and managerial structures, are combined with other intangible (e.g. software) and tangible (e.g. hardware) assets. Due to the fast pace of technological change, mainly driven by the exponential growth of ICT, it has become clear that investing in economic competences can contribute to better reaping the opportunities created by the ICT boom and which require, for instance, the use of new

business models and the deployment of specific skills that maximise exploitation of these technologies. Failing to acknowledge the need to invest in these complementary competences limits the desirable impact of ICT on productivity growth. This may be one of the explanations behind the 'productivity paradox'.

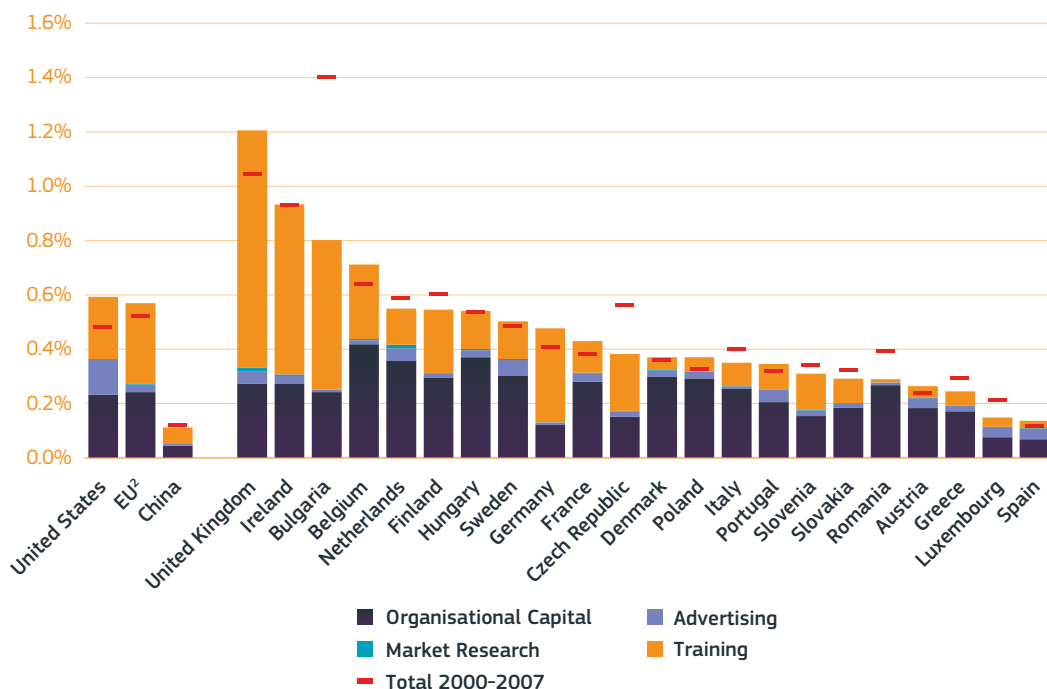
*Public investment in economic competences in the EU has not substantially increased in contrast to developments in the United States.*

The UK, Ireland and Bulgaria stand out as the Member States which, between 2008 and 2015, on average invested the most in economic competences, with a share above 0.8% of GDP. This is driven mainly by significantly higher investments in *training* relative to other Member States that mostly focus their public investments in this area on *organisational capital* (Figure I.3-D.1). More recently, the EU has been outperformed by the United States due to significant investments in *advertising*.

9 'Brand equity' includes advertising expenditure and market research for the development of brands and trademarks; 'firm-specific human capital' concerns the costs of developing workforce skills, i.e. on-the-job training and tuition payments for job-related education; organisational structure is related to the costs of organisational change and development as well as company training expenses (see Corrado et al., 2005); finally, 'market research' includes aspects such as feasibility studies and firm-specific foresight exercises (see Thum-Thysen et al., 2017).



**Figure I.3-D.1** Public investment in economic competences<sup>1</sup> by type, as % of GDP, 2008-2015 (and for 2000-2007 without breakdown by type)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, SPINTAN project: Smart Public intangibles

Notes: <sup>1</sup>Economic competences is one of the three broad categories of intangible assets. The other two categories are: computerised information and innovative property. <sup>2</sup>EU was estimated as the average of the values of the Member States for which data are available.

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***Private investment in economic competences is also lower in the EU than in the United States. However, generally speaking, there is an increase in investment in the majority of the EU Member States<sup>10</sup>.***

Bloom et al. (2017) showed that ‘good management’ practices increase a firm’s total factor productivity. Accordingly, the importance of competent management can be illustrated through the McDonald’s example. Essentially, the company’s success came from an effective and efficient organisational and managerial system applied at first to just one restaurant “which required upfront effort”, but then could be replicated and scaled across stores<sup>11</sup> nation and worldwide. Moreover, brand equity, in particular in the ‘tech sector’, has grown significantly. While in 2010, eight of the 20 most valuable brands, according to Forbes, were technology companies, in 2016, their representation increased to half and four of them were in the ‘top 5’. In addition, companies should invest in training and skills development in the context of fast-changing demand for new skills (OECD, 2017) especially if they want to remain competitive and thrive in the current digital era.

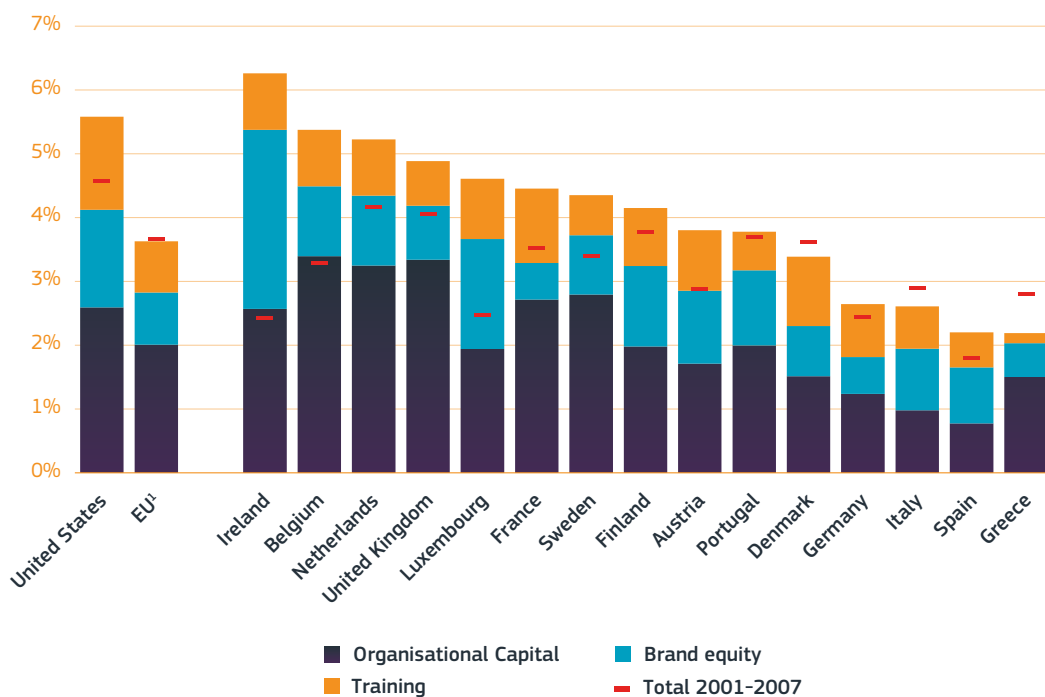
With the exception of Denmark, Italy and Greece, intangible investments in economic competences by businesses in the EU Member States (with available data) increased over 2008–2014 relative to the period 2000–2007. This rise was mostly noticeable in Ireland (where it more than doubled), Luxembourg and Belgium. However, on average, private investments in economic competences ranged from more than 6% of GDP in Ireland to slightly more than 2% of GDP in Greece between 2008 and 2015. Private intangible investments in *organisational capital* dominate in the majority of EU Member States, except Ireland, Luxembourg, Italy and Spain, where *brand equity* is the individual category within economic competences that drives most of these business investments<sup>12</sup>. The EU lags behind the United States mainly due to higher relative private investments dedicated to *brand equity* and *training* in the latter.

10 However, this analysis of the EU should be made with the necessary caveats due to the lack of data available for more EU Member States.

11 <https://hbr.org/2017/10/the-real-reason-superstar-firms-are-pulling-ahead>.

12 In principle, public support should not target economic competences that build monopoly rents, e.g. brand equity (see Thum-Thyssen et al., 2017).

**Figure I.3-D.2** Private investment in economic competences<sup>1</sup> by type, as % of GDP, 2008-2014 (and for 2001-2007 without breakdown by type)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, INTAN invest project

Notes: <sup>1</sup>Economic competences is one of the three broad categories of intangible assets. The other two categories are: computerised information and innovative property. <sup>2</sup>EU was estimated as the average of the values of the Member States for which data are available.

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# CHAPTER

# I.4

# SCIENTIFIC, TECHNOLOGICAL AND INNOVATION PRODUCTION

Scientific and technological production is the very basis of innovation outputs and reflects the efficiency and effectiveness of a research system in transforming investment in knowledge-creation activities into tangible and intangible assets that enable higher value-added activities. For innovation, the quest for excellence in scientific and technological activities is particularly important to ensure high-impact innovations, as well as favourable conditions for a thick weave of knowledge to flow.

Against this backdrop, and using a set of different measures, this chapter assesses the EU's scientific, technological and innovation performance in an international context as well as the robustness of knowledge flows across different innovation stakeholders.

## CHAPTER I.4-A SCIENTIFIC PRODUCTION AND SCIENTIFIC EXCELLENCE

Science is recognised at the global scale as an indispensable asset to understand and address today's economic and societal challenges, embrace emerging opportunities, and create technologies and innovations that benefit humanity and create wealth.

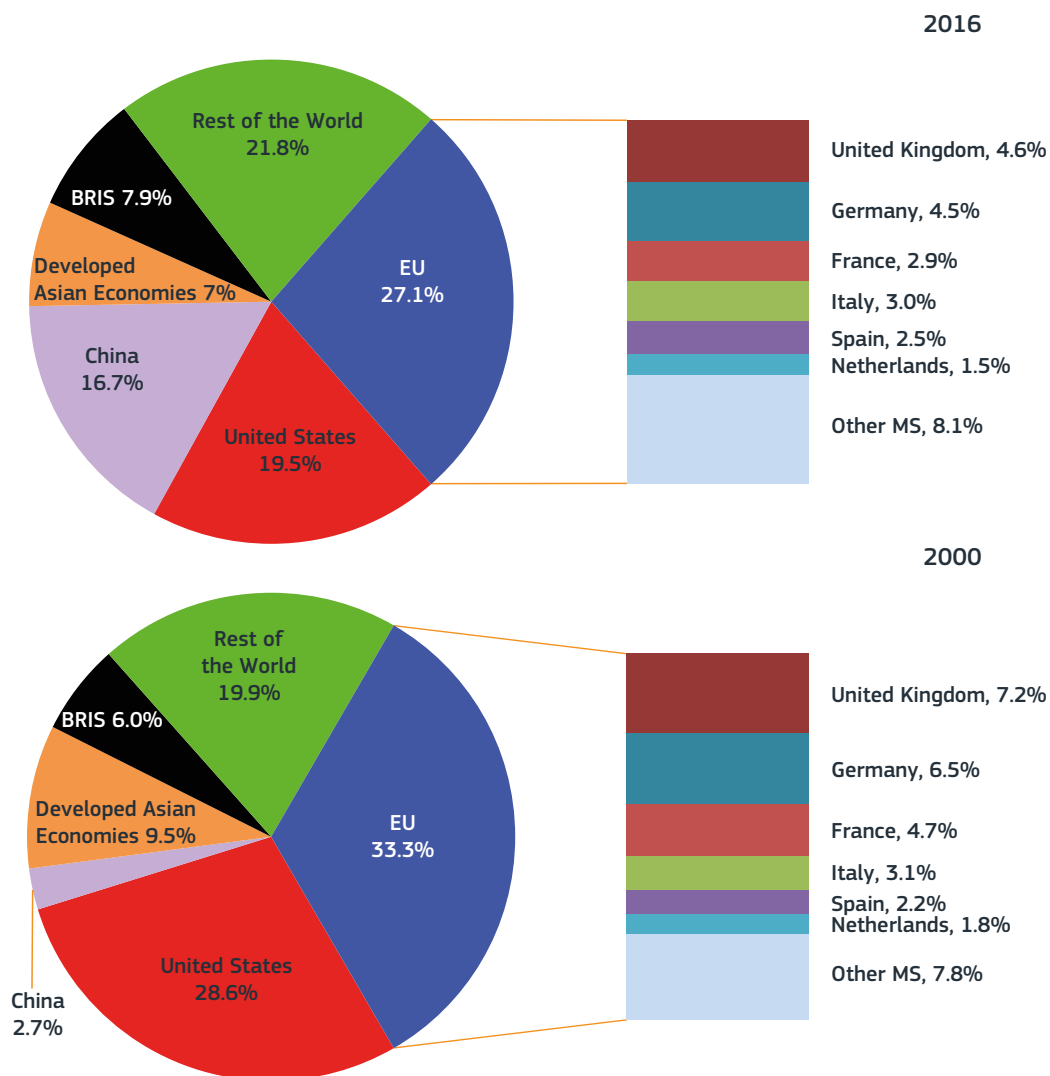
*In terms of overall scientific production, Europe is in the lead, ahead of the United States and China; a lead that has been maintained over time despite the emergence of an increasingly multipolar scientific landscape.*

Back in 2000, the EU and the United States dominated global knowledge production, together being the home for almost two-thirds of

scientific publications worldwide. However, China's significant investment in science over the last two decades has started to pay off and the country's world share of scientific publications has risen exponentially from 2.7% in 2000 to 16.7% in 2016. This has assured China a solid third position in the global ranking. Simultaneously, the United States' world share of scientific publications shrank from 28.6% in 2000 to 19.5% in 2016, increasing the gap with the EU, which managed to preserve its global leadership with over 27% of the world's knowledge production (see Figure I.4-A.1).



Figure I.4-A.1 World share of scientific publications<sup>1</sup>, 2000 and 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Fractional counting method.

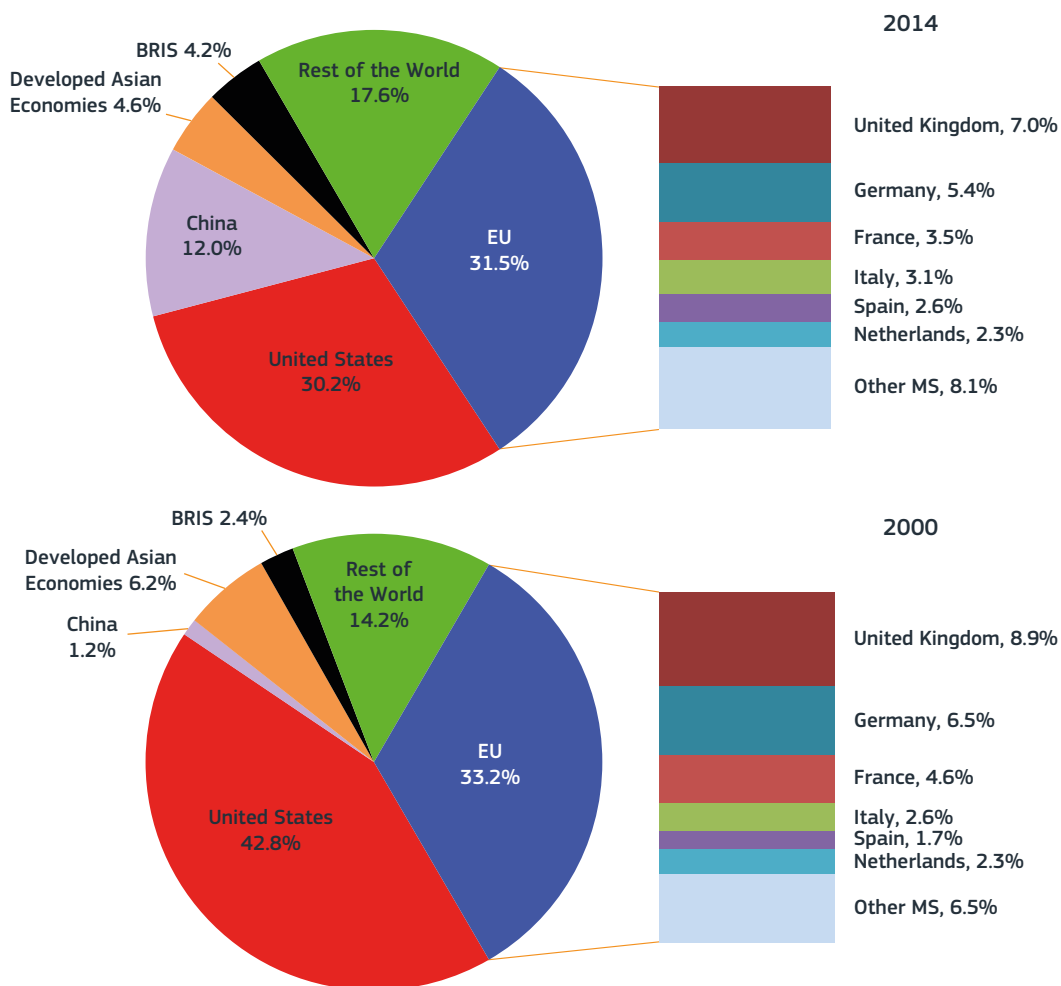
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***Europe has also maintained its global share in terms of highly cited publications. It has managed to overcome the United States as the world leader, despite China's sharp rise as a scientific superpower.***

In times of increasingly competitive global research dynamics, the EU has succeeded in steadily maintaining its world share of highly cited scientific publications (within 10% most cited) and has replaced the United States as the world leader. The United States experienced a heavy decline in the number of highly cited scientific publications, from 42.8% in 2000 to 30.2% in 2014, while China increased its share tenfold from 1.2% in 2000 to 12.0% in 2014. The share of other developed Asian economies in worldwide highly cited publications has also been falling (see Figure I.4-A.2).

A similar trend is observed for the top 1% of most-cited articles. However, despite the strong fall noted for top-cited American publications from 2000 to 2014 (from 49.0% to 35.1%) and Europe's ability to slightly improve its global share of top-cited publications over the last decade, the United States remains the global leader in top science although the gap with the EU has substantially narrowed (see Figure I.4-A.3).

**Figure I.4-A.2** World share of top 10% highly cited scientific publications<sup>1</sup>, 2000 (citation window: 2000-2002) and 2014 (citation window: 2014-2016)



Science, Research and Innovation performance of the EU 2018

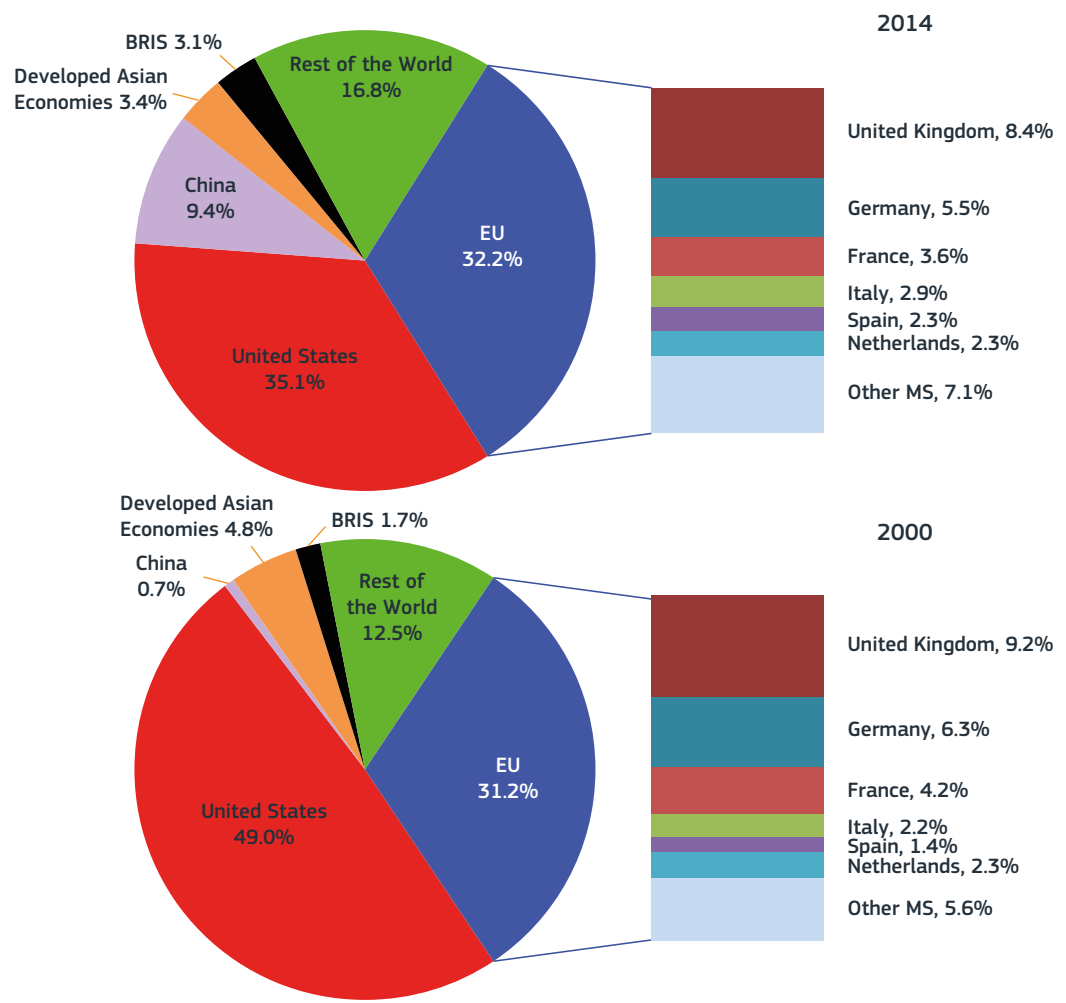
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 10% most-cited scientific publications worldwide as % of total scientific publications of the country; fractional counting method.

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**Figure I.4-A.3** World share of top 1% highly cited scientific publications<sup>1</sup>, 2000 (citation window: 2000-2002) and 2014 (citation window: 2014-2016)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 1% most-cited scientific publications worldwide as % of total scientific publications of the country; fractional counting method.

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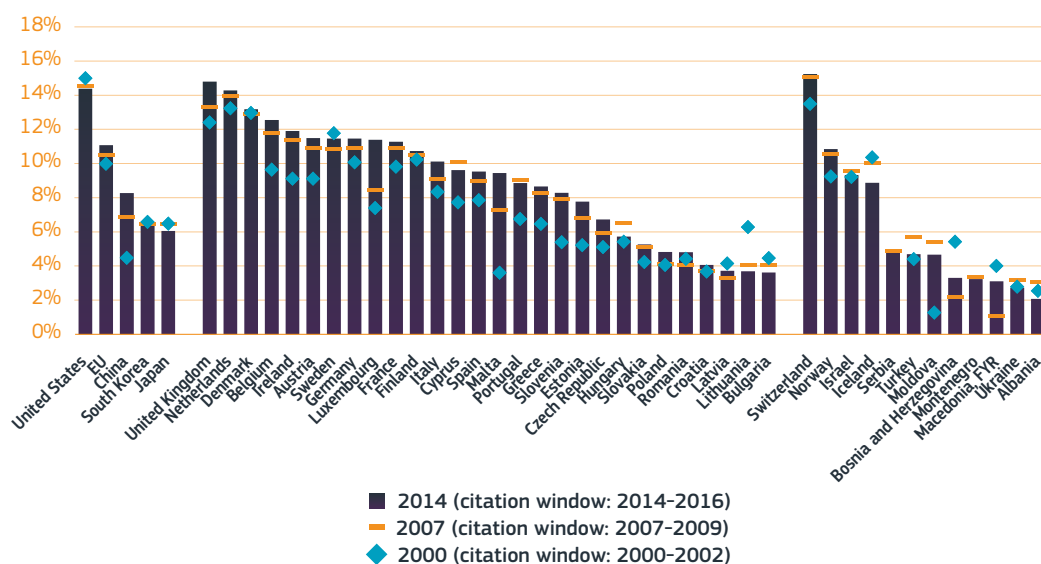
*In relative terms, Europe lags behind the United States in the share of the top 10% highly cited publications of total publications. In dynamic terms, Europe has advanced in making its science more excellent. Although large national differences exist across Member States, overall, most countries are making significant progress.*

Despite a slight fall in the share of total publications among the 10% most-cited worldwide since 2000 (see Figure I-4-A.4), the United States still outperforms the EU, which has more publications than the former but with a lower impact in terms of citations. Moreover, China is quickly bridging the gap with the EU since its top 10% most-cited publications have almost doubled since 2000.

Inside the European Research Area, strong differences among countries' performances persist.

Switzerland confirms its leading global position, while as from 2014, the United Kingdom has managed to surpass the United States in terms of high-impact scientific publications, with the Netherlands following closely behind. Numerous Western European and Scandinavian countries have continued to raise their scientific performance since 2000 (e.g. Denmark, Belgium, Ireland, Norway, Germany, Austria, Luxembourg and France). While several Mediterranean and Eastern European countries like Malta, Italy, Spain, Greece and Slovenia have managed to raise their scientific output significantly compared to 2000 and 2007, a post-2007 drop has been noted for Cyprus, Hungary, Bulgaria and Lithuania. Iceland experienced the largest fall in highly cited publications over the period 2000-2014. It should be noted that the scientific performance among the Eastern Partnership and Balkan countries has been volatile over the last decade.

**Figure I.4-A.4** Top 10% highly cited scientific publications<sup>1</sup>, 2000, 2007 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

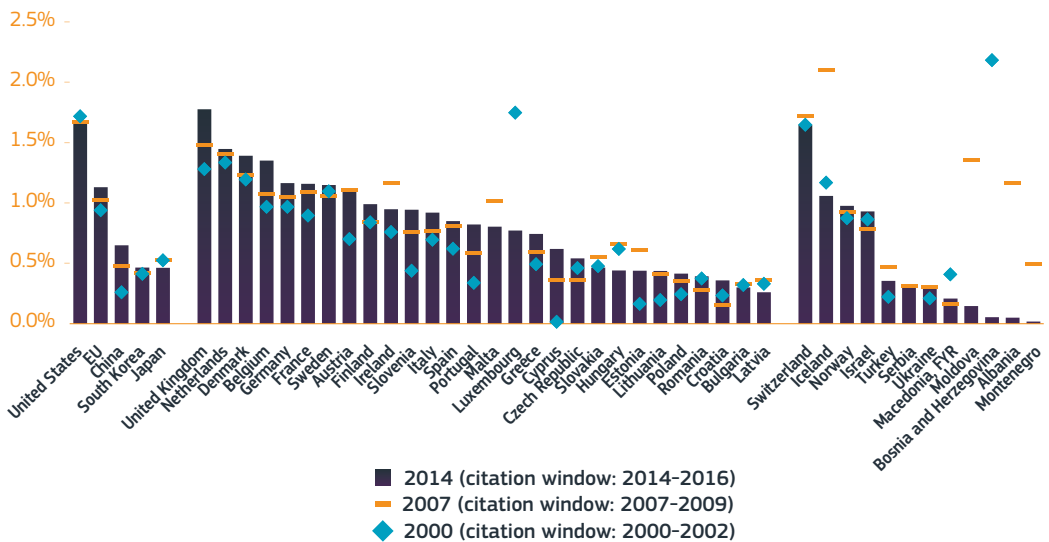
Note: <sup>1</sup>Scientific publications within the 10% most cited scientific publications worldwide as % of total scientific publications of the country; fractional counting method.

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Overall, and despite persisting differences between the Member States, the EU is raising its scientific impact as well as progressing in relative terms when examining the top 1% of highly cited scientific publications as a percentage of total scientific production (see Figure I.4-A.5), a proxy for top scientific excellence. This indicator confirms the trends presented

above: while the United States and Japan declined, the performance of the EU and China increased steadily. The UK is the world top performer in science where the top 1% of articles is concerned, ahead of the United States, and followed by Switzerland, the Netherlands, Denmark, Belgium, Germany, France and Sweden, which all score above the EU average.

**Figure I.4-A.5 Top 1% highly cited scientific publications<sup>1</sup>, 2000, 2007 and 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 1% most cited scientific publications worldwide as % of total scientific publications of the country; fractional counting method.

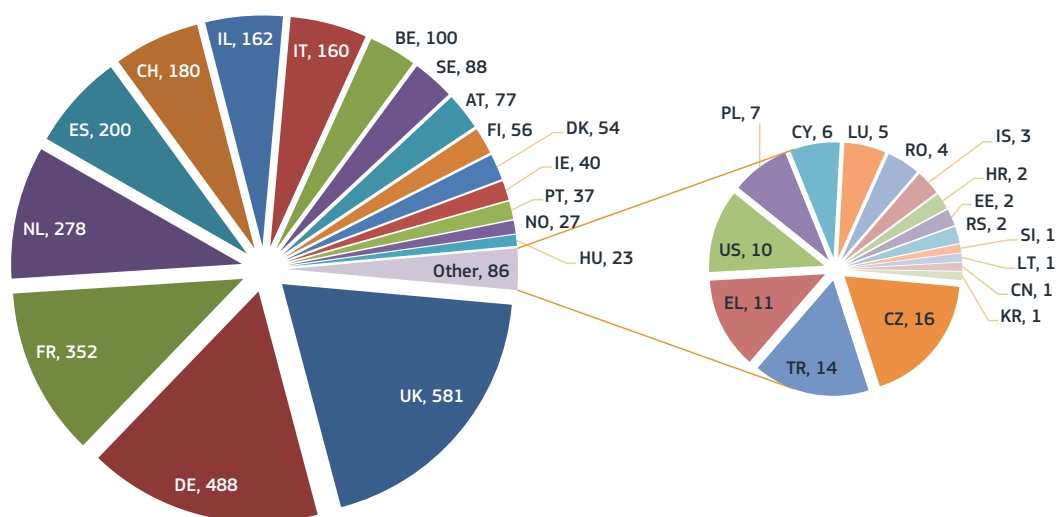
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*European Research Council (ERC) grantees are increasingly recognised as a measure of excellence. The UK and the Netherlands perform particularly strongly in ERC grantees, notably in comparison to their overall level of public R&D investment.*

Shortly after its establishment in 2007, the ERC became a reference for the funding of international, excellent, frontier research conducted on the basis of Europe-wide competition. The ERC

is continuously improving its high-quality evaluation systems, including under the current Horizon 2020 Framework Programme. By 2017, researchers based in the UK, Germany, France and the Netherlands had been awarded most ERC grants under Horizon 2020. The grants are focused on research-intensive countries since almost 90% of those distributed are concentrated in 10 countries, while half of the 20 remaining European Research Area (ERA) countries have less than 10 grants (see Figure I.4-A.6).

**Figure I.4-A.6** Number of European Research Council (ERC) grants by country, 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: DG Research and Innovation (CORDA database)

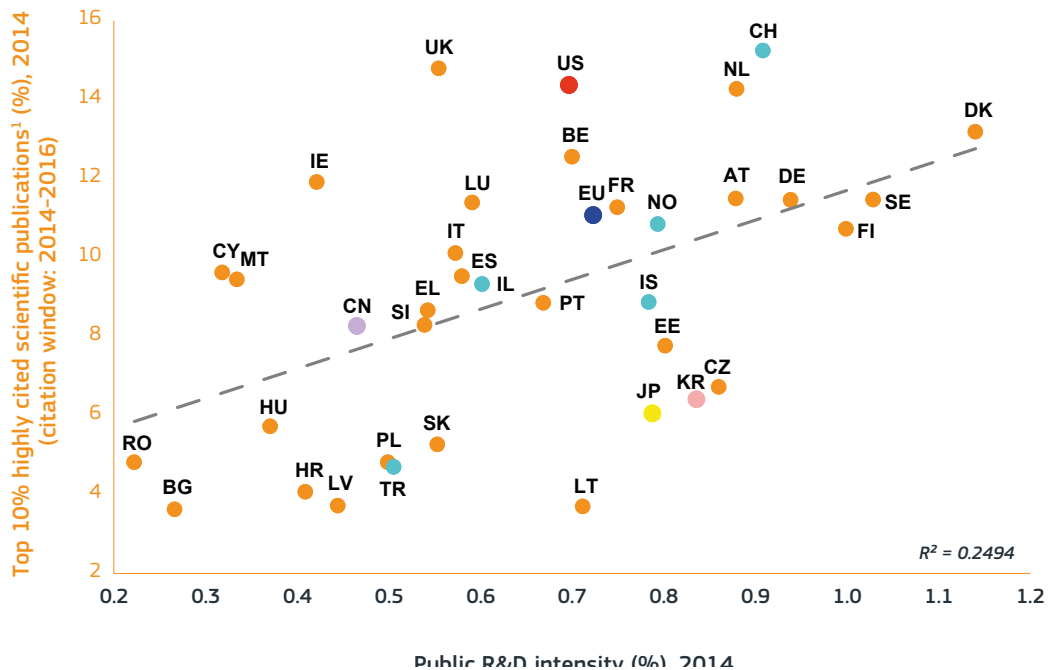
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_6.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_6.xlsx)

*Despite progress in building up excellence in EU science, numerous ERA countries punch below their public R&D weight, suggesting persistent weaknesses in building more impactful research excellence which requires sustained investments and efficient reforms of the public research systems to increase the quality and impact.*

At the global level, where the share of total publications among the 10% most-cited worldwide is concerned, the United States makes a higher scientific impact than the EU, despite its slightly lower public R&D intensity, while South Korea and Japan show relatively low levels of scientific quality in relation to

their public investments (see Figure I.4-A.7). In Europe, weaker research excellence in Central and Eastern European countries confirms the persistence of an East-West science divide, with Mediterranean countries ranked just in the middle (although below the EU average). Simultaneously, a positive correlation between investments and scientific quality is evident for most countries. Switzerland, Denmark, Sweden, Germany, the Netherlands, Austria and France enjoy higher levels of public investments in R&D than the EU average, as well as better scientific results. Eastern European countries have below-EU-average investment levels matched with equally low levels of scientific excellence.

**Figure I.4-A.7 Public R&D intensity, 2014 and top 10% highly cited scientific publications<sup>1</sup> 2014 (citation window: 2014-2016)**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 10% most cited scientific publications worldwide as % of total scientific publications of the country; fractional counting method.

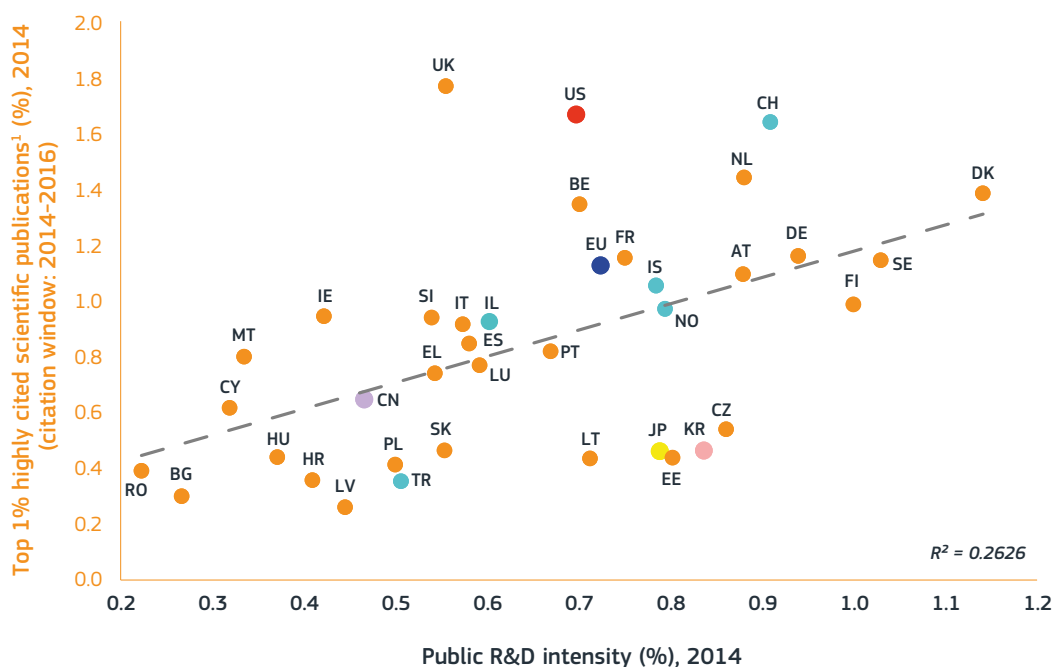
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However, it should also be noted that the UK, Belgium and Ireland perform significantly better than would be expected from their public R&D investment levels. Conversely, the resources put into public research in countries like Estonia, the Czech Republic, Lithuania or

Iceland do not appear to lead to sufficiently high-quality results. Interestingly, the trends described above are confirmed by looking at the top 1% of highly cited publications in relation to countries' public investments (see Figure I.4-A.8).

**Figure I.4-A.8** Public R&D intensity, 2014 and top 1% highly cited scientific publications<sup>1</sup> 2014 (citation window: 2014-2016)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 1% most cited scientific publications worldwide as % of total scientific publications of the country; fractional counting method.

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The diversity of the European research landscape is explained not only by the levels of national R&D investment but also by their effectiveness. Countries which systematically pursue a better quality and impact of their public science base through sustained public investments and structural reforms of their national science and innovation systems<sup>1</sup> tend to be those that extract the maximum from their public R&D investments. The Horizon 2020 Policy Support Facility supports the design, evaluation and implementation of such national reforms<sup>2</sup>.

*Since the globalisation of research has intensified over the last decade, particularly collaborative research, international co-publications are becoming increasingly significant in fostering the production of new knowledge worldwide and stimulating positive impacts in scientific performance.*

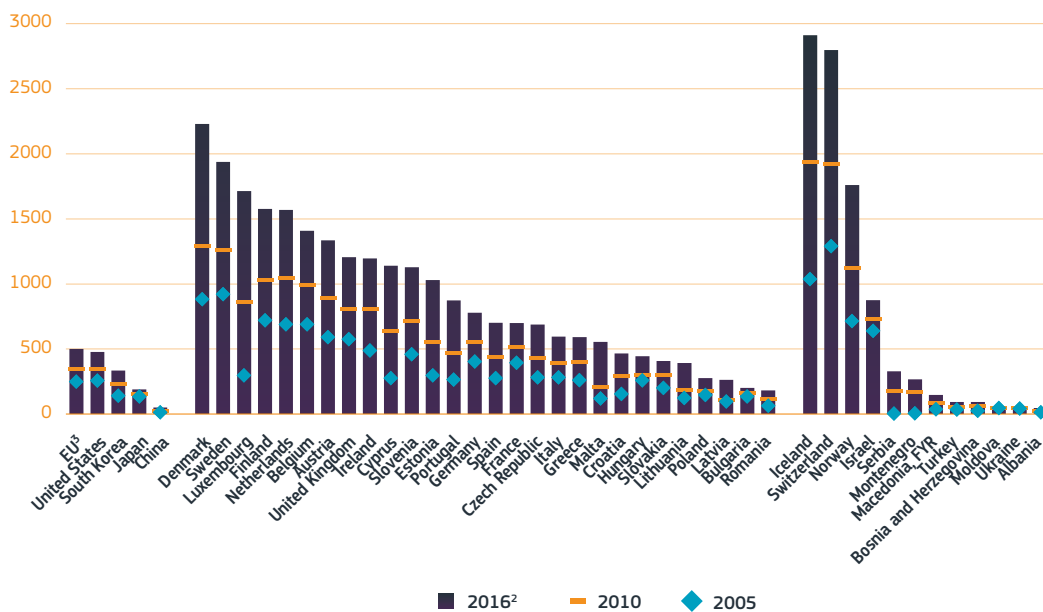
All ERA countries have steadily increased their share of international co-publications since 2000, a trend that is also confirmed at the global level for the United States and Asian economies (see Figure I.4-A.9). Several Eastern European countries (Poland, Slovakia, Romania and Bulgaria)

have lower levels of international exposure and collaboration, and some of their researchers enjoy less international mobility. While the low level of excellence in some of these countries does not provide opportunities for international collaboration, it is also clear that the low level of internationalisation has an impact on the level of scientific excellence, leading to lower scores in highly cited scientific publications in these countries. On the other hand, research-intensive countries, both large (such as the United States, UK, Germany and France) and small (like the Netherlands, Switzerland and Denmark) enjoy higher levels of international collaboration coupled with higher scores in quality science. In short, open research systems perform better in scientific quality since scientists achieve greater impact from their international collaborations.

International collaboration in science is becoming increasingly important and leads to improved scientific quality, as measured by the publications' citation impact. This is confirmed by the fact that the citation impact of international co-publications is greater than that of single-country publications for all countries (see Figure I.4-A.10).

- 
- 1 Such reforms include aspects such as: the establishment of adequate mechanisms to reward, through public funding, a higher research performance by institutions; effective incentives for researchers and institutions to perform high-quality and impactful research; policies that combat the fragmentation of national science and higher education systems; optimisation of the institutional environment of public institutions performing R&D to facilitate collaborative research and cooperation with industry; strategies to improve international scientific collaboration and researcher mobility; and public action in support of knowledge transfer.
  - 2 The Horizon 2020 Policy Support Facility (PSF) gives Member States and countries associated to Horizon 2020 practical support to design, implement and evaluate reforms that enhance the quality of their R&I investments, policies and systems (<https://rio.jrc.ec.europa.eu/en/policy-support-facility>).

**Figure I.4-A.9 International scientific co-publications<sup>1</sup> per million population, 2005, 2010 and 2016**



Science, Research and Innovation performance of the EU 2018

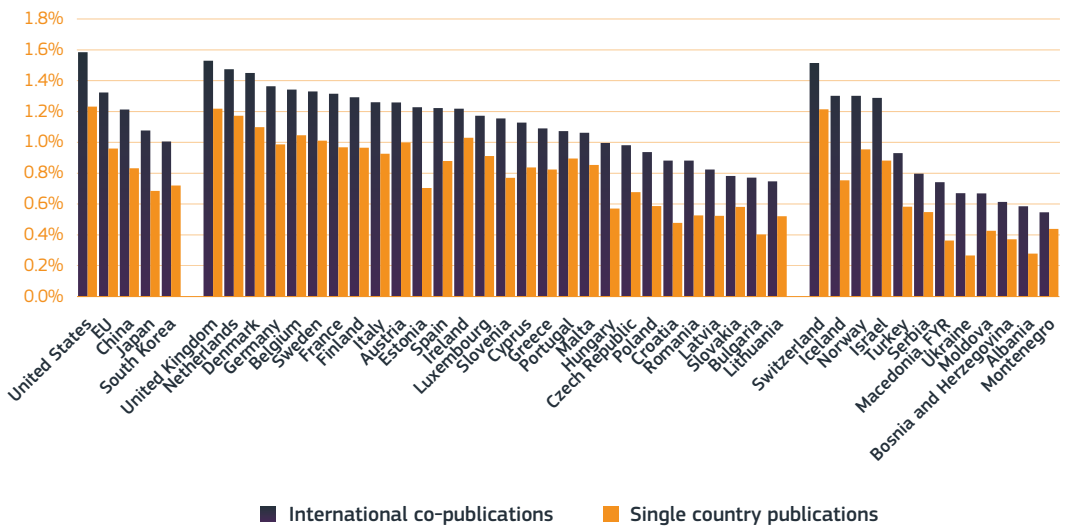
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Notes: <sup>1</sup>Scientific publications with at least one co-author based abroad. <sup>2</sup>AL, BA, UA, IL, US, JP, CN, KR: 2015.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_9.xlsx)

**Figure I.4-A.10 Citation impact<sup>1</sup> of scientific publications, 2014**  
(citation window: 2014-2016)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Citation impact normalised by field and publication year (ratio of the average number of citations received by the considered papers and the average number of citations received by all papers in the main field, or 'expected' number of citations), citation window publication year plus two years.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_10.xlsx)

***Global higher education rankings are increasingly perceived and used as the international measure of impactful scientific research and teaching quality. The EU has more ‘world-class’ universities among the top 500 institutions while the United States still leads in the top 100, as measured by the two most popular rankings.***

After periods of strong massification of higher education institutions, and with the advance of their globalisation and marketization, over the last 15 years, more and more attention has been paid to their internationally measured performance. The Academic Ranking of World Universities<sup>3</sup> (ARWU), also called the Shanghai Ranking, and the Times Higher Education (THE) ranking are currently the most-quoted university rankings in the world.

Although the validity and impact of a growing number of league tables with international university rankings is still being debated, many higher education institutions use them to inform strategic decisions or shape priorities, and being in the ‘top 100’ is widely defined as a national or institutional strategy. Visibility in international rankings is naturally associated with universities’ capability to conduct globally impactful, excellent scientific research, and gives them ‘world-class’ status.

According to ARWU, which is based on six indicators mainly related to an institution’s scientific output (number of Nobel Prizes and Fields Medals, highly cited researchers, papers published), the EU has more universities (182) in the top 500 than the United States (135), a number which has been stable since 2005 (see Figure I.4-A.11). However, the United States still slightly outperforms the EU in the top 500 universities per million population, has a higher number of universities in the top 100, and holds 8 of the top 10 ranks. The EU, on the other hand, outperforms South Korea, Ja-

pan and China (which in the ARWU includes Hong Kong, Macao and Taiwan) in terms of top institutions per million population (see Figure I.4-A.12). Leading EU countries in terms of the ARWU top 500 institutions per million inhabitants are Sweden, Finland and Denmark. Portugal has improved its performance most since 2010, while the performance of Finland, Austria, Italy and Hungary has declined. The Baltic States (except Estonia), Bulgaria, Romania, Croatia, Cyprus, Luxembourg, Malta<sup>4</sup> and Slovakia do not have a university among the top 500 worldwide, while Romania, Croatia, Luxembourg, Slovakia and Lithuania have institutions ranked in the top 800 of the ARWU.

The THE, established in 2004, has a broader scope and also includes indicators on teaching, international outlook and industry income (and hence knowledge transfer). As regards research, it includes subjective factors, too, such as reputation. As a result, while international performance patterns are broadly similar compared to the ARWU, the EU comes out better than the United States in areas like teaching and internationalisation.

In the THE ranking, the EU has nearly twice as many top 500 institutions as the United States which still outperforms the EU in the top 100 of the ranking (see Figure I.4-A.13). However, while two American institutions (Harvard and Stanford) are in the lead in the ARWU, the THE ranking lists Oxford and Cambridge as the world’s top universities.

According to the THE ranking, Luxembourg is the best EU performer in the top 500 universities per million population (with one institution), followed by Ireland, Finland, Denmark and Sweden (see Figure I.4-A.14). The majority of Central and Eastern European Member States do not have universities in the THE top 500 (Estonia and Hungary being the only exceptions).

3 The Academic Ranking of World Universities (ARWU) was first published by the Graduate School of Education of the Shanghai Jiao Tong University in June 2003 and has been updated since on an annual basis.

4 It should be noted that Malta and Luxembourg have only one university (Malta has two higher education institutions). In total, there are about 3300 higher education institutions in the EU.

**Figure I.4-A.11** Number of top 100 and top 500 universities in the Shanghai ranking

	Top 100 universities				Top 500 universities			
	2005	2010	2015	2017	2005	2010	2015	2017
EU <sup>1</sup>	30	28	29	28	191	191	192	182
United States	53	54	51	48	168	154	146	135
China	-	-	-	2	18	34	44	57
Japan	5	5	4	3	34	25	18	17
South Korea	-	-	-	-	8	10	12	12

Science, Research and Innovation performance of the EU 2018

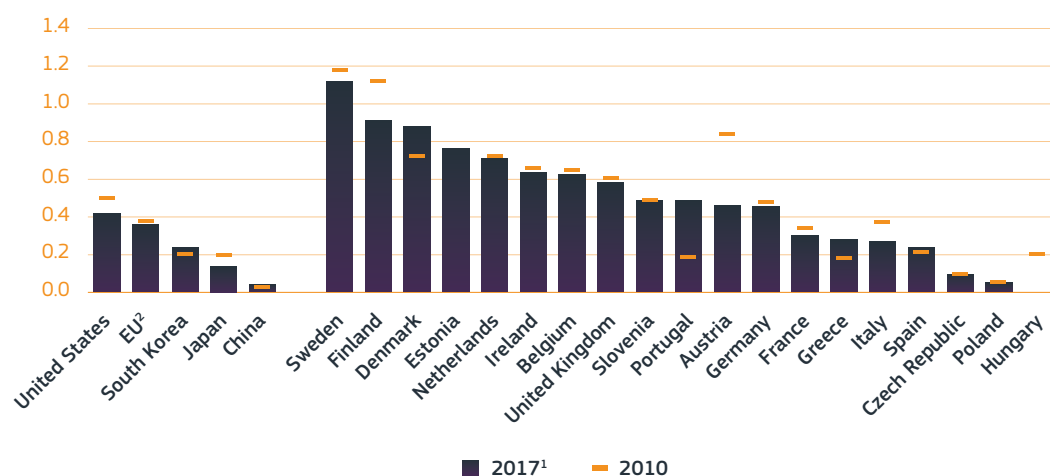
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Shanghai rankings (<http://www.shanghairanking.com/>)

Note: <sup>1</sup>EU was estimated by DG Research and Innovation based on the data available for the Member States.

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**Figure I.4-A.12** Number of top 500 universities in the Shanghai ranking per million population<sup>1</sup>, 2010 and 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Shanghai rankings (<http://www.shanghairanking.com/>)

Notes: <sup>1</sup>Population refers to 2016 for all countries except US, JP, CN, and KR in respect of which population refers to 2015.

<sup>2</sup>EU was estimated by DG Research and Innovation based on the data available for the Member States.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_12.xlsx)

**Figure I.4-A.13** Number of top 100 and top 500 universities in the Times Higher Education World university rankings

	Top 100 universities			Top 500 universities		
	2016	2017	2018	2016	2017	2018
EU <sup>1</sup>	40	36	35	228	226	225
United States	39	41	43	122	120	125
China	2	2	2	11	12	12
Japan	2	2	2	11	12	10
South Korea	1	2	2	11	11	11

Science, Research and Innovation performance of the EU 2018

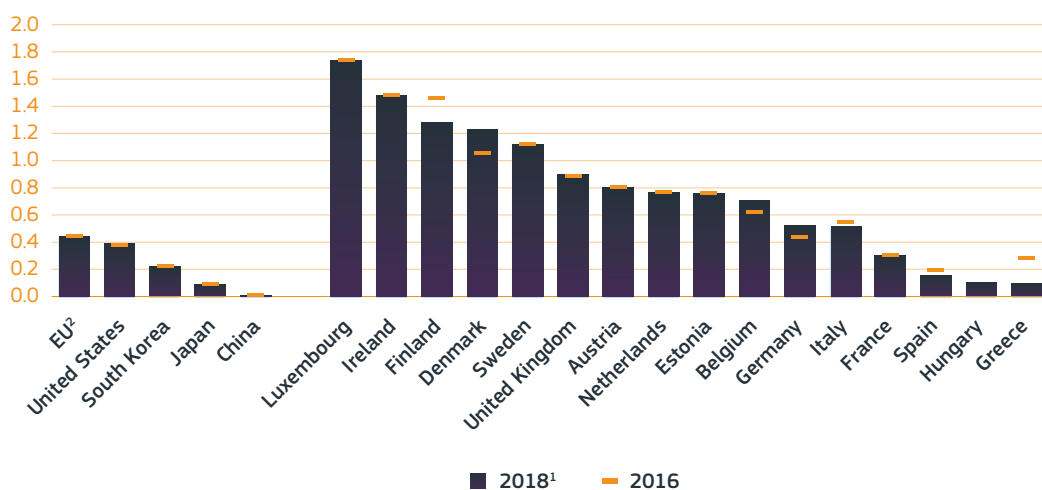
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Times Higher Education - World university rankings (<https://www.timeshighereducation.com/world-university-rankings/2018>)

Note: <sup>1</sup>EU was estimated by DG Research and Innovation based on the data available for the Member States.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_13.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_13.xlsx)

**Figure I.4-A.14** Number of top 500 universities in the Times Higher Education World university rankings per million population<sup>1</sup>, 2016 and 2018



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

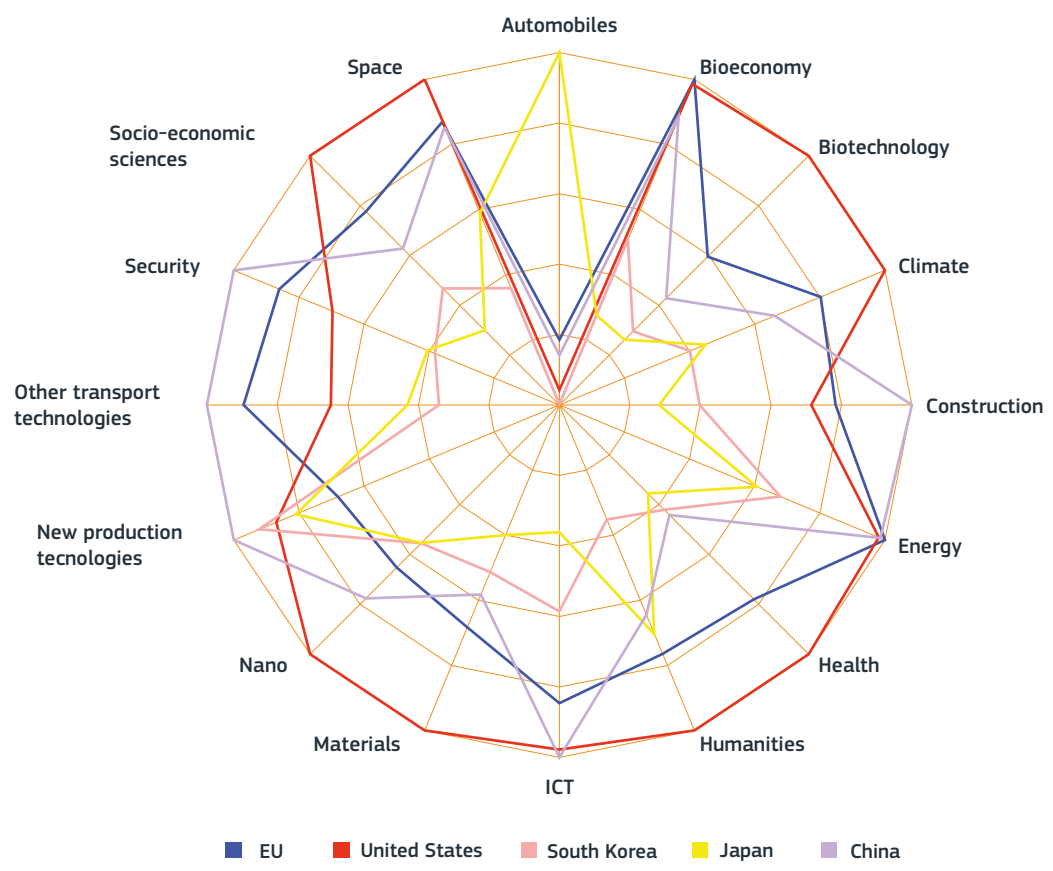
Data: Times Higher Education - World university rankings (<https://www.timeshighereducation.com/world-university-rankings/2018>)

Notes: <sup>1</sup>Population refers to 2016 for all countries except US, JP, CN, and KR in respect of which population refers to 2015.

<sup>2</sup>EU was estimated by DG Research and Innovation based on the data available for the Member States.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_14.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_14.xlsx)

**Figure I.4-A.15** Top 10% highly cited scientific publications<sup>1</sup>, by sector, 2014  
(citation window: 2014-2016)



Science, Research and Innovation performance of the EU 2018

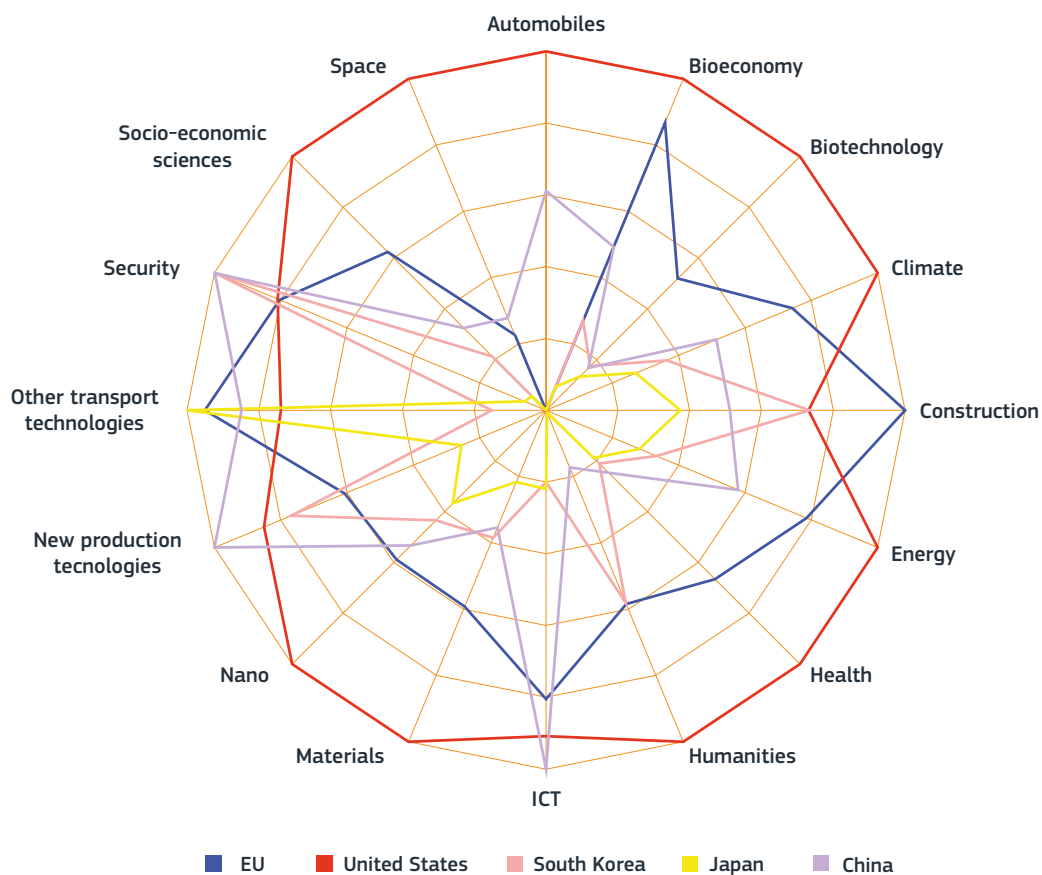
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 10% most cited scientific publications worldwide as a % of total scientific publications of the country; fractional counting method.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_15.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_15.xlsx)



**Figure I.4-A.16** Top 1% highly cited scientific publications<sup>1</sup>, by sector, 2014  
(citation window: 2014-2016)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Scientific publications within the 1% most cited scientific publications worldwide as a % of total scientific publications of the country; fractional counting method.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-a\\_figures/f\\_i\\_4-a\\_16.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-a_figures/f_i_4-a_16.xlsx)

## CHAPTER I.4-B: KNOWLEDGE FLOWS

*Knowledge diffusion has always been crucial to support the creation and dissemination of innovation across companies, sectors and countries. Against a backdrop where innovation diffusion from leading to laggard firms seems to stall our economies' productivity, knowledge flows become even more important.*

Recent work by the OECD (2015)<sup>5</sup> shows that over the past decade the productivity gap between frontier and laggard firms has widened. One of the main reasons for this is the persistently insufficient diffusion of technologies and innovations across firms and countries, both between and within sectors. Consequently, understanding the dynamics of knowledge diffusion is critical to make a proper assessment of innovation performance.

*Innovation diffusion depends on three principles: (i) Open Science (ii) Open Innovation and (iii) Open to the World.*

This chapter analyses how knowledge is disseminated in the EU through different channels. More precisely, innovation diffusion depends on three principles: (1) *Open Science*, with scientific outputs being used and integrated more and more widely to produce faster and more impactful scientific advances; (2) *Open Innovation*, with robust and strong science-business linkages; and (3) *Open to the*

*World*, with knowledge flowing freely and not limited to territorial boundaries. These principles guide the European research<sup>6</sup> policy and will form the basis of the analyses of knowledge flows presented in this chapter.

### Open Science

This section looks at the progress achieved in making science more open in Europe, notably through better open access to scientific publications and greater mobility of researchers across institutions. In an ever-more globalised and knowledge-driven world, in which data is increasingly valuable and considered as a competitive advantage<sup>7</sup>, it is key to ensure that advances in science and technology are open as far as possible. This makes the scientific discovery process increasingly robust as, for example, it allows for an easier verification and replication of research results.

*Overall, and despite still lagging behind the United States, European science is becoming increasingly more open-access oriented, with significant progress across all Member States.*

The trend towards providing a wider audience with access to scientific output has continued for decades, driven by the growth of ICT, amongst others, making data and knowledge increasingly accessible beyond national

5 OECD (2015), *The Future of Productivity*, OECD Publishing, Paris. See also, Chapter II.1 of this report for a recent update on the work by the OECD in this field.

6 European Commission (2016a). *Open Innovation, Open Science, Open to the World - a Vision for Europe*. DG Research and Innovation.

7 [http://europa.eu/rapid/press-release\\_SPEECH-11-872\\_en.htm?locale=en](http://europa.eu/rapid/press-release_SPEECH-11-872_en.htm?locale=en)

boundaries. For years, the European Commission has actively supported creating the right conditions for open access in Europe, e.g. via the creation of a European Open Science Cloud or the 2012 Recommendation on open access policies relating to scientific research funded by public funds<sup>8</sup>. This was also reinforced by the Amsterdam Call for Action on Open Science in 2016<sup>9,10</sup>. The EU distinguished between two forms of open access: gold (open access publishing) and green (not published in an open access journal but self-archived)<sup>11</sup>.

As shown in figure I.4-B.1, although EU scientific publications are becoming increasingly open, the EU is still lagging behind the United States and a few associated countries such as Switzerland, Iceland, Norway, Macedonia, Serbia and Bosnia and Herzegovina. This is mainly driven by the differences between the Member States, given that central European and Nordic countries report a larger share of open access publications than the rest of the

EU. However, overall a positive trend can be observed across all countries, with the exception of Croatia, Bosnia and Herzegovina and Montenegro. The graph also shows differences in the relative share of gold versus green open access publications, with a higher relative share of gold open access in the lower-performing countries, both in the EU and internationally.

Another relevant channel for scientific diffusion is linked to the mobility of researchers and scientists. When moving from one job to the next, the knowledge acquired by individuals is disseminated in the new workplace. Every year, Eurostat collects statistics related to the mobility of human resources in science and technology (HRST)<sup>12</sup> via the EU Labour Force Survey. Figure I.4-B.2 presents the number of scientists who changed jobs in two consecutive time periods as a share of the total human resources in science and technology available in a country in the initial period.

8 European Commission (2012a). Commission Recommendation of 17.7.2012 on access to and preservation of scientific information. C(2012) 4890 final.

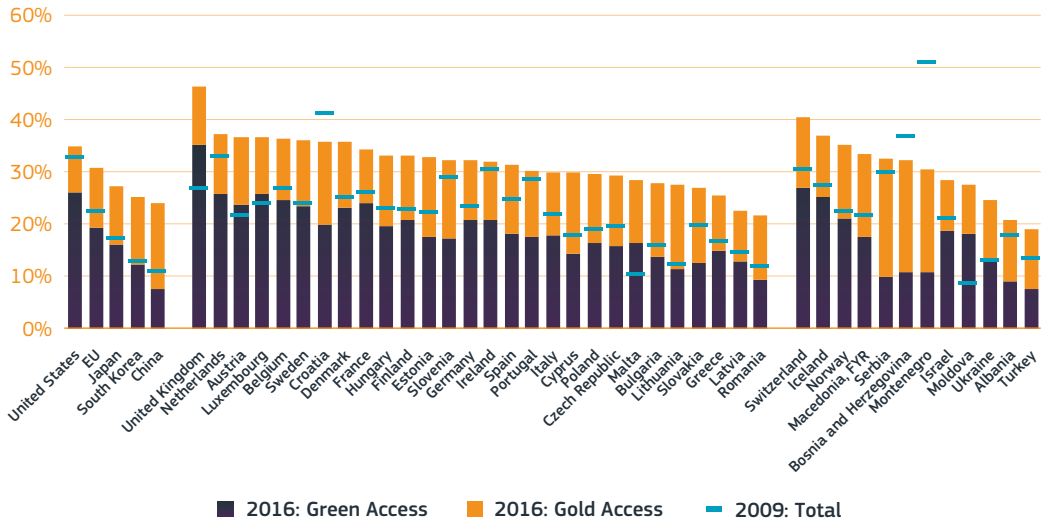
9 European Commission (2016b) European Cloud Initiative: Building a competitive data and knowledge economy in Europe.

10 See also Amsterdam Call for Action on Open Science, 2016: <https://www.government.nl/documents/reports/2016/04/04/amsterdam-call-for-action-on-open-science>

11 European Commission (2012b). Towards better access to scientific information: Boosting the benefits of public investments in research. COM(2012) 401 final.

12 Job-to-job mobility HRST are individuals who have changed employers during the last year, and fulfil the condition of being employed HRST, i.e. (1) they have successfully completed education at the third level and are employed in any kind of job; or (2) they are not formally qualified as above but are employed in an occupation where the above qualifications are normally required – for more details: [http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Human\\_resources\\_in\\_science\\_and\\_technology\\_\(HRST\)](http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Human_resources_in_science_and_technology_(HRST)).

**Figure I.4-B.1 Open access scientific publications<sup>1</sup> with digital object identifier (DOI) as % of total scientific publications with DOI, 2009 and 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>Open access publications are online publications that are freely available to the reader.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-b\\_figures/f\\_i\\_4-b\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-b_figures/f_i_4-b_1.xlsx)

*While HRST mobility has remained broadly stable at the EU level, there are significant differences across Member States where a mixed pattern can be observed, suggesting a divide between the core and the periphery, which appears to widen over time.*

Between 2007 and 2016, most of the decline in job-to-job mobility of HRST can be observed in Eastern and some Southern Member States, while remaining roughly stable for the EU as a whole. As can be seen in Figure I.4-B.2, Member States which already had a lower share of mobile researchers reduced that share even further, with the exception of

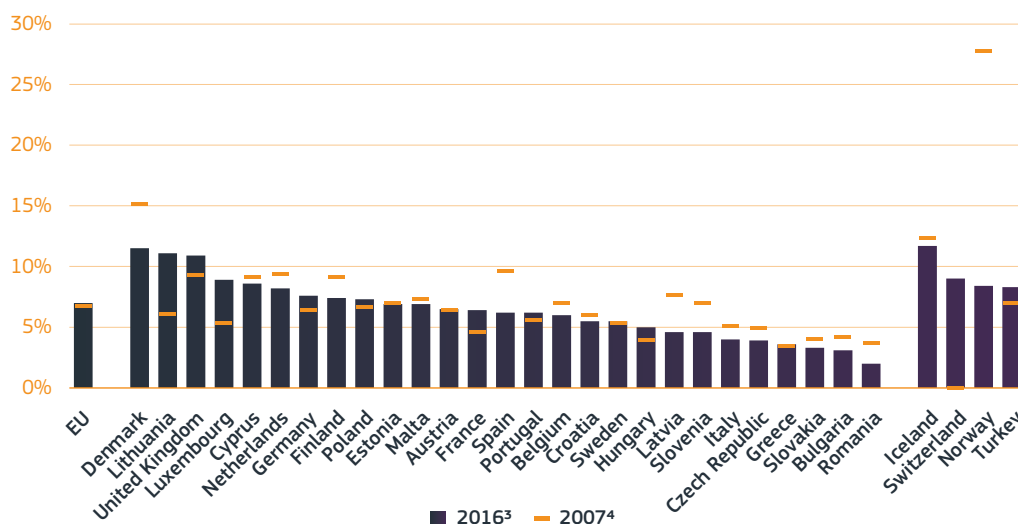
a few countries where increased mobility can be observed. In some cases, the share of mobile researchers declined significantly in countries where mobility was relatively high, such as Denmark, Spain and Norway. Conversely, research mobility increased more significantly in Lithuania, Luxembourg, the UK, Germany, France and Hungary. In general, a divide can be detected between the core and the periphery, with a widening trend over time. These patterns might be the result of various factors, including the effects of the crisis or brain-drain phenomena – the latter notably in Bulgaria, Romania and Slovakia – which has been attributed to, amongst others, increased

competition linked to the opening of labour markets<sup>13,14</sup>. Thus, finding a good balance between flexible and secure labour markets is an important precondition to enable workers to overcome obstacles to mobility between jobs and sectors, as well as creating attractive conditions for research and science to encourage mobile workers to return to their home countries to take full advantage of this exchange of knowledge. Public policy has proven

to be a catalyst of such mobility, as discussed in Chapter I.5. on Framework Conditions.

At the European level, the Marie Skłodowska-Curie Actions (MSCA) are relevant in supporting the attraction and mobility of highly skilled researchers by providing more high-quality training and career development for researchers and their career mobility between academia and non-academia.

**Figure I.4-B.2 Job-to-job mobility<sup>1</sup> of human resources in science and technology (HRST)<sup>2</sup> as % of total HRST, 2007 and 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat

Notes: <sup>1</sup>The movement of individuals between one job and another from one year to the next. It does not include inflows into the labour market from a situation of unemployment or inactivity. <sup>2</sup>HRST: Persons with tertiary education and/or employed in science and technology. <sup>3</sup>CH: 2015. <sup>4</sup>BG: 2008.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-b\\_figures/f\\_i\\_4-b\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-b_figures/f_i_4-b_2.xlsx)

13 Doria Arrieta, O., Pammolli, F. and Petersen, A. (2017). Quantifying the negative impact of brain drain on the integration of European science. *Science Advances*. 3. 10.1126/sciadv.1602232.

14 European Commission (2016c). European Research Area Progress Reports: Technical Report. DG Research and Innovation.

## Open innovation

One of the most impactful channels for knowledge diffusion is the cooperation between businesses and other businesses and science. Eurostat produces the Community Innovation Survey which asks companies if in the past three years they were engaged with third parties in cooperation related to the introduction of product or process innovations, and what type of partners were involved in these cooperations.

***Across the EU, large companies engage more in cooperation activities with third parties than SMEs. However, the degree of cooperation varies widely across Member States.***

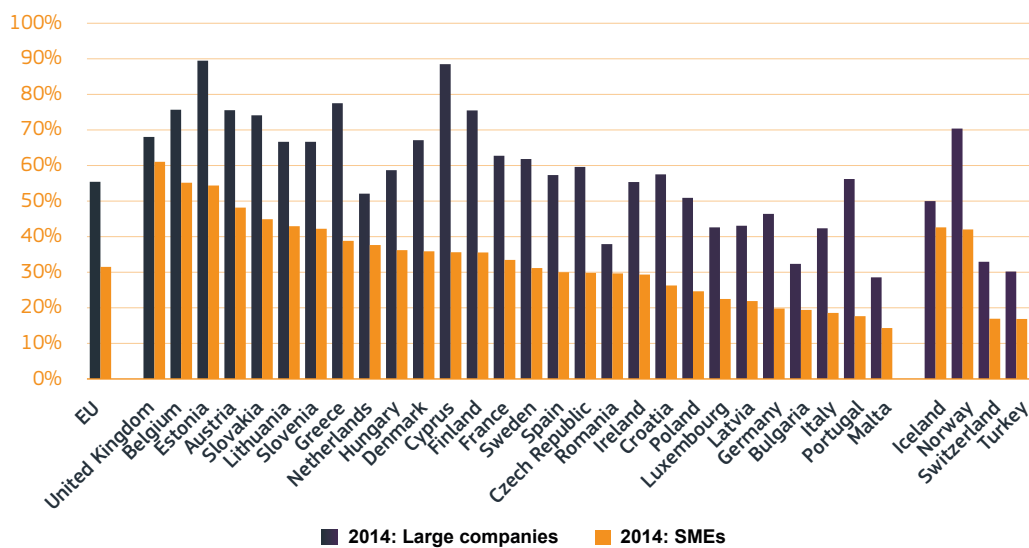
Figure I.4-B.3 provides an overview of business cooperation, showing the overall share of innovative enterprises involved in any type

of cooperation with other enterprises or organisations<sup>15</sup>. However, while there are many forms of cooperative activities, the below analysis will focus mostly on business cooperation with research institutions, such as (i) universities or other higher education institutions; (ii) governments, public and private research institutes; as well as (iii) their competitors. It is not surprising to note that SMEs have a lower cooperation rate with third parties than large companies. However, the differences between Member States are striking. When examining whether companies are cooperating at all, no general pattern is observed. Indeed, while Germany and Luxembourg are surprisingly underperforming compared to other Member States, Estonia, Slovakia, Lithuania, Slovenia and Greece have relatively high levels of cooperation. In general, in countries with higher levels of cooperation among large companies, SMEs also cooperate more.

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15 This includes cooperation with (1) enterprises from the same group; (2) suppliers of equipment, materials, components or software, with customers from the; (3) private; or (4) public sectors; with (5) competitors or other enterprises from the same sector; with (6) consultants or commercial labs; with (7) universities or other higher education institutes; and with (8) government, public or private research institutes.

**Figure I.4-B.3** % share of innovative enterprises<sup>1</sup> involved in any type of cooperation, 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (CIS 2014)

Note: <sup>1</sup>Product and/or process innovative enterprises, regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or ongoing innovation activities).

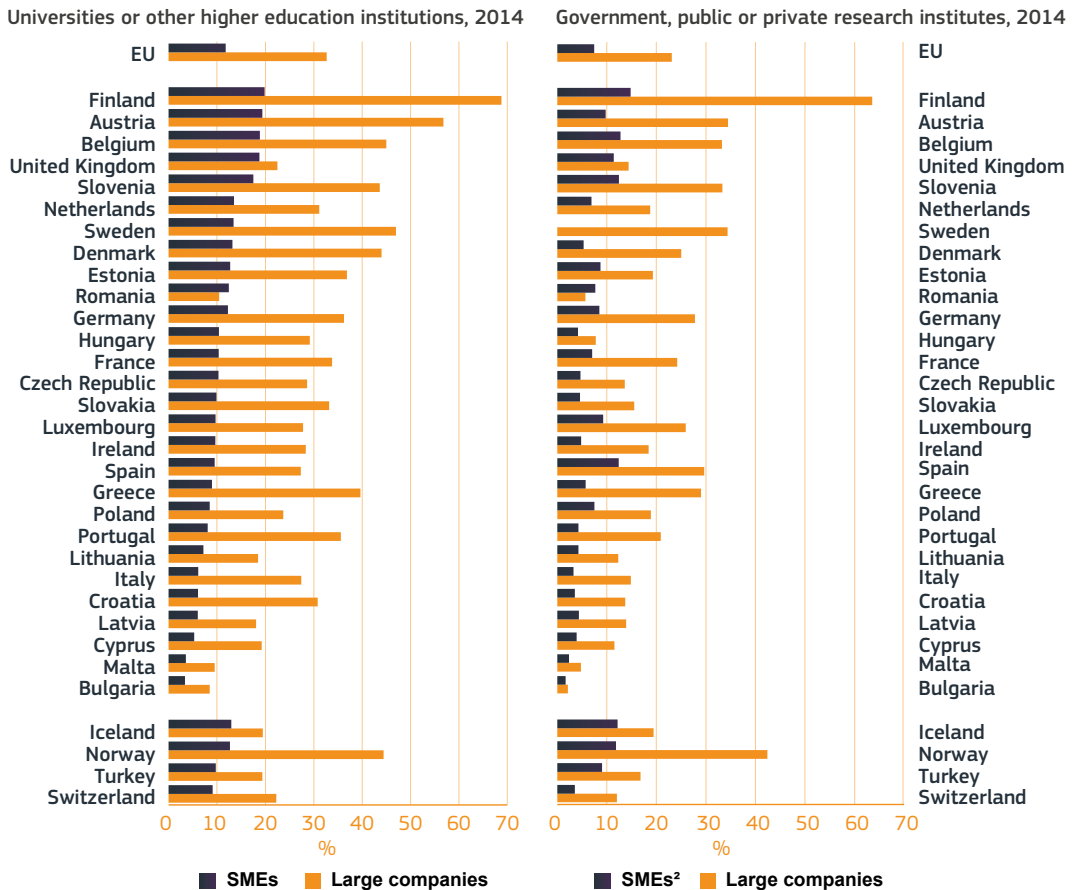
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*Although not clear-cut, a divide between the EU's core and periphery appears to be emerging when focusing on cooperation patterns with universities and higher education institutions, as well as with governments and public and private research institutions. This is also true for business cooperation with competitors or other enterprises in the same sector.*

Countries such as Finland, Belgium, Austria and the UK report the highest cooperation shares between SMEs and universities and higher education institutes, as well as government, public and private research institutions.

Many Eastern European countries also report relatively high cooperation levels, such as Slovenia, Estonia, Romania and Hungary. The bottom of the distribution is made up of a mix of Eastern and Southern European countries, with Malta and Bulgaria reporting the lowest values (see Figure I.4-B.4). A similar pattern can be observed when looking at the share of cooperation with competitors or other enterprises in the same sector, with some notable exceptions, such as Greece, which has a relatively high share of this kind of cooperation among SMEs, while Germany is at the bottom of the distribution (see Figure I.4-B.5).

**Figure I.4-B.4 % share of innovative enterprises<sup>1</sup> cooperating with:**

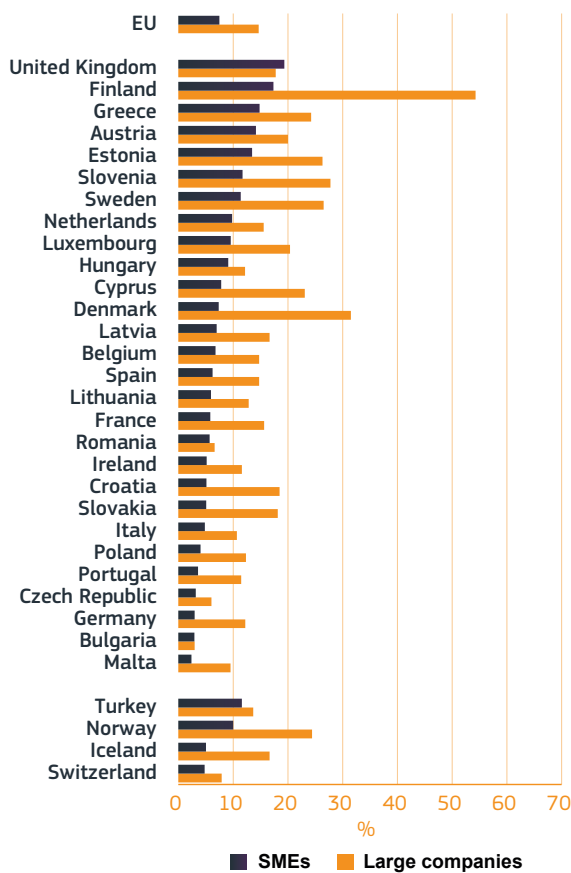


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat (CIS 2014)  
 Notes: <sup>1</sup>Product and/or process innovative enterprises, regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or ongoing innovation activities). <sup>2</sup>EU average does not include Sweden.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-b\\_figures/f\\_i\\_4-b\\_4.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-b_figures/f_i_4-b_4.xlsx)



**Figure I.4-B.5 % share of enterprises cooperating with:**

Competitors or other enterprises in the same sector, 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (CIS 2014)

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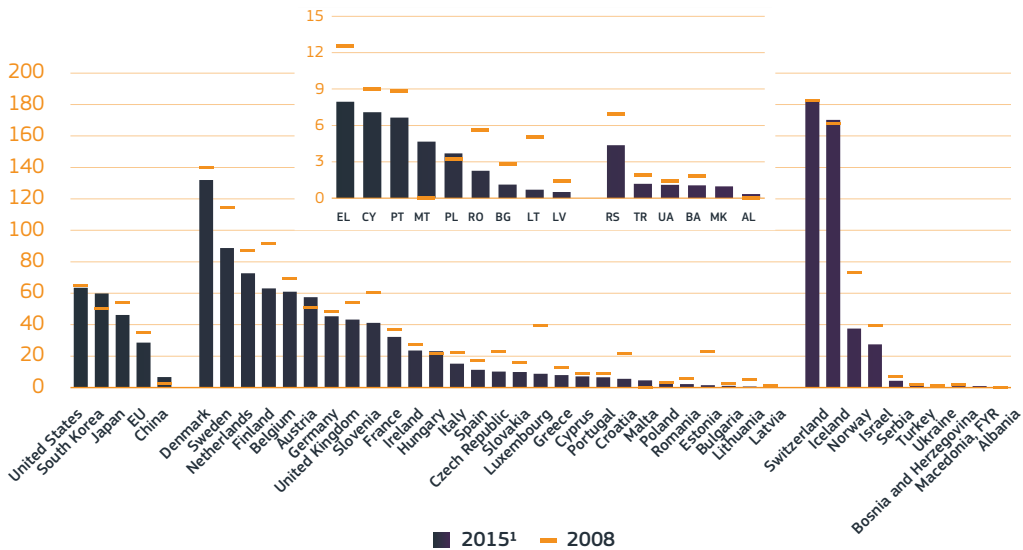
*The number of public-private co-publications has fallen slightly in the EU and continues to lag behind the United States, Japan and South Korea, although this aggregate value masks large differences across Member States, especially between countries in the EU's core and periphery.*

forming countries, with Denmark (132) and Sweden (88.7) at the top, and Latvia (0.5), Lithuania (0.7) and Bulgaria (1.1) at the bottom. As regards the Southern European countries, Italy is the best performing with 15.2 co-publications per million population, while Malta is the worst with 4.7<sup>16</sup>.

Figure I.4-B.6 depicts the number of public-private co-publications per million of population for the EU, its main competitors and associated countries. While for the EU as a whole the indicator fell between 2008 and 2015 (34.7 and 28.7 respectively), more variation can be observed when looking at the Member-State level. Overall, it can be seen that the EU is a long way behind the United States (63.4 in 2015), South Korea (59.9) and Japan (46.2). There is also a clear divide between Central and Northern, and Eastern and Southern European countries, with the former performing considerably better. The gap is striking when looking at the best-and-worst-per-

The drivers of these striking differences can be found in 'push' factors relating to the quality of the scientific research performed by universities and public research organisations as well as to the institutional environment of government and public scientific institutions. This includes governance arrangements and the incentive mechanisms in place to engage in this type of cooperation. However, 'pull' factors related to firms' scientific ability to interact with these institutions, and the existence of adequate framework conditions and public support to underpin stronger science-business cooperation can also play their part.

**Figure I.4-B.6 Public-private co-authored scientific publications per million population, 2008 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: EIS 2016, CWTS based on Web of Science database (March 2017 data), Eurostat, OECD  
 Note: <sup>1</sup>LV, AL: 2013; US, JP, CN, KR, IL, BA: 2014.

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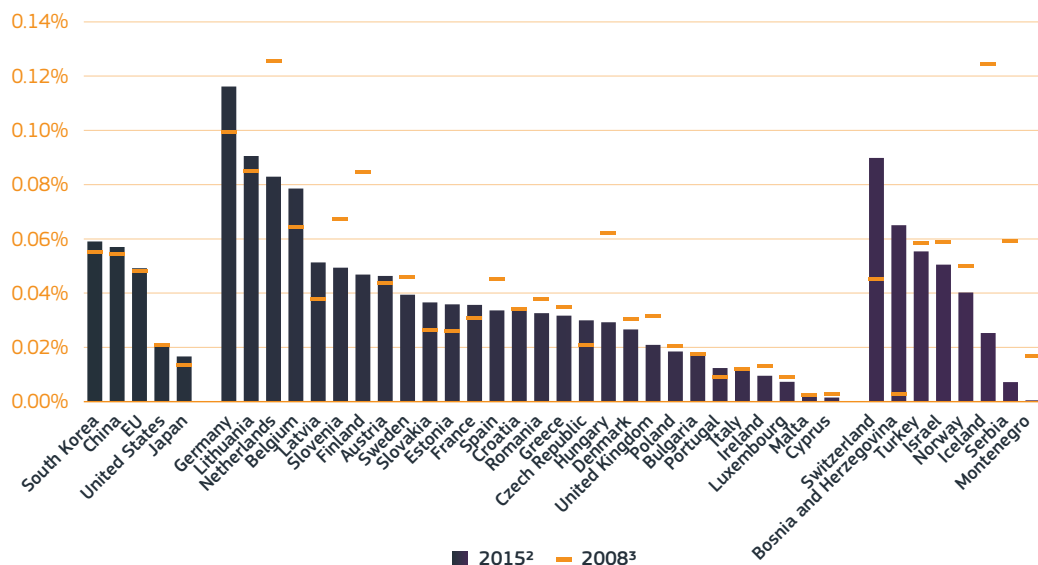
16 It must be noted that the analysis does not control for factors such as geography or the R&I system's critical mass.

**Public expenditure on R&D financed by business enterprises has risen slightly in the EU since 2008, but there is large heterogeneity among the Member States.**

Figure I.4-B.7 shows that while public expenditure on R&D financed by business enterprises as a percentage of GDP has slightly increased overall in the EU since 2008, several Member States report a significant fall in the value. Indeed, the Netherlands, Finland, Hungary and Slovenia report the most significant drops, while a lower but still significant reduction can also be seen in Spain, the United Kingdom, Sweden, Romania, Denmark, Ireland, Greece, Poland, Luxembourg, Cyprus and Bulgaria. Conversely, Germany reports the most significant increase, followed by Belgium, Latvia, Slovakia, Estonia, the Czech Republic, Lithuania, France, Portugal and Austria. Overall, Northern, Central and Eastern European countries have the highest share of public expenditure on R&D financed by business enterprises, although differ-

ences between Member States are significant and no clear geographic divide can be observed. Three country clusters can be identified, with the highest values in: (i) Germany, Lithuania, the Netherlands and Belgium ranging between a share of 0.12% and 0.08%, (ii) the middle range reporting shares between 0.05% for Latvia to 0.03% for Denmark, and finally the bottom cluster (iii) ranging between 0.02% for the United Kingdom and 0.002% for Cyprus. On an international scale, the EU outperforms the United States and Japan by far, while performing below the values reported by South Korea and China. For the associated countries, Switzerland and Bosnia and Herzegovina reported the highest values, although still below the values reported for Germany. Overall, while Figure I.4-B.7 shows that the EU is performing well on an international scale for public-private cooperation, the large differences between Member States reveal that there remains a lot of room for improvement to foster linkages between the public and private sectors in most Member States.

**Figure I.4-B.7 Public expenditure on R&D financed by business enterprise<sup>1</sup> as % of GDP, 2008 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Public expenditure on R&D financed by business enterprise does not include financing from abroad. <sup>2</sup>IL: 2013; FR, BA: 2014; EL, IS, RS: 2016. <sup>3</sup>DK, LU, NL, AT, SE, NO, RS: 2009; EL, ME: 2011, BA: 2012.

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### Open to the world

Much of the knowledge created in a country does not stem from within its borders. Greater openness to the world remains crucial to support stronger knowledge flows. It is no longer enough to cooperate with the closest neighbours. New forms of communication and transportation and the global networks being built around the world are creating opportunities for international exposure and more knowledge flows, having a positive effect on the development of a country's science base, its productivity and growth. This encompasses closer cooperation within the ERA and the rest of the world.

***Europe continues to be a leading pole in international scientific collaboration which has increased sharply worldwide.***

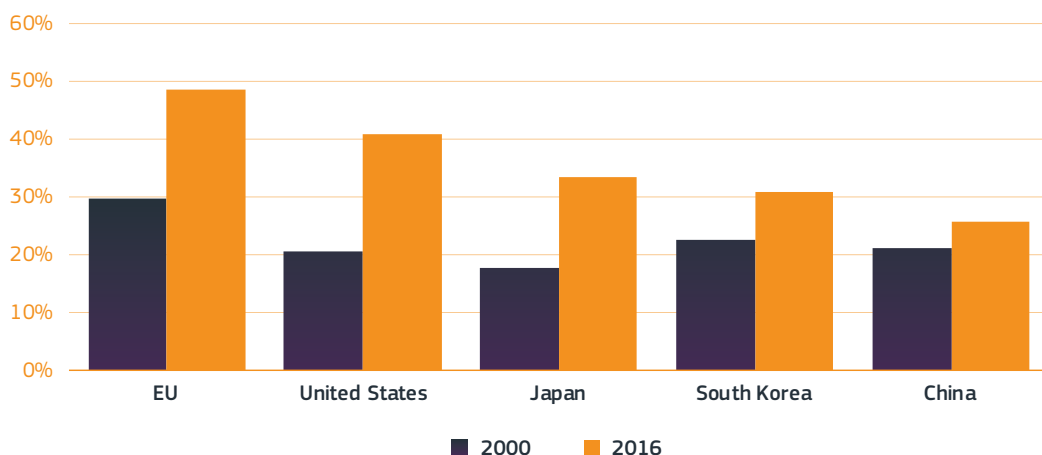
As reported in Figure I.4-B.8, the importance of international collaboration is visible for all countries, having risen significantly from 2000

to 2016. The EU experienced an extraordinary increase in its share of international scientific collaborations (including intra-EU publications) relative to its total publications, from 29.6% to 48.4%, while the rise was even higher in the United States and Japan, from 20.6 % to 40.9% and 17.5% to 33.4%, respectively. Interestingly, unlike all the other countries observed which report a considerable increase in the overall number of scientific publications, Japan is the only country where a fall can be seen, despite the significant increase in the number of international co-publications. a significant rise in international scientific co-publications can also observed in South Korea and China, from 22.5% to 30.8% and 21.1 % to 25.6%, respectively, paired with considerable increases in the overall number of scientific publications. While the trend in greater international collaboration is a natural consequence of globalisation, the EU, which actively supports international cooperation in research and science via various initiatives and funding schemes, remains a scientific pole for international cooperation<sup>17</sup>.

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17 European Commission (2016a).

**Figure I.4-B.8 International scientific co-publications as % of total scientific publications, 2000 and 2016**



	2000					2016				
	EU <sup>1</sup>	United States	Japan	South Korea	China	EU <sup>1</sup>	United States	Japan	South Korea	China
International scientific co-publications	91,186	54,624	12,918	3,072	5,761	227,471	147,412	23,295	16,156	70,369
Total scientific publications	308,406	265,723	73,686	13,680	27,255	469,826	360,283	69,723	52,509	274,886
% share of international co-publications	29.6	20.6	17.5	22.5	21.1	48.4	40.9	33.4	30.8	25.6
International co-publication growth <sup>2</sup> (%)						60	63	45	81	92
Total scientific publications growth <sup>2</sup> (%)						34	26	-6	74	90

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CWTS based on Web of Science database

Note: <sup>1</sup>EU average includes intra-EU collaborations. <sup>2</sup>The growth formula used is  $(y_{\#2016} - y_{\#2000}) / y_{\#2000} * 100$ .

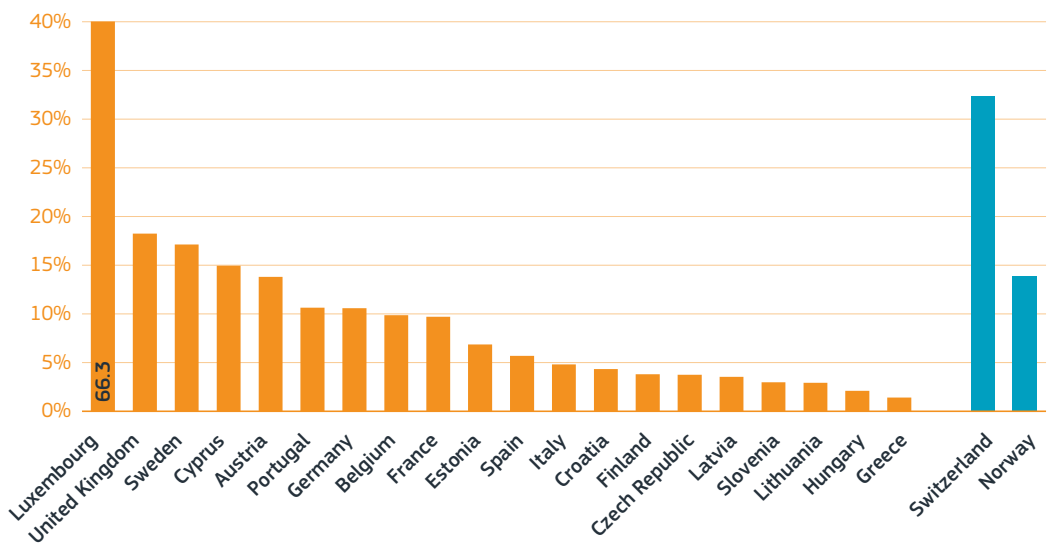
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*Foreign-born human resources working in science and technology are crucial for European research as they allow international knowledge to flow across countries.*

The number of incoming researchers and scientists countries can attract is another relevant source of knowledge. Openness and an attractive scientific environment built on quality public research, competitive wages and solid

career prospects for researchers are essential to attract top scientists from abroad. Figure 1.4-B.9 reveals disparities across the Member States, with countries such as Luxembourg, the UK, Sweden, Cyprus and Austria, as well as Switzerland and Norway, where foreign-born HRST form an important part of the workforce, and others such as Hungary, Greece, Slovenia, Lithuania and Latvia which report a very low share of researchers from abroad<sup>18</sup>.

**Figure 1.4-B.9 Foreign-born human resources in science and technology core (HRSTC)<sup>1</sup> as % of total HRSTC, 2014**



Science, Research and Innovation performance of the EU 2018  
 Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat (LFS survey, Migration and labour market module, 2014)  
 Note: <sup>1</sup>HRSTC: Persons with tertiary education (ISCED) and employed in science and technology.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-b\\_figures/f\\_i\\_4-b\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-b_figures/f_i_4-b_9.xlsx)

18 HRSTC are HRST who fulfil the HRST criteria as well as the criteria of being employed in science and technology occupations.

*Europe and the United States lead in international technological cooperation, proxied by the share of patents with foreign co-inventors in the total number of patents<sup>19</sup>, although large differences can be observed across the Member States.*

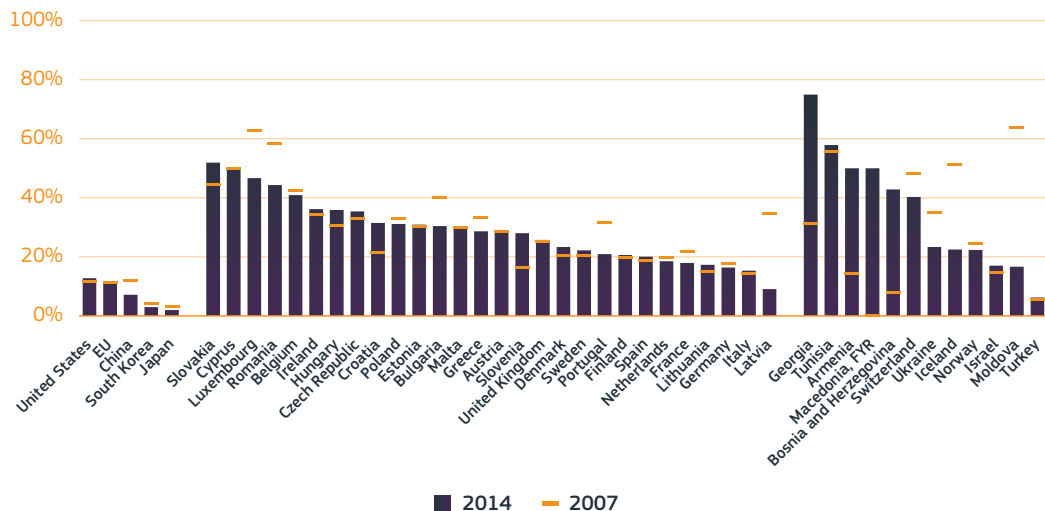
While for the EU aggregate, the share of patents filed with foreign co-inventors remained roughly stable from 2007 to 2014, large variations can be observed for most Member States. Eastern European countries have the highest share of patents filed with foreign co-inventors, with Slovakia, Cyprus, Luxembourg and Romania reporting the highest values. Unsurprisingly, large countries such as Germany, Italy, France and the Netherlands are at the bottom of the distribution, given that the necessity to cooperate is lower than in small countries. It is therefore more interesting to compare countries of similar size (in population). For example, while Romania has a share

of 44.3 % of patents with foreign co-inventors, the Netherlands has 18.5 %, although the countries are of a similar size. Belgium, Hungary and the Czech Republic significantly outperform Sweden and Greece whilst lagging behind values found, for example, in Tunisia. The most striking values can be found for Latvia and Lithuania with particularly low shares of patents filed with foreign co-inventors, especially when compared to associated countries of similar size, such as Georgia. Last but not least, cooperation within the EU is of particular importance for Member States, given that the shares of patents with foreign co-inventors are significantly higher for each Member State, with the exception of Latvia, than those reported for the EU as a whole<sup>20</sup>. Overall, no clear geographic pattern emerges, while the EU as a whole is almost on a par with the United States and performs significantly better than China, Japan and South Korea (Figure I.4-B.10).

19 It should be noted that while this indicator can provide valuable information on international technological cooperation, the numbers should be handled with care, taking into account the small amounts in some cases, notably for small countries, which make values volatile.

20 The EU value is excluding intra-EU cooperation.

**Figure I.4-B.10** Share (%) of WIPO-PCT<sup>1</sup> patents with foreign co-inventor(s) in total number of patents<sup>2</sup>, 2007 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD

Notes: <sup>1</sup>Patent Cooperation Treaty (PCT) patents, at international phase designating the European Patent Office. <sup>2</sup>Full counting method used.

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**Foreign direct investment and foreign business research investment**

*In addition to scientific and technological international cooperation, knowledge also flows via FDIs.*

If a company decides to invest into or transfer part of its R&D production to a new location, part of its knowledge will be transferred with it. While knowledge transfer is linked to most forms of foreign investment, the most tangible is via inward BERD (business enterprise research and development expenditure) flows.

*Inward BERD<sup>21</sup> (into the EU) shows large variations between Member States, accompanied by a positive general outlook for the EU as a whole.*

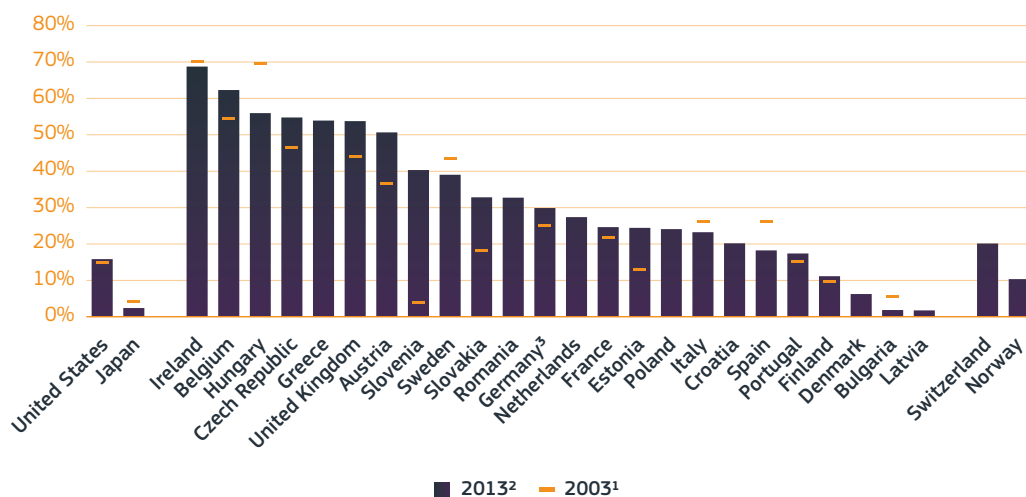
centage of total BERD) has increased for most countries, Ireland, Hungary, Sweden, Italy, Bulgaria and Spain, as well as Japan show a contraction of the share of such investments. Overall, large disparities can be noticed, with Ireland, Belgium, Hungary, the Czech Republic Greece and the UK attracting proportionately the highest shares of BERD from outside and the lowest shares being attracted by Bulgaria, Latvia, Denmark and Finland. Slovenia, Slovakia, Estonia and Austria show a remarkably high increase in the share of BERD inward flows. For a large set of Eastern and Southern European countries BERD inflows as a percentage of GDP, however, continue to be low.

Figure I.4-B.11 shows that from 2003 to 2013, while the inward flow of BERD (as a per-

21 R&D expenditure by foreign-owned firms.



**Figure I.4-B.11 Inward BERD (R&D expenditure of foreign-owned firms) as % of business expenditure on R&D, 2003 and 2013**



2013		US	JP	IE	BE	HU	CZ	EL	UK	AT	SI	SE	SK	RO	DE
Inward BERD															
% of BERD		15.9	2.4	68.8	62.3	56.0	54.7	53.9	53.8	50.6	40.4	39.0	32.9	32.7	29.9
% of GDP		0.31	0.06	1.41	1.07	0.54	0.57	0.13	0.57	1.06	0.53	0.89	0.13	0.04	0.58

2013		NL	FR	EE	PL	IT	HR	ES	PT	FI	DK	BG	LV	CH	NO
Inward BERD															
% of BERD		27.4	24.6	24.4	24.1	23.2	20.2	18.3	17.4	11.1	6.3	1.9	1.8	20.1	10.3
% of GDP		0.31	0.41	0.14	0.09	0.17	0.08	0.12	0.10	0.29	0.11	0.01	0.01	0.41	0.09

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: DG Research and Innovation (BERD flows study)

Notes: <sup>1</sup>LV, HU, RO: 2004; NO: 2005; PL: 2007; NL, CH: 2008; EL: 2009. <sup>2</sup>LV: 2006; IE, DK, PT: 2007; EL, FI: 2011; CH, JP: 2012; CZ: 2014. <sup>3</sup>DE (2013): R&D expenditure on services is not included.

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## Trade

Finally, knowledge can be transferred via trade, especially in the form of exports of high-tech and medium-high-tech goods (MHT) and services. However, to adequately assess how much of a country's knowledge has been transferred, it is important to compute the amount of knowledge (proxied here by the value added) that was added by the country itself versus how much knowledge stemmed from foreign contributions. A high share of foreign value added would indicate how much knowledge has flown into the country, while a high share of domestic value added paired with high shares of exports would indicate an outflow of knowledge, which means both can be evaluated positively. Figure I.4-B.12 shows the evolution of foreign value added in high-tech and MHT exports between 2000 and 2011 as a percentage of total exports, as well as now-cast values for 2014.

***The importance of foreign created value added in high-tech and MHT exports is crucial in Europe, notably for several Central, Eastern and Southern European countries, for which it is a particularly important source of technological inflows.***

The foreign value added of gross exports in high-tech and MHT sectors, presented in Figure I.4-B.12, shows that China (with 43.6% in 2014) and South Korea (38.4%), as well as the Eastern European countries (59.7% for Hungary and 59.3% for Slovakia), report high shares of foreign value added, while also enjoying both high shares of high-tech and medium high-tech exports (see figure I.4-C.4 for Hungary and Slovakia). In general, an increase in foreign value added in high-tech and MHT goods can be observed for most countries, with the exception of e.g. China, several the Eastern European countries, Greece and to a lesser extent Spain. For highly exporting countries such as China and South Korea, as well as Eastern European countries, around half of the value was added to the

goods before entering the country, indicating a large inflow of knowledge. This contrasts with the considerably lower, share of foreign value added in Germany, Denmark, France, the UK, Austria and Sweden, which are thereby exporting their knowledge. China has decreased its foreign value added considerably, which might suggest that it increased its in-house expertise over the past decade and also its production.

This chapter has aimed at analysing the evolution of knowledge flows in and out of the EU. The objective has been to provide nuances to the discussion on why productivity is slowing down and to see whether trends in knowledge flows contribute to the slowdown of innovation diffusion. In general, the flow of knowledge is less smooth in the EU than its international counterparts, and notably the United States.

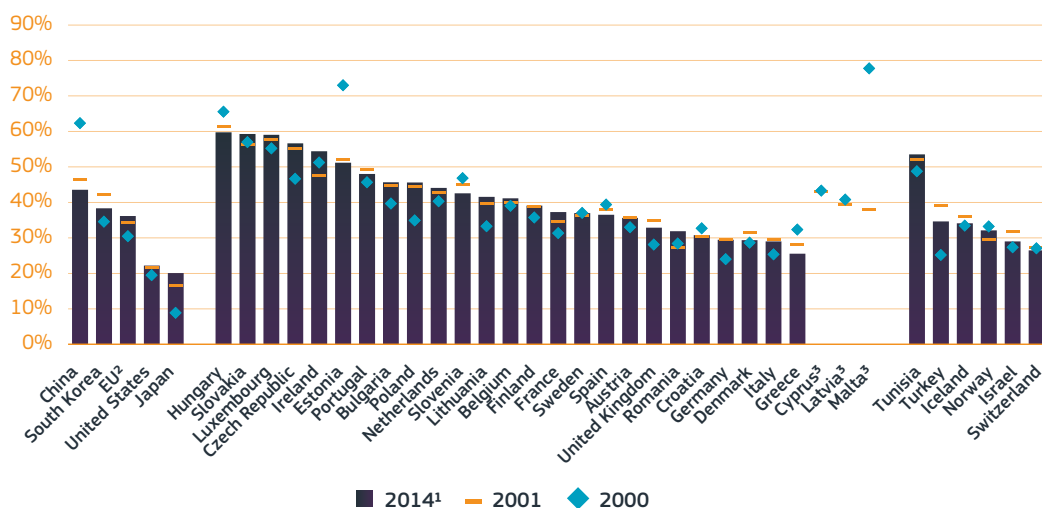
A lack of *open innovation* can be observed in the EU, as measured by the knowledge transferred between the public and the private sector in the form of public-private co-publications and the share of public R&D expenditure funded by the private sector. The EU lags considerably behind the United States, South Korea and Japan, with no significant evolution in recent years. More positive patterns emerge when the focus is on the *openness of the EU to the world*. As a consequence of globalisation, international scientific collaboration has increased worldwide. The EU continues to act as scientific pole and has been increasing its shares since the 2000s, although during that period the United States experienced a significantly higher rise in international collaborations. This might indicate that the EU is not taking enough advantage of international dynamics. Similarly, it can be observed that, when looking at output as proxied by patents with foreign co-inventors, the EU is not yet taking sufficient advantage of international advances, and still lags behind the United States in spite of a positive trend to close the gap. Overall, while the EU has

strong research links with international peers, it is not fully reaping the potential benefits of these links for innovation.

Furthermore, a mixed picture emerges when examining individual Member States. A divide between the core and the periphery can be traced across the Open Science, Open Innovation and Open to the World dimensions, with Eastern European countries standing out and showing important progress. In recent

years, discussions about an innovation divide within the EU have emerged<sup>22</sup>, with Central and Northern European countries traditionally displaying the best innovation performance (Sweden, Denmark, the Netherlands, the UK and Germany), and the more modest innovators (such as Latvia, Poland, Croatia, Bulgaria and Romania<sup>23</sup>) following. These trends are mirrored when knowledge flows are analysed, although it is also evident that considerable efforts have been made.

**Figure I.4-B.12 Foreign value-added share (%) of gross exports in high-tech and medium-high-tech sectors, 2000, 2011 and 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: OECD (Trade in Value Added (TiVA))

Notes: <sup>1</sup>The nowcast approach was used for 2014. <sup>2</sup>EU for 2014 was estimated from the available data for Member States and does not include CY, LV and MT. <sup>3</sup>CT, LV, MT: Data are not available for 2014.

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22 Veugelers, R. (2016). The European Union's growing innovation divide. Bruegel, Bruegel policy contribution.

23 European Commission (2017). European Innovation Scoreboard 2017.

## CHAPTER I.4-C: INNOVATION OUTPUTS

### Innovation outputs

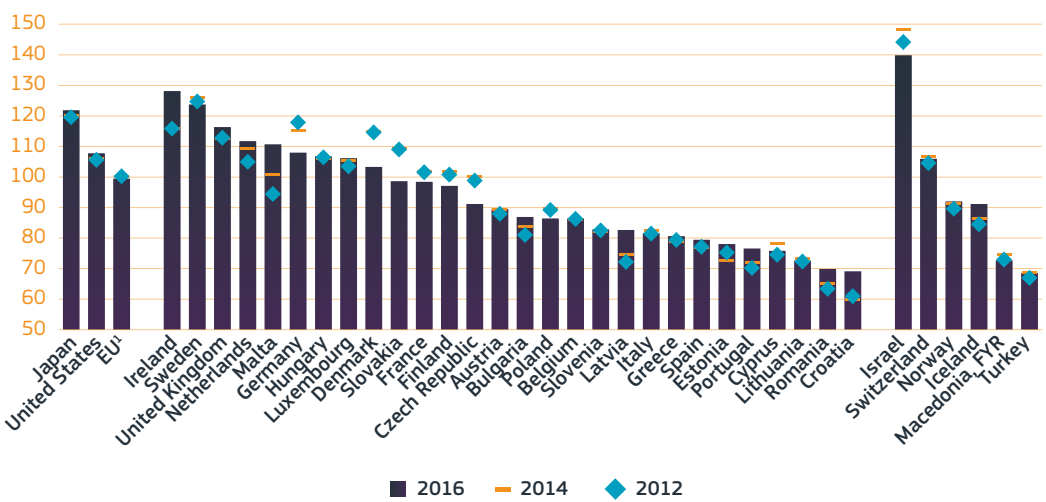
*As regards key innovation outputs, progress in the EU has been slow in recent years. According to the Innovation Output Indicator, the EU now performs slightly below the United States and is clearly outperformed by Japan. There is a general North-South and West-East gap in innovation output performance, with some notable exceptions, such as Malta and Hungary. The gap between top and middle-group performers has widened in recent years.*

According to the Commission's Innovation Output indicator (IOI)<sup>24</sup>, which is based on four components (patents, employment in knowledge-intensive activities, trade in knowledge-based goods and services, innovativeness of high-growth enterprises) and five sub-indicators, the

EU has been outperformed by the US and Japan, both of which have slightly improved their performance since 2012, while the EU's performance stagnated from 2012 to 2016.

In terms of differences across Member States, Ireland is the best EU performer, followed by Sweden, the UK and the Netherlands. A low level of innovation outputs is found in Romania and Croatia. However, the two countries have progressed well in recent years in their upwards convergence, together with Malta, the Netherlands and Ireland while, since 2012, innovation outputs have declined in Germany, Denmark, Slovakia, Finland and the Czech Republic. The decline in performance of some of these Member States is mainly caused by a lower share of employment in fast-growing enterprises in innovative sectors, while performance in other indicators has been more stable.

**Figure I.4-C.1 Innovation output indicator (EU2011 = 100), 2012, 2014 and 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD, DG JRC

Note: <sup>1</sup>EU: Two sets of values are available: values for worldwide comparison and values for European comparison. The values for worldwide comparison are shown on the graph. The value for European comparison for 2014 is 99.6.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_1.xlsx)

24 For further details on data sources and how the indicator was calculated, see Vertesy (2017).

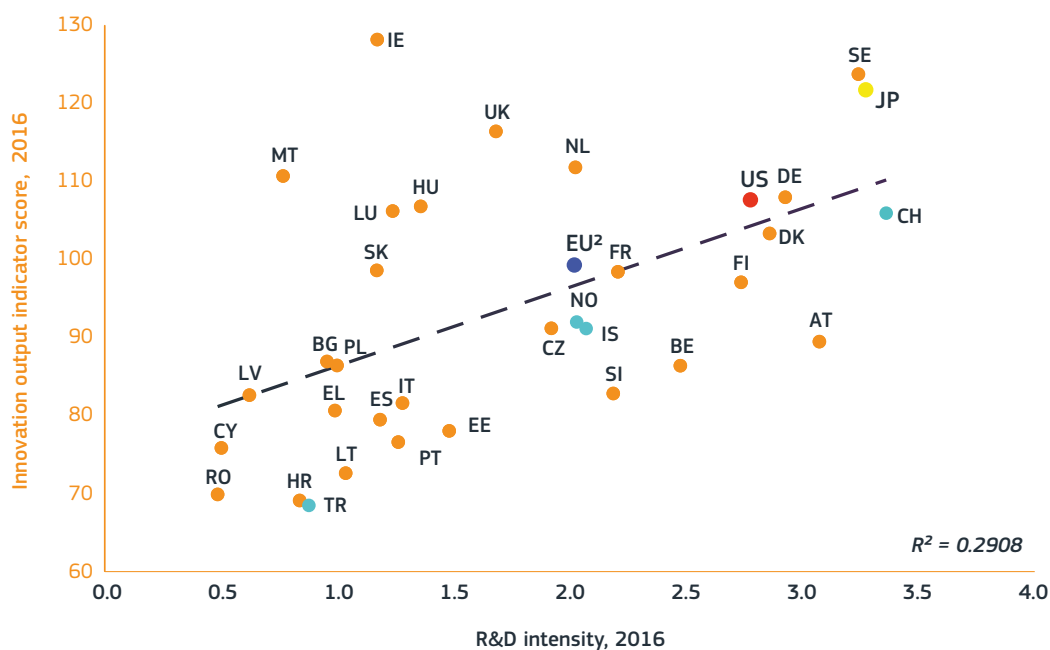
*Innovation outputs are broadly linked to investment in R&D and correlated with GDP per capita (productivity) and economic outcomes.*

Figure I.4-C.2 below shows the correlation between the IOI and R&D investment. In general, there is a good correlation and countries with a high level of R&D investment also perform well on innovation outputs. Countries performing well on innovation outputs compared to their effective level of R&D spending include Ireland, Luxembourg and Cyprus. Countries where innovation outputs do not match spending levels include Denmark, Slovenia, Croatia, Lithuania and Greece. It should be noted that this direct correlation does

not account for time lags or spillover effects and economic structures. Strong performance differences between Member States (see Figure I.4-C.2) imply there is room for improvement, including through adequate framework conditions.

As regards the different components of the IOI, Sweden, Finland and Germany perform best in PCT patents, as shown in the section on patents below. Many Central and Eastern European countries perform poorly in this field, partly as a result of a lack of global players in patent-intensive manufacturing sectors. The EU performs at a similar level as the United States, but is clearly outperformed by Japan.

**Figure I.4-C.2 Innovation output indicator score, 2016 and R&D intensity, 2016<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, DG JRC

Notes: <sup>1</sup>BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK, CH, TR, US, JP: 2015. <sup>2</sup>EU: for the innovation output Indicator two sets of values are available: values for worldwide comparison and values for European comparison. The values for worldwide comparison are shown on the graph. The value for European comparison for 2016 is 99.6.

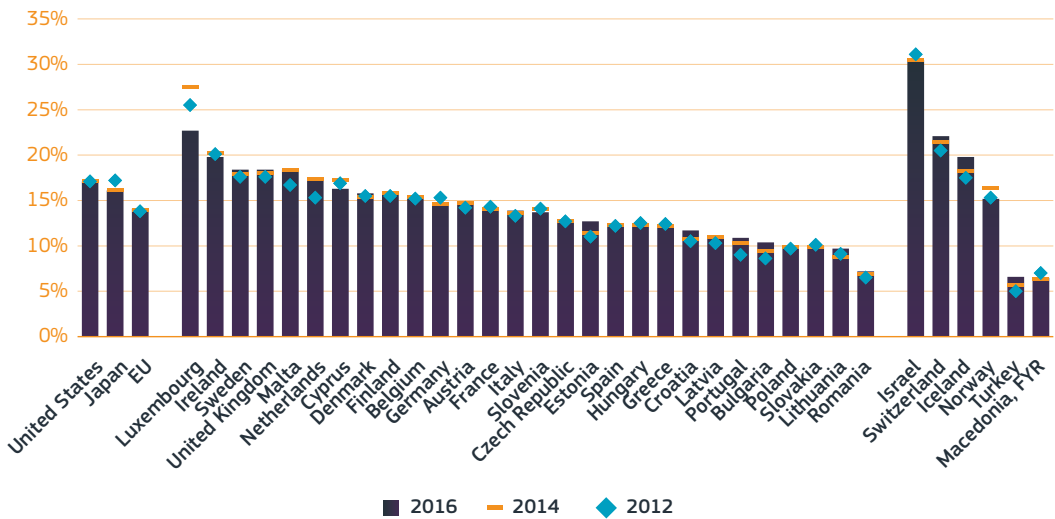
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As concerns employment in knowledge-intensive activities, the United States and Japan outperform the EU. Economies with strong financial services and software sectors, such as Luxembourg and Ireland, show the best results in the EU.

and Ireland (financial services, software) perform best, while Eastern European countries such as Romania and Lithuania are among the worst performers. Both the United States and Japan outperform the EU. Performance reflects a North-South and West-East innovation divide in Europe, although in smaller southern Member States, such as Malta and Cyprus, their efforts to focus on high-value-added services are making a difference to overcome this pattern.

When it comes to employment in knowledge-intensive activities, the second component of the indicator and an important economic outcome of innovation, Luxembourg (financial services)

**Figure I.4-C.3** Employment in knowledge-intensive activities in business industries as % of total employment, 2012, 2014 and 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, DG JRC

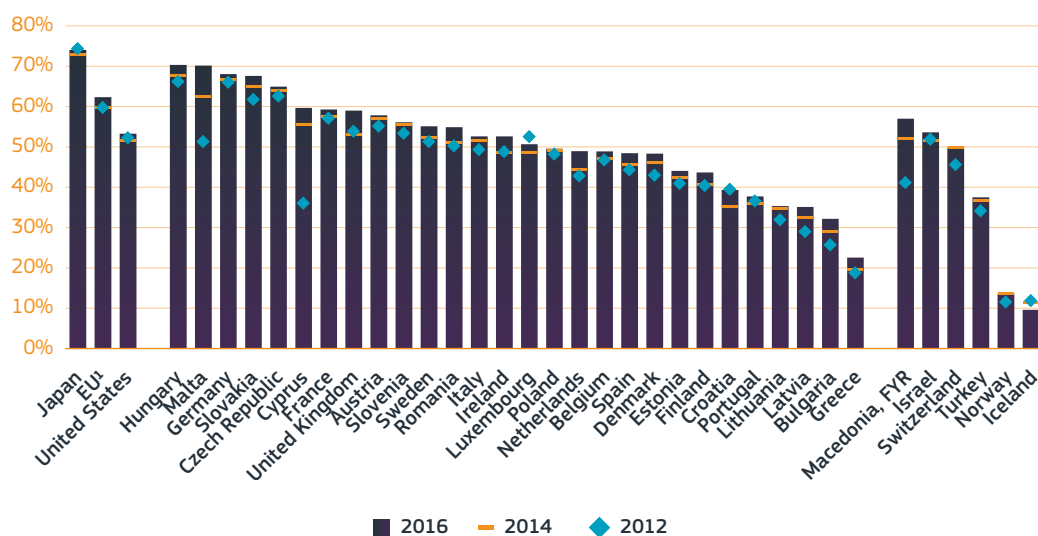
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*Apart from Germany and Malta, Central and Eastern European countries show the best performance in medium- and high-tech exports, mainly thanks to strong car exports.*

As regards the export share of medium- and high-tech (MHT) products, Germany and some Eastern European countries (notably Hunga-

ry, Slovakia and the Czech Republic) perform well as a result of high exports of cars and machinery. In addition, Malta is a strong performer (although from a small export base and hence with fluctuating results), thanks to semiconductor exports. The EU has a higher share of MHT exports than the United States, but clearly lags behind Japan.

**Figure I.4-C.4 Exports of medium- and high-technology products as % of total product exports, 2012, 2014 and 2016**



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: DG JRC (based on Eurostat and UN data)

Note: <sup>1</sup>Two sets of values are available: values for worldwide comparison and values for European comparison. The values for worldwide comparison are shown on the graph. The value for European comparison for 2016 is 57.0.

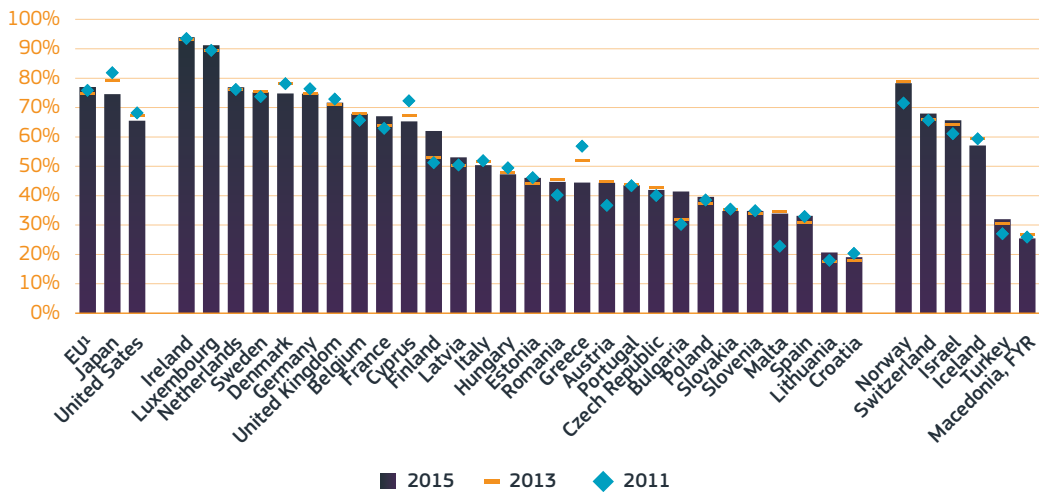
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_4.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_4.xlsx)

*The EU has a higher share of knowledge-intensive service exports than the United States and a similar share to Japan. Countries with a high share of financial services and ICT services in their economy show the best results in the EU.*

take the lead in the EU, as a result of high shares of financial and ICT services exports in these countries. Countries with a large tourism industry (tourism-related services are not classified as knowledge intensive), such as Spain and Croatia, tend to perform poorly in this indicator.

When it comes to knowledge-intensive service exports, Ireland and Luxembourg

**Figure I.4-C.5 Knowledge-intensive services exports as % of total services exports, 2011, 2013 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: DG JRC (based on Eurostat and UN data)

Note: <sup>1</sup>Two sets of values are available: values for worldwide comparison and values for European comparison. The values for worldwide comparison are shown on the graph. The value for European comparison for 2015 is 69.3.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_5.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_5.xlsx)



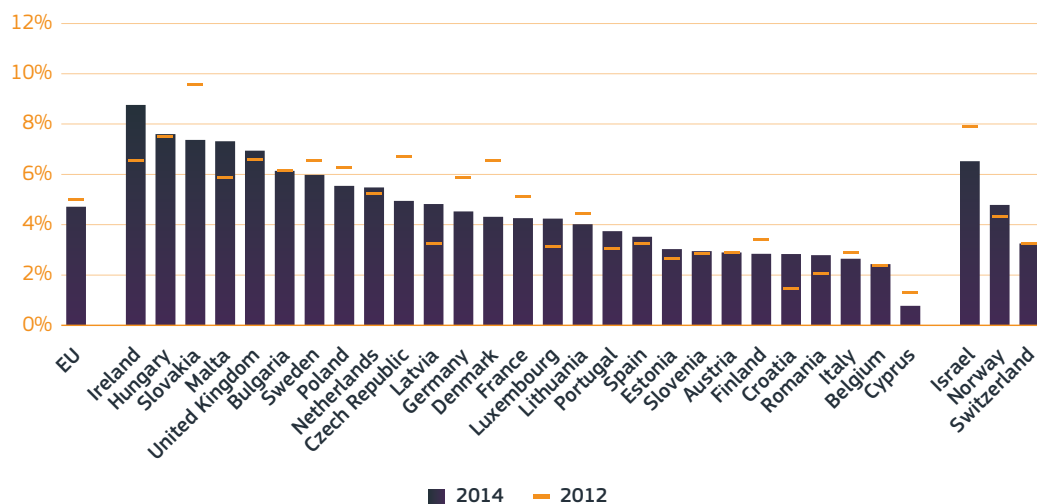
*There is a more mixed pattern regarding the share of employment in fast-growing enterprises in innovative sectors, with a good performance registered in both Eastern and Western Europe.*

The final component of the IOI relates to the share of employment in fast-growing enterprises in innovative sectors. Here, Ireland is in the lead, followed by Hungary. In recent years, these two countries have experienced fast employment growth in innovative sectors of the economy. However, Slovakia, the leader in 2012, has fallen back since then. Cyprus, which is still affected by a recession in the reference period, is the worst performer in this indica-

tor, followed by Belgium and Italy. Economic growth, and related employment growth, have been slow in recent years in these countries – reflected in a low share of fast-growing companies measured by employment.

The European Innovation Scoreboard (EIS) presents another, yet larger, composite index on innovation, based on 27 indicators. All five components of the Innovation Output Indicator are also indicators of the EIS. The 2017 edition of the IUS shows Sweden, Denmark, Finland, the Netherlands, the UK and Germany as innovation leaders in Europe, while Romania and Bulgaria are in the lowest category of modest innovators.

**Figure I.4-C.6** Employment in fast-growing enterprises in the top 50% most innovative sectors as % of total employment, 2012 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, DG JRC

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_6.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_6.xlsx)

**Technological and non-technological outputs**

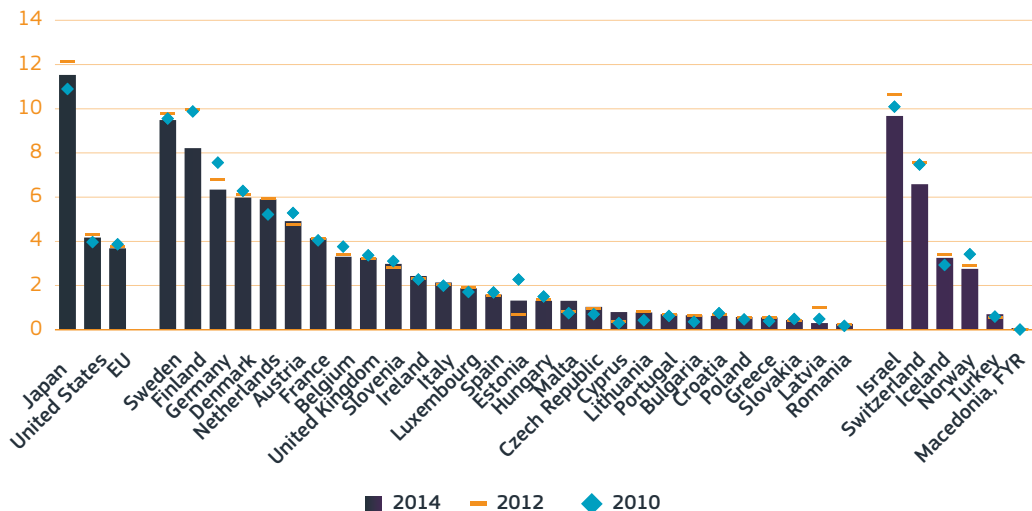
*In relative terms, the EU performs on a similar level in international patent applications as the United States, but is outperformed by Japan and South Korea. Technological performance varies widely across EU Member States, reflecting a persistent innovation divide.*

As concerns international (PCT) patent applications, the EU performs at a similar level as the United States when patents are related to GDP. However, on a per-capita basis, the United States outperforms the EU. Both Japan and South Korea clearly outperform the EU on both measures. Patents are a standard component of composite indicators on innovation, mainly used to proxy technological output. Structural differences in economies are an important determinant of performance as regards patent applications. Patent propensity is linked, amongst others, to the share of manufacturing in value

added (manufacturing companies tend to patent more than service-sector companies), to the high-tech orientation of the manufacturing sector (higher patent activity in the high-tech sector), to the share of ICT services (the software industry is patent intensive), and to the enterprise size distribution in a country (larger enterprises tend to have a higher patent propensity). Patenting is also linked to the location of a company's headquarters as patenting tends to be carried out in the headquarter country.

Innovation leaders, such as Finland, Germany and Sweden, perform strongly in patent applications, while moderate and modest innovators, such as Lithuania, Malta and Romania show low levels of patenting, especially as regards international (PCT) patents. In order to catch up with the patenting level of competitors it will be important to reduce the innovation divide in Europe by increasing patent propensity in low-performing Member States.

**Figure I.4-C.7 PCT patent applications<sup>1</sup> per billion GDP (in PPSE), 2010, 2012 and 2014**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, DG JRC

Note: <sup>1</sup>Patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO). Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

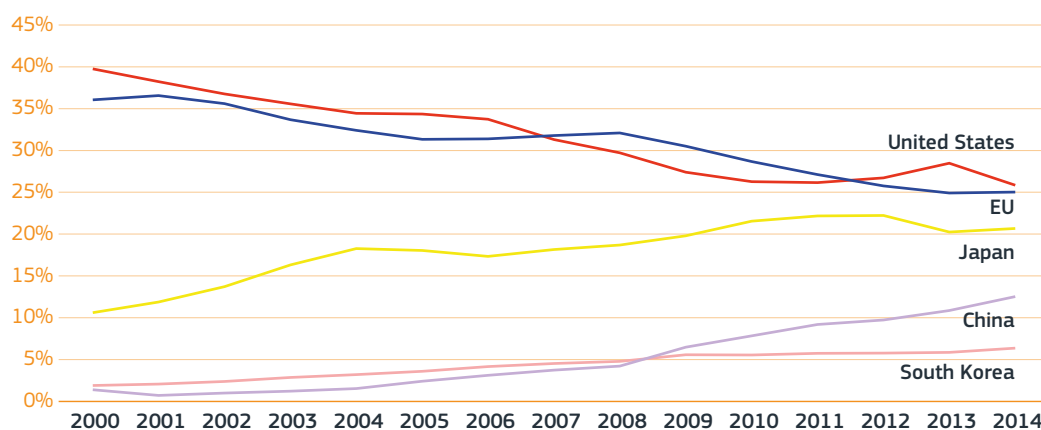
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_7.xlsx)

*While Europe's share in international patent applications is declining, Asian countries, notably China, are catching up.*

In many European countries, the number of international and national patent applications has declined recently, while patenting has been

expanding quickly in East Asian countries. As a result, these countries, especially China, are catching up in world patent shares, while Europe's share is falling. The United States' share, which has long been in decline, stabilised in recent years before falling again in 2014.

**Figure I.4-C.8** World share (%) of PCT patent applications<sup>1</sup>, 2000–2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD

Note: <sup>1</sup>Patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO).

Patent counts are based on the priority date, the inventor's country of residence and fractional counts.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_8.xlsx)

Europe is fairly efficient in translating its relatively low business R&D expenditure into technological outputs, especially compared to the United States, although it is outperformed by Japan.

As a whole, the EU and most of its innovation leaders perform relatively well as regards transforming business R&D expenditure into

technological outputs, such as patent applications. The Netherlands stands out in this context with a particularly good performance, while Sweden and Finland also perform well. On the other hand, the EU is outperformed by Japan, which shows a high patent intensity, even when compared to its high level of business expenditure on R&D.

Figure I.4-C.9 Patent applications per billion GDP (PPS€), 2014 and business R&D intensity, 2013



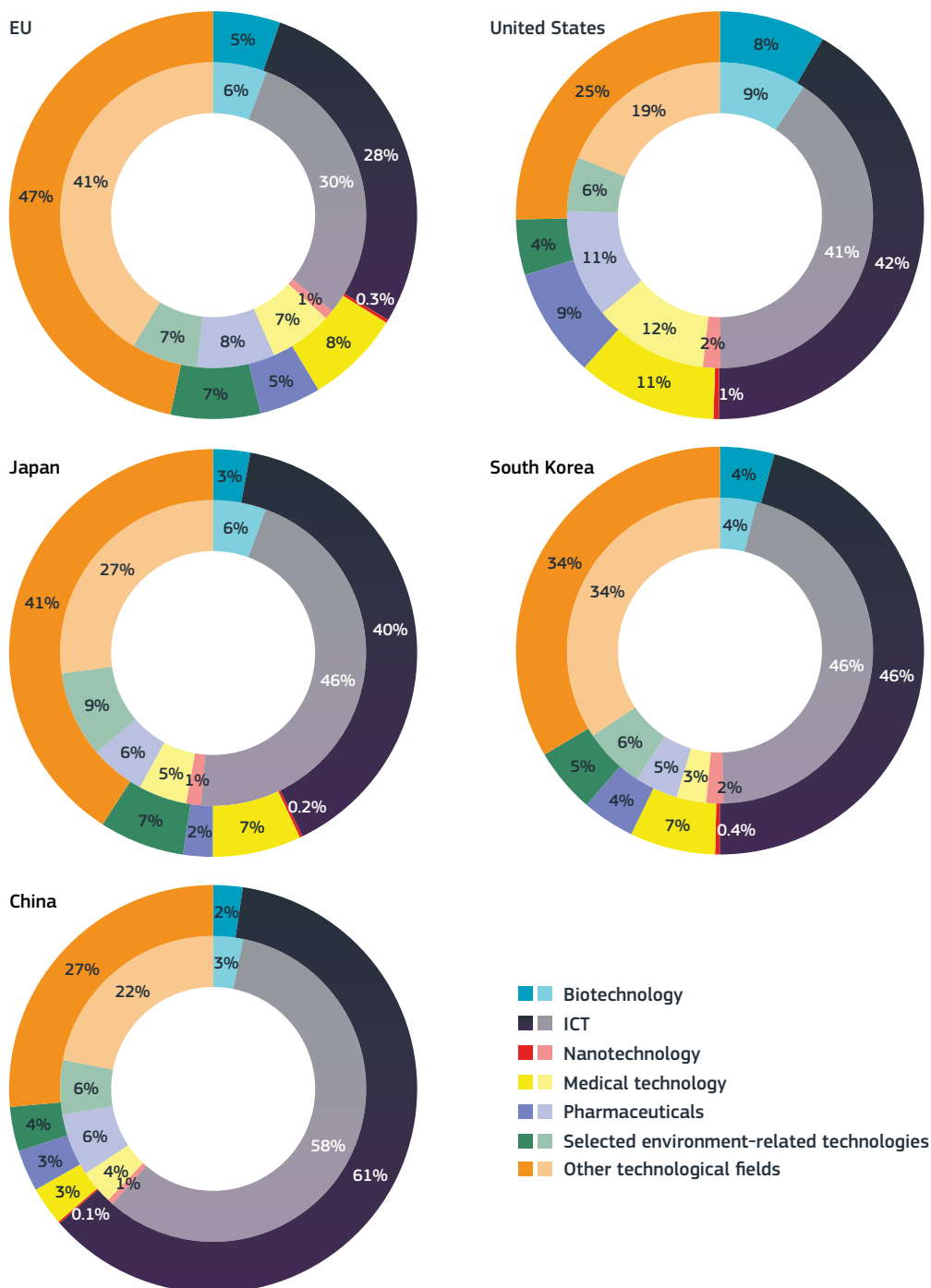
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat, OECD, UNESCO (UIS database)  
 Note: <sup>1</sup>CH: 2012; TN: 2014.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_9.xlsx)

The EU is technologically less specialised than the United States, Japan, South Korea and China. While Japan, South Korea and especially China have strengths in ICT, in addition the United States is strong in bio- and medical technology and in pharmaceuticals.

Patent specialisation patterns differ between countries and change over time. The comparison between 2005 and 2013 (see Figure I.4-C.10) shows a lower share of EU patents in the field of ICT compared to

competitors, and that the gap with some countries has increased since 2005. The data also show the growing importance of other technological fields and of environmental technologies, where Europe has relative strengths. The United States performs particularly well in pharmaceuticals, medical technology and ICT. Japan and South Korea have relative strengths in ICT and environmental technologies. China has a strong and growing specialisation in ICT. In general, the EU is less specialised than key competitors in fields that have a high patent propensity, notably ICT.

**Figure I.4-C.10** Share of patent applications (WIPO-PCT) by technology fields, 2014 (exterior) versus 2005 (interior)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD

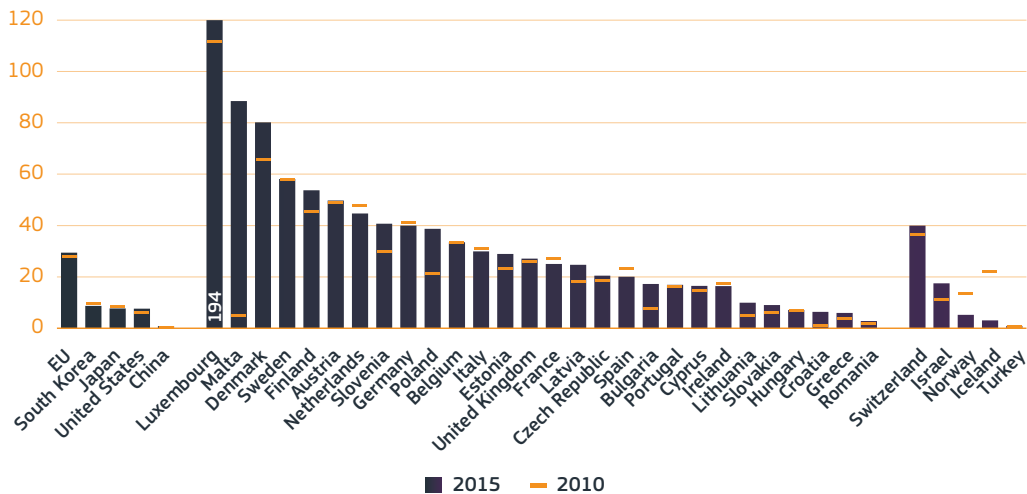
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_10.xlsx)

*With reference to community design applications, performance patterns reflect factors outside R&I. It appears easier for Europe to advance in non-technological outputs than in more traditional innovation outputs, such as patents, as evidenced by the good performance of smaller Member States and Central and Eastern European countries.*

Performance in IP areas such as community designs (see figure below) and community trademarks is influenced less by the quality of the innovation system, than that related to patents, as designs relate more to products' aesthetic features, while trademarks are linked to marketing. This is connected with the fact that designs are less technology-oriented, costs are lower and time lags shorter. Differences in taxation and regulation also seem to play a role, as evidenced by the strong performance of very small

Member States (such as Luxembourg and Malta), reflecting the attractive framework conditions in these countries<sup>25</sup>. Countries performing traditionally well in innovation, like Sweden, Denmark and Finland, also perform well in IP outputs such as community designs. Some Eastern European countries, such as Slovenia, Poland and Estonia, rank much better in this area than in patents, with high growth rates in recent years, partially reflecting initial reforms in incentive systems and framework conditions. However, other EU countries performing poorly, in general, on innovation, tend to be less active and innovative in community designs. Performance patterns in community trademarks are similar to those shown for community designs and are also affected by factors outside the direct innovation policy umbrella, such as differences in taxation and regulation, as evidenced by the strong performance of very small Member States.

**Figure I.4-C.11 Community design<sup>1</sup> applications to the EU Intellectual Property Office (EUIPO) per million population, 2010 and 2015**



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat  
 Note: <sup>1</sup>A registered community design is an exclusive right that covers the external appearance of a product or part of it.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_11.xlsx)

25 However, these tax incentives can be used in aggressive tax planning schemes, very often to the detriment of other Member States.

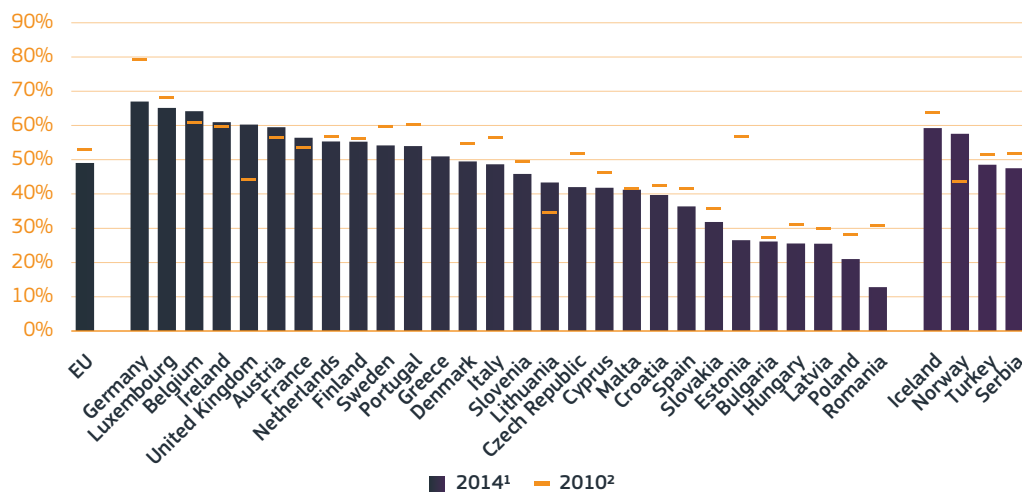
## Innovative enterprises

*The share of innovative enterprises is highly correlated with productivity and hence GDP per capita levels. Of concern is the decline in the share of innovative enterprises in most EU countries since 2010.*

Germany, Luxembourg, Belgium and Ireland – all countries with GDP and productivity levels above the EU average and with a developed science base – show the highest shares of innovative enterprises (see figure below). Latvia, Poland and Romania, countries with a below-EU-average GDP per capita and building their science and innovation capacity, show the

lowest shares. The latter countries might still profit from low-wage-related cost-competitiveness, while high-wage countries are in greater need of innovation to remain competitive and compensate for high production costs. The share of innovative companies is also linked to countries' economic structure. Those with a higher share of medium-high and high-tech manufacturing companies usually face stronger competitive pressures, shorter product cycles or higher shares of knowledge-intensive services (ICT, finances), and naturally show a higher share of innovative enterprises. Somewhat worrying is the fact that the share of innovative enterprises has declined in many EU countries since 2008-2010, as evidenced by the CIS results.

**Figure 1.4-C.12** Innovative enterprises as % of total number of enterprises, 2010 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (CIS 2014, CIS 2010)

Note: <sup>1</sup>TR, RS: 2012.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_12.xlsx)

*As regards the different types of innovation activities, leading innovation countries perform above the EU average both in product and process innovations, as well as in marketing and organisational innovations.*

With reference to the different types of innovation activities (see Figure 1.4-C.13), there is a clear

innovation divide in Europe, with leading innovation countries performing well in both product and process innovations as well as in marketing and organisational innovations within their enterprises. Countries with overall low innovation levels perform poorly in all innovation activities, but particularly in product innovations, which typically require more resources to generate than other types of innovations.

**Figure I.4-C.13 Innovative enterprises by type of innovation activity as % of total enterprises, 2014**

	Product and/or process innovative enterprises	of which:		Organisation and/or marketing innovative enterprises	of which:	
		Product innovative enterprises	Process innovative enterprises		Organisation innovative enterprises	Marketing innovative enterprises
EU	36.8	23.9	21.6	35.9	27.3	22.8
Belgium	52.9	31.9	38.8	46.2	35.9	28.4
Bulgaria	17.1	10.9	9.2	16.3	10.8	11.7
Czech Republic	35.7	25.1	22.4	27.3	17.1	20.5
Denmark	38.0	24.4	23.7	38.4	30.1	29.0
Germany	52.6	34.4	24.1	50.7	37.8	35.9
Estonia	20.8	11.0	13.0	15.9	10.4	12.1
Ireland	48.8	35.7	37.8	53.5	44.4	39.6
Greece	38.7	23.4	29.6	40.7	25.5	32.5
Spain	23.5	11.2	14.8	26.4	21.8	15.8
France	40.9	27.7	27.1	42.7	35.0	25.3
Croatia	26.9	18.7	21.6	32.1	23.2	23.6
Italy	37.0	24.7	24.5	35.3	24.5	23.5
Cyprus	33.6	22.9	27.6	32.2	25.0	25.5
Latvia	13.8	8.5	9.7	20.0	14.9	13.6
Lithuania	36.8	20.9	31.4	25.2	16.7	18.7
Luxembourg	42.0	28.8	25.7	55.3	47.0	34.1
Hungary	18.2	12.0	9.6	16.3	9.6	11.3
Malta	30.7	19.6	20.8	31.8	26.4	20.0
Netherlands	47.3	32.5	28.1	33.3	25.2	20.0
Austria	44.4	30.8	32.8	47.7	37.3	29.8
Poland	15.8	9.5	10.9	12.5	9.0	7.8
Portugal	44.8	28.4	35.4	38.4	25.9	29.0
Romania	6.5	3.6	4.3	9.4	6.7	6.6
Slovenia	33.0	25.2	22.6	34.9	24.4	25.1
Slovakia	20.3	12.6	12.9	23.1	14.7	16.8
Finland	48.3	34.5	32.0	38.4	29.7	25.9
Sweden	44.3	31.4	25.8	36.1	22.7	28.1
United Kingdom	40.9	26.8	17.9	45.5	40.1	18.5
Iceland	50.1	36.2	34.0	45.0	33.4	32.0
Norway	46.2	32.9	26.9	44.0	30.0	31.4
Switzerland	52.7	41.7	26.0	62.6	45.9	50.5
Turkey	38.0	22.7	26.8	41.0	28.5	33.6

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (CIS 2014)

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_13.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_13.xlsx)

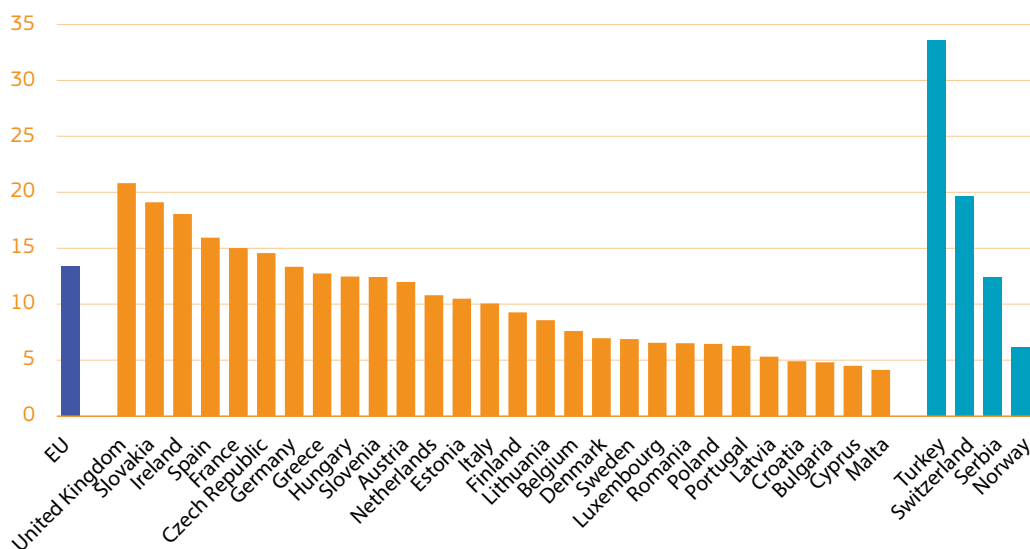


*However, at country level, the share of innovation turnover does not seem directly correlated to the share of innovative enterprises.*

As concerns the share of innovation turnover in total turnover (see Figure I.4-C.14 below), there would appear to be almost no correlation with the share of innovative enterprises. However, when analysing the results, it should be noted that data on the share of companies are dominated by the high number of SMEs whilst, as regards turnover, larger companies play a bigger role, including foreign affiliates,

which tend to import innovations from the headquarter country. According to the latest CIS data, the share of innovation turnover in the EU is the highest in the UK with Slovakia and Ireland ranking second and third, respectively. This might be explained by foreign affiliate companies producing goods characterised by shorter product cycles and higher turnover related to innovation (automobiles, ICT hardware and pharmaceuticals). Low performers, such as Latvia, Bulgaria and Romania, also perform poorly in the share of innovative enterprises.

**Figure I.4-C.14 Innovation turnover as % of total turnover, 2014<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat (CIS 2014, CIS 2012)

Note: <sup>1</sup>TR, RS: 2012.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_4-c\\_figures/f\\_i\\_4-c\\_14.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_4-c_figures/f_i_4-c_14.xlsx)

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# CHAPTER 1.5

# **FRAMEWORK CONDITIONS**

Framework conditions have a significant role to play in shaping investment behaviour and the innovation capacity of economies. Favourable framework conditions are expected to positively affect innovative investments and their impact on productivity as they help to allocate and reallocate resources towards innovative activities that support productivity growth.

The definition of good and supportive framework conditions encompasses different dimensions. In this chapter, we characterise and analyse four of those, namely: (1) the existence of robust and well-functioning public institutions; (2) the efficiency of the products market; (3) the functioning of the labour market; and (4) the extent to which financial markets grant access to resources to innovative businesses.

A business environment characterised by over-regulation and inadequate levels of competition will reduce the opportunities to invest and increase the probability of a misallocation of resources which has a negative effect on the ability of innovative companies to grow. For new firms to be created and for non-productive firms to exit the market when they are no longer competitive, institutional and legal settings are crucial as they speed up the process of business creation and destruction. An effective legal framework, coupled with an efficient business environment, sets the right incentives for investment and reduces the scope for rent-seeking behaviour.

Similarly, a well-functioning labour market should facilitate the reallocation of workers towards activities with higher knowledge content and productivity prospects, making it easier for companies to hire and reducing the burden in case of failure. At the same time, job security can positively affect productivity growth via the economy's capacity to attract and retain high-skilled employment, while job losses may be harmful and costly for displaced workers and for their ability to keep up with the skills required in the market. Therefore, a good balance between flexibility, efficiency and security is fundamental.

Last but not least, an efficient reallocation of resources towards more productive activities requires financial markets that work correctly in support of innovative investments, from start-ups to scaling up. Constraints in access to credit for those activities with higher productivity and innovative prospects are harmful for long-term sustainable economic growth, although they may favour the survival of low-productivity but established companies.

## CHAPTER I.5-A: THE FUNCTIONING OF INSTITUTIONS

The World Bank's 'Ease of doing business' index ranks economies by the attractiveness of their regulatory frameworks for the creation of new businesses. It encompasses several dimensions of the regulatory environment and provides an aggregate measure of regulations for starting and running a business. The index is expressed as the distance from the frontier on a scale 0-100, where a value of 100 represents the best possible outcome in each single dimension: the higher the aggregate value, the more business-friendly regulations a country has<sup>1</sup>.

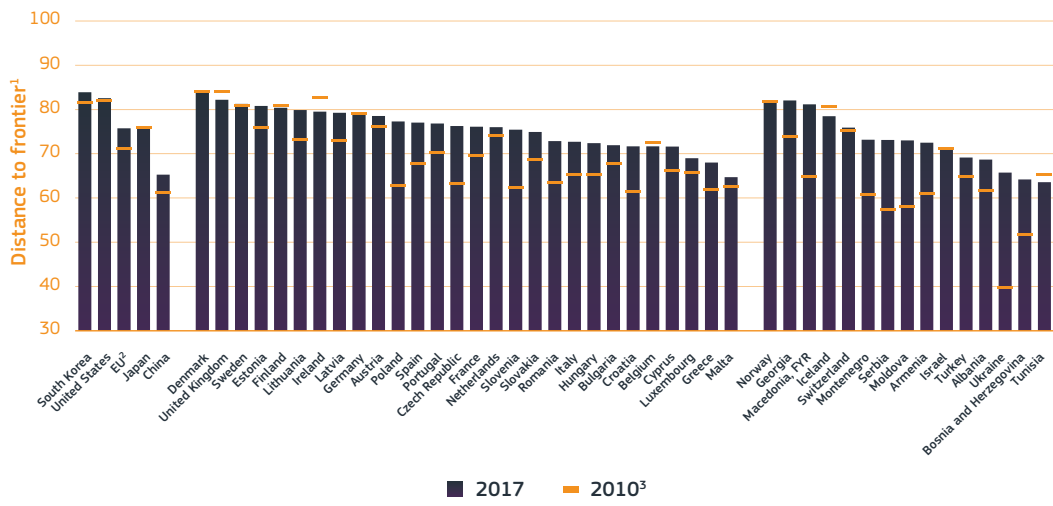
*During the last years, driven by efforts by the EU and its Member States towards deepening the internal market<sup>2,3</sup> and with an increased reform momentum following the crisis, Europe seems to have managed to create more favour-*

*able conditions for businesses and a catching-up process can be observed in those Member States distant from the frontier.*

The most significant improvements are visible in eastern European countries, notably those that joined the EU relatively recently, such as Romania (2007), the Czech Republic, Poland, Slovenia and Croatia (2013), hinting at the positive effect of accession to the EU internal market (Figure I.5-A.1). Similarly, the countries most affected by the crisis experienced an improvement in the ease of doing business, with the exception of Ireland. This trend might reflect these countries' efforts to apply market-friendly reforms to the regulatory framework in the years following the latest economic crisis.

- 
- 1 Please note that the Ease of Doing Business 2018 report was used. In particular, the index is the result of the aggregation of 10 different dimensions, namely: starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, and resolving insolvency. For further details, see: <http://www.doingbusiness.org/~media/WBG/DoingBusiness/Documents/Annual-Reports/English/DB2018-Full-Report.pdf>.
  - 2 European Commission (2015). Upgrading the Single Market: more opportunities for people and business, COM(2015) 550 final.
  - 3 For more details and the progress towards the internal market, see Figure I.5-B.11 below.

**Figure I.5-A.1** Ease of doing business - distance to frontier<sup>1</sup> (0 = lowest performance to 100 = frontier)<sup>1</sup>, 2010 and 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Ease of Doing Business Indicator (World Bank)

Notes: <sup>1</sup>The distance to frontier score illustrates the distance of an economy to the 'frontier' which represents the best performance observed across all economies. The highest scores represent the friendliest regulatory environments for doing business. <sup>2</sup>EU is the unweighted average of the available data for Member States and does not include Malta for 2010. <sup>3</sup>MT: 2012; US, JP, CN: 2014.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-a\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-a_1.xlsx)

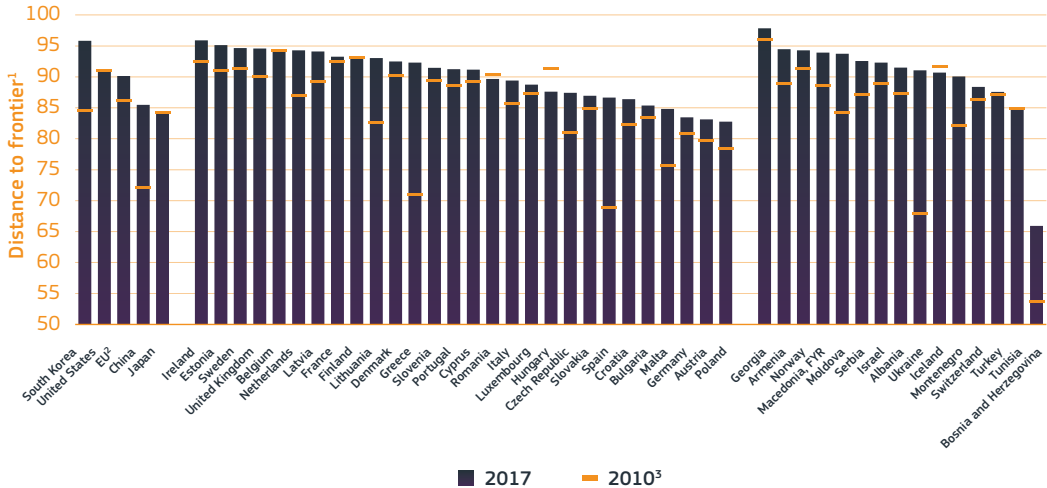
***This is reflected by general improvements in the reduction of costs and bureaucratic burdens to start a business or in simplifying the resolution of insolvency procedures.***

With the exception of Hungary, Romania (with a slight decrease), Finland and Belgium (no evolution), all Member States improved their conditions for starting a business, leading to the EU as a whole slowly catching up with the United States, while both have been overtaken by South Korea. This trend is shown in Figure I.5-A.2, which plots the World Bank indicator measuring the costs, time and number of procedures needed to set up a company, which is one of the 10 dimensions used to compose the aggregate ease of doing business index. Compared to 2010, an overall improvement can be observed across almost all European economies, without the emergence of a clear divide within the EU.

The EU has also achieved significant improvements in facilitating the procedures to allow businesses to leave the market, with a slow catch-up process to leading countries such as Japan, South Korea and the United States, as well as associated countries such as Norway and Iceland. Furthermore, a convergence trend can be observed within the EU. Indeed, while Eastern and Southern Member States show significant progress (with the exception of Lithuania), the Northern and Central European countries, like Finland, Denmark, Belgium, the Netherlands, the UK, Sweden and Ireland, show a relative decline in the efficiency of their insolvency proceedings. The trend is shown in Figure I.5-A.3, which plots the corresponding dimension of the World Bank index.



**Figure I.5-A.2** Ease of starting a business - distance to frontier<sup>1</sup> (0 = lowest performance to 100 = frontier)<sup>1</sup>, 2010 and 2017



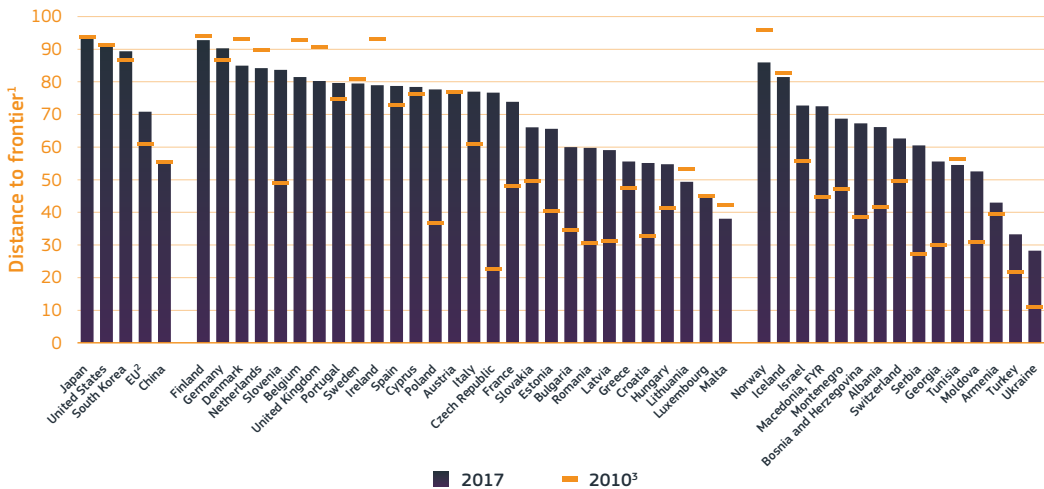
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Ease of Doing Business Indicator (World Bank)

Notes: <sup>1</sup>The distance to frontier score illustrates the distance of an economy to the 'frontier' which represents the best performance observed across all economies. The highest scores represent the friendliest regulatory environments for incorporating and formally operating a business. <sup>2</sup>EU is the unweighted average of the available data for Member States and does not include Malta for 2010. <sup>3</sup>MT: 2012; US, JP, CN: 2014.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-a\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-a_2.xlsx)

**Figure I.5-A.3** Ease of resolving insolvency - distance to frontier<sup>1</sup> (0 = lowest performance to 100 = frontier)<sup>1</sup>, 2010 and 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Ease of Doing Business Indicator (World Bank)

Notes: <sup>1</sup>The distance to frontier score illustrates the distance of an economy to the 'frontier' which represents the best performance observed across all economies. The highest scores represent the easiest regulatory environments for resolving insolvency. <sup>2</sup>EU is the unweighted average of the available data for Member States and does not include Malta for 2010. <sup>3</sup>MT: 2012; US, JP, CN: 2014.

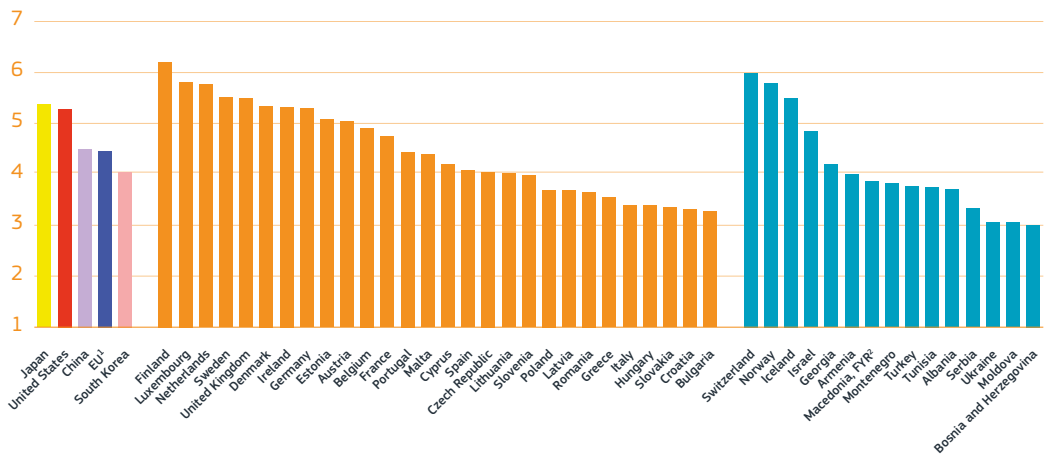
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-a\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-a_3.xlsx)

*However, significant improvements can still be made to raise businesses' perception of the efficiency of public institutions in the EU. a clear divide can be observed between the Northern European countries and the Southern and Eastern ones.*

According to business opinion, expressed in a yearly survey by the World Economic Forum, public institutions in the EU perform significantly less well than in Japan, the United States, Switzerland, Norway, Iceland and Israel, but only slightly below China (Figure I.5-A.4). Only Finland ranks higher than all these extra-EU

countries, while Luxembourg, the Netherlands, Sweden and the UK perform better than Japan and the United States but still fall short of Switzerland. The index encompasses, amongst others, questions relating to government efficiency and trustworthiness, the perceived bureaucratic burdens imposed by regulation and the efficiency of the legal framework. While most of these burdens are not directly linked to entrepreneurship, they are signs that businesses perceive public processes as more cumbersome and riskier in Southern and Eastern European countries, which may have an impact on investment decisions.

**Figure I.5-A.4 Global Competitiveness Index - public institutions, 2017**  
values are on a scale of 1 to 7 (best)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018

Notes: <sup>1</sup>EU is the unweighted average of the values for the EU Member States. <sup>2</sup>MK: 2016.

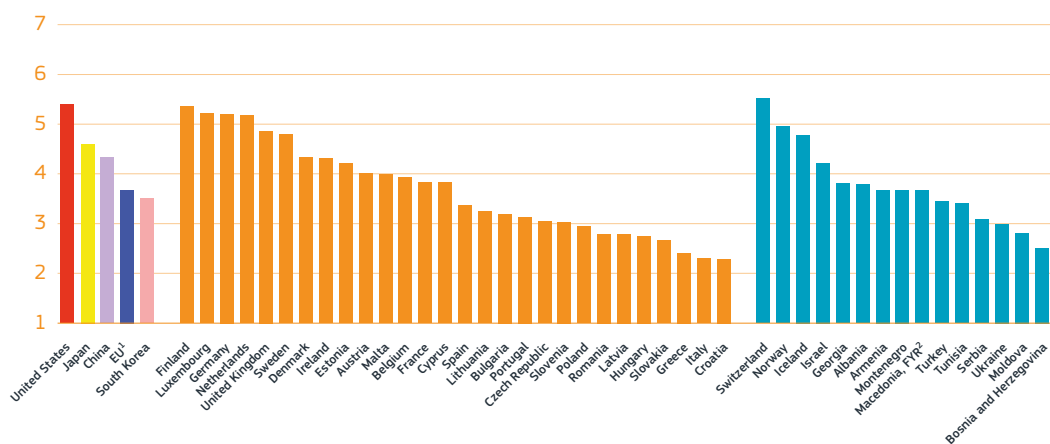
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-a\\_4.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-a_4.xlsx)

*The perceived underperformance of public institutions is mirrored and driven by perceived inefficiencies at the government level, a sub-indicator of the aforementioned public institutions index.*

Again, if we examine an indicator measuring perception regarding the efficiency of governments, northern EU Member States outperform the eastern and northern and central European countries. The EU as a whole also ranks behind the United States, Japan, China, Switzerland, Norway, Iceland and Israel, and to a lesser extent behind Georgia and Albania, too (Figure I.5-A.5).

Next to the burdens perceived at the public institutions level, the strength of the legal system appears crucial in providing regulatory safety for firms to rely on, and thereby for reducing the risk to open a business in a particular country. The World Bank constructed an indicator in which the time required for and the costs associated with enforcing a contract are estimated with equal weight, as well as the overall quality of the judicial system based on a set of 'good practices'<sup>4</sup> measures.

**Figure I.5-A.5 Global Competitiveness Index - government efficiency, 2017**  
values are on a scale of 1 to 7 (best)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018

Notes: <sup>1</sup>EU is the unweighted average of the values for the EU Member States. <sup>2</sup>MK: 2016.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-a\\_5.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-a_5.xlsx)

4 'Good practices' are measured based on the evaluation of the availability of a specific list of regulations, services or standards in a judicial system, as defined by the World Bank for the doing business index. It covers four areas: court structure and proceedings, case management, court automation, and alternative dispute resolution.

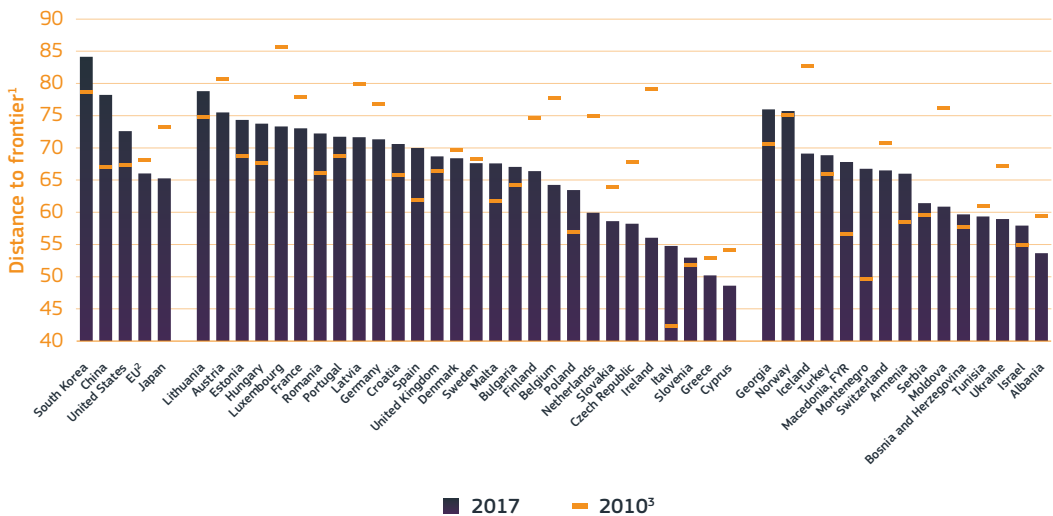
See: <http://www.doingbusiness.org/Methodology/Enforcing-Contracts>

*A decline in the EU performance on the contract enforcement indicator shows that it falls even further behind South Korea, China, the United States, Norway, Switzerland and Iceland than seen in previous indicators. Convergence, although driven by an aggregate negative trend, can be observed across Member States as the gap between the best performers and the followers has been decreasing over time.*

While central European countries are increasing their distance from the frontier, with the biggest gap being visible for Ireland, the Netherlands, Belgium and Luxembourg, the countries in the periphery are catching up, with some exception such as Greece and Cyprus in the south, or the Slovak Republic, Latvia and the Czech Republic in the east (Figure I.5-A.6). Overall, the convergence process within the EU is not driven by a generalised improvement across all countries, but by both a catching up of some of the laggards and a decline in performance of some of the Member States closer to the frontier.

Summing up, the above analysis shows an overall positive evolution of the institutional and legal framework for businesses in the EU. Driven by efforts made to deepen the internal market and pushed by the necessity to make significant reforms in the years following the crisis, the EU's improvement in the ease of doing business index can be explained via the catching up of some Member States which have made significant efforts, amongst others, to ease conditions to start and run business or for companies to leave the market. However, heterogeneity in the efficiency of the legal system persists, and differences in public institutions are still an important factor for explaining the divide between Member States. This underlines the importance for the EU and its Member States to continue their reform efforts and strive to deepen the internal market. Overall, further improvements across all dimensions will be beneficial to the EU as a whole and will contribute to narrowing the gap with international competitors.

**Figure I.5-A.6 Ease of enforcing contracts - distance to frontier<sup>1</sup> (0 = lowest performance to 100 = frontier)<sup>1</sup>, 2010 and 2017**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Ease of Doing Business Indicator (World Bank)

Notes: <sup>1</sup>The highest scores represent the easiest regulatory environments for enforcing contracts. <sup>2</sup>EU is the unweighted average of the available data for Member States and does not include Malta for 2010. <sup>3</sup>MT: 2012; US, JP, CN: 2014.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-a\\_6.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-a_6.xlsx)

## CHAPTER I.5-B: THE FUNCTIONING OF GOODS, LABOUR AND CAPITAL MARKETS

### Product market efficiency

*Overall, goods markets are less efficient in the EU compared to the United States, Japan and South Korea, although there are large differences across Member States, with the best-performing countries scoring higher than the United States and many of the Eastern and Southern European economies lagging behind.*

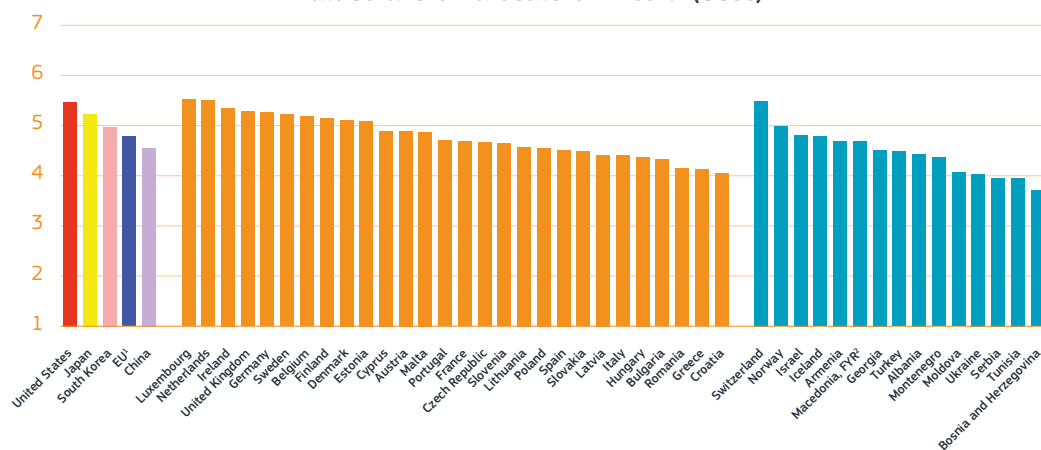
Figure I.5-B.1 presents a measure of “goods market efficiency” developed by the World Economic Forum. It is a composite index resulting from the aggregation of 16 indicators from different sources, encompassing the different aspects defining the functioning of the market<sup>5</sup>. Overall, the different indicators can be broadly classified into four main dimensions: the regulatory framework, competition, taxation and demand. The aggregate

index provides a summary measure of the efficiency of the market, with the value 7 given to the most- and 1 to the least-efficient markets.

The market is relatively less efficient in countries in the periphery. In the south, Greece, Italy and Spain register among the lowest values, while Portugal is just below the EU average. Among the Eastern European countries, Estonia performs well above average, while others such as Croatia, Romania, Bulgaria and Hungary are at the bottom of the distribution. Among the associated countries, Switzerland and Norway are characterised by a high level of efficiency.

To better understand the driving forces behind the aggregate index, the specific domains underlying the overall performance will be analysed in the rest of this section.

**Figure I.5-B.1 Global Competitiveness Index - goods market efficiency, 2017**  
values are on a scale of 1 to 7 (best)



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018  
Notes: <sup>1</sup>EU is the unweighted average of the values for the EU Member States. <sup>2</sup>MK: 2016.  
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_1.xlsx)

5 For further details on this and following indicators from the Global Competitiveness Index, refer to the Methodological Appendix and to <http://reports.weforum.org/global-competitiveness-index-2017-2018/appendix-a-methodology-and-computation-of-the-global-competitiveness-index-2017-2018/>

## Competition

*Competitive markets constitute a level playing field that allows different companies to compete equally, and the most productive ones to enjoy the returns on their investment. Competition promotes equal opportunities for all businesses in the market by reducing the barriers protecting incumbent firms and providing newcomers with an incentive to invest.*

The most competitive firms can grow, while the least efficient and productive exit the market, favouring an efficient reallocation of resources and boosting aggregate productivity growth. Higher competition is also a direct source of innovation. A larger number of competitors increase the probability of innovations taking place, providing incentives to incumbent firms to innovate, invest in R&D and adopt technology to “escape competition” and maintain their rents<sup>6</sup>. This argument is very intimately linked to the concept of entry of new firms which are supposed to bring disruptive ideas and technologies that are going to change and/or create new markets<sup>7</sup>.

*The degree of competition in the EU is lower than in Japan, the United States and China, but slightly above that in South Korea. The landscape in Europe is diverse and clear differences persist between core and peripheral countries.*

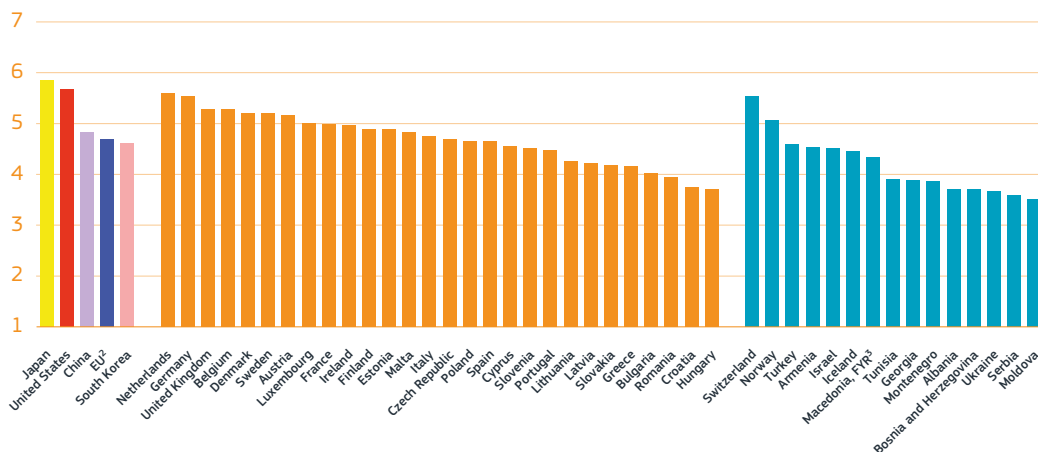
Figure I.5-B.2 plots a summary index of competition, built by aggregating three indicators from the WEF Global Competitiveness Index. In particular, the graph considers the average between the following measures: i) intensity of local competition; ii) extent of market dominance; and iii) effectiveness of anti-monopoly policy. The index is built on survey data and registers a value of 7 when competition is seen as intense and 1 when it is perceived as very low. The eastern economies are characterised by less-competitive markets, with the notable exception of Estonia which performs above the EU average. Southern Member States take an intermediate position, with Greece lagging behind. Among the associated countries, Switzerland and Norway outperform the others and the EU, too. The level of competition in China’s goods market is slightly above that in the EU, while both countries are still considered to be less competitive than in Japan and the United States<sup>8</sup>.

6 Aghion, P. and Griffith, R. (2008). Competition and growth: reconciling theory and evidence. MIT press.

7 Cohen, W.M. (2010). Fifty years of empirical studies of innovative activity and performance. Handbook of the Economics of Innovation, 1, 129-213.

8 The lower performance was estimated according to the OECD Product Market Regulation Index. See European Commission (2016, p. 91).

**Figure I.5-B.2 Global Competitiveness Index - competition environment<sup>1</sup>, 2017**  
values are on a scale of 1 to 7 (best)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018

Notes: <sup>1</sup>The indicator is the unweighted average of the following three sub-indicators: 6.01 Intensity of local competition, 6.02 Extent of market dominance, and 6.03 Effectiveness of anti-monopoly policy. <sup>2</sup>EU is the unweighted average of the values for the EU Member States. <sup>3</sup>MK: 2016.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_2.xlsx)

***Excessive market concentration can also reduce investment when new entrants' prospects of future competition are low. This is particularly true in markets with a winner-takes-most structure.***

The rise of superstar firms may hinder current and future investments in industries where market shares are relatively too high, i.e. concentration rises and competition falls. Concentration in sales and employment, measured as the share of the largest companies in each sector, has been increasing across US industries since 1980. For instance, the top 20 companies account for more than 70% of sales in manufacturing, over 60% in finance, and

64% and 55% in transportation and wholesale trade, respectively<sup>9</sup>. While this trend is also correlated with firms' multifactor productivity growth, suggesting technological gains, excessively low entry rates due to low competition may reduce the need of incumbents to invest more to stay competitive. Recent evidence suggests that greater concentration has reduced investment rates in the United States over the last 30 years, while at the same time increasing profit rates<sup>10</sup> and reducing the labour share<sup>11</sup>. Resources and employment have been reallocated between companies favouring those winning firms which enjoy increased market shares, with an overall rise in profits and a reduction in labour share.

9 Dorn, D., Katz, L.F., Patterson, C. and Van Reenen, J. (2017). Concentrating on the Fall of the Labor Share. *American Economic Review*, 107(5), 180-85. See also Chapter I.1 in this Report.

10 Gutiérrez, G. and Philippon, T. (2016). Investment-less growth: an empirical investigation. NBER Working papers, n.22897.

11 Autor, D., Dorn, D., Katz, L.F., Patterson, C. and Van Reenen, J. (2017). The fall of the Labor Share and the rise of Superstar firms. IZA Discussion Paper Series, n.10756.

**Intellectual property rights protection**

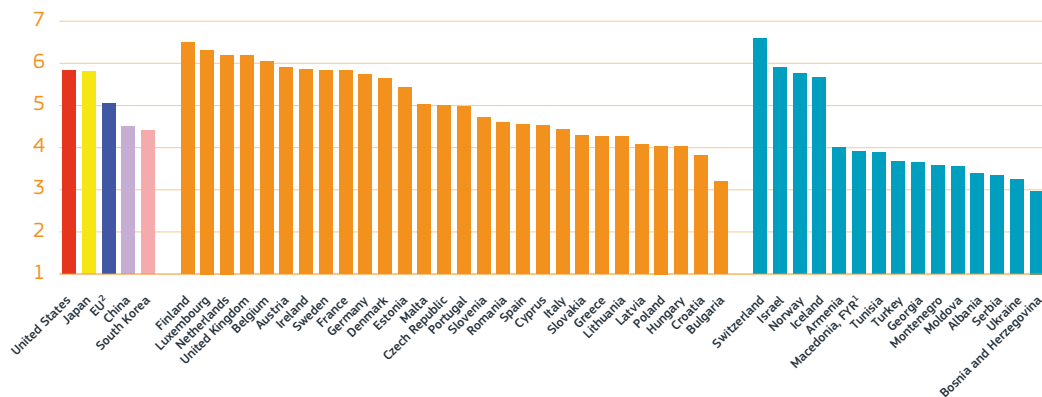
*While competition is a driving force behind productivity growth and an efficient reallocation of resources, securing the returns on investment to those companies which engage in innovative projects is crucial to guarantee a proper set of incentives.*

Investing in risky R&D projects is indeed a process with uncertain outcomes and one that requires adequate financial means. R&D activities are often characterised by non-excludability and potential spillover effects to competitors in the wider economy. Therefore, benefits act as leverage for innovation and call for a balance between adequate framework conditions that ensure a competitive market economy and the protection of intellectual property rights.

**Intellectual property rights protection in the EU is higher than in South Korea and China, but lags behind Japan and the United States.**

Within Europe, several countries have better protection than Japan, Finland being the best performer, followed by Luxembourg, the Netherlands and the UK (Figure I.5-B.3<sup>12</sup>). There are significant differences between Member States. In the periphery, countries' intellectual property rights protection is perceived as weaker. In Bulgaria, for instance, the index scores around half of that reported for Finland, while Estonia and the Czech Republic perform better, just below Germany and Denmark. For associated countries, intellectual property rights protection is weaker than in the EU, with the exception of Switzerland, Israel, Norway and Iceland which perform at a similar level to the highest European standards.

**Figure I.5-B.3 Global Competitiveness Index - intellectual property protection, 2017 values are on a scale of 1 to 7 (best)**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018

Notes: <sup>1</sup>MK: 2016. <sup>2</sup>EU is the unweighted average of the values for the EU Member States.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_3.xlsx)

12 Effective intellectual property rights protection is measured here via a survey for business representatives. See World Economic Forum (2017). The Global Competitiveness Index dataset 2016-2017, for further details.



## Labour market efficiency

***Efficient labour markets that reduce frictions in the allocation of the workforce towards more innovative and productive activities, within and across sectors and firms, are crucial to foster innovation.***

New emerging sectors may require new competences or a greater supply of highly skilled workers to move from less to more productive activities or companies. An efficient labour market should facilitate this reallocation process, making it easier for companies to hire and reducing the burden in case of failure. In addition, in a market economy the growth of real wages should follow productivity developments, while labour taxation should not be detrimental to work and business activities. Similar to the conditions in the goods market, the above arguments are particularly relevant for sectors that are knowledge-intensive, characterised by riskier investments and more uncertainty in the results, while the speed of change in the technological content is faster.

***Flexible employment relationships can enhance the ability of firms to adapt quickly to changes in the market and respond better to demand fluctuations, especially for small firms or new entrants. Furthermore, the capacity to attract and retain talent and inclusive labour markets contributes to boosting an economy's innovation potential.***

Excessive rigidities, such as hiring and firing practices which are too burdensome and high redundancy costs, may hinder the efficient allocation of the labour force, affect the innovation potential of the economy and eventually productivity growth, especially for new innovative firms<sup>13</sup>. Similarly,

high taxation on labour can negatively affect the incentives to hire and to work, while a country which is unable to attract and retain highly skilled workers will have a lower innovation potential and reduced prospects of productivity growth. Figure I.5-B.4 shows the degree of efficiency in the labour market. The indicator used is one of the components of the Global Competitiveness Index and accounts for several labour market characteristics, including the flexibility of wage determination, hiring and firing practices, redundancy costs, the link between wages and productivity, the effect of taxation on incentives to work, the alignment between productivity and wages, the inclusion of women in the labour force, and the capacity of countries to attract and retain human capital<sup>14</sup>. Overall, the aim of the index is to define the efficiency of the labour markets by including indicators of flexibility and the efficient use of human capital.

***The degree of labour market efficiency in the EU ranks behind that of the United States, Japan and China, but performs slightly better than South Korea. Switzerland, Norway and Iceland are the best performers among the associated countries. Within the EU, the labour markets in the periphery are perceived as less efficient than those in core countries, with the exception of Latvia, Estonia and the Czech Republic.***

The UK and Denmark rank at the top of the distribution, followed by the Netherlands and Germany. Italy and Greece are at the bottom, despite the recent reforms after the last economic crisis. In particular, reforms to increase labour market flexibility have been undertaken to reduce the segmentation between temporary and open-ended contracts, reducing the cost and uncertainty of dismissals in Spain<sup>15</sup>,

13 See Andrews, D. and Criscuolo, C. (2013). Knowledge-based capital, innovation and resource allocation. OECD Economic Department Working Papers, (1046), O\_1, and Andrews, D., Criscuolo, C., Menon, C. (2014). Do resources flow to innovative firms? Cross country evidence from firm level data. OECD. Economics Department Working Papers.

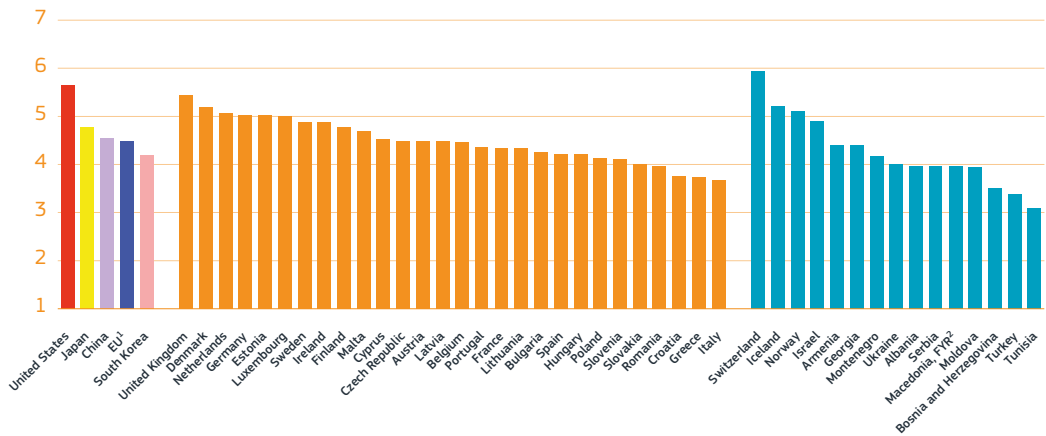
14 The overall indicator comprises 10 variables, eight of which were obtained via a survey among business representatives.

15 See European Commission (2017a). Country Report Spain.

Italy<sup>16</sup> and Portugal<sup>17</sup>. The relatively low score in Figure I.5-B.4 is mainly due to the low participation of women in the labour market, the effect of taxation on workers' incentives, and

the inability to attract and retain talents<sup>18</sup>. Furthermore, these factors more than counteract the flexibility of wage determination characterising labour markets in eastern economies.

**Figure I.5-B.4 Global Competitiveness Index - labour market efficiency, 2017**  
values are on a scale of 1 to 7 (best)



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018  
 Notes: <sup>1</sup>EU is the unweighted average of the values for the EU Member States. <sup>2</sup>MK: 2016.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_4.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_4.xlsx)

***At the same time, as far as possible, policy should ensure the security of employment and the adoption of effective active labour market policies to reduce the economic and social impact of job losses, and favour re-training and the potential reinstatement of displaced workers.***

for instance by promoting flexicurity policies, and not to reduce workers' bargaining power and job security per se. Indeed, while flexible labour markets may have a positive effect on the efficient allocation of the labour force, job security can positively affect productivity growth via the capacity of an economy to attract and retain high-skilled<sup>19</sup> employment<sup>20</sup>. In addition, jobs losses are harmful and costly for displaced workers, especially those whose skills endowment becomes obsolete, youth and women<sup>21</sup>.

Indeed, the overall aim is to increase efficiency and to shift the burden of market functioning from firms and workers to society as a whole,

16 See European Commission (2017b). Country Report Italy.  
 17 See European Commission (2017c). Country Report Portugal.  
 18 In addition, given that the indicator is built based on a survey and therefore opinion-based, the 'perceived' effects of the reforms might only be visible with a time lag once the changes have had time to take full effect.  
 19 Education and training play a crucial role in the labour reallocation process. See European Commission (2017d). Reflection paper on the deepening of the economic and monetary Union.  
 20 Égert, B. (2016). Regulation, Institutions, and Productivity: New Macroeconomic Evidence from OECD Countries. *American Economic Review*, 106(5), 109-113.  
 21 OECD (2016a). OECD employment outlook. Technical report, OECD, Paris.

## BOX 6: Reform fatigue: slowdown in reform adoption

*The speed of reforms, which was significant notably for Eastern European and other countries hit hardest by the crisis, seems to have slowed down, losing momentum and signalling reform fatigue.*

As can be observed throughout the sections on legal, institutional, product and labour market indices, the overall evolution of framework conditions to conduct business has been positive, although as the worst of the financial and economic crisis is now over, the question is whether the momentum can be maintained. First, the overall positive trend for the EU as a whole hides significant differences between Member States and between different policy areas. While the period immediately following the crisis brought institutional and market pressures providing the necessary momentum for engaging in reforms throughout the EU, a slowdown in policy actions can be observed in recent years, as reported in the yearly policy reform analysis 'Going for Growth' produced by the OECD.

The report provides an index on the reform responsiveness of countries, based on the set of policy priorities understood as necessary to improve business conditions and favour growth. In particular, the assessment is based on a qualitative index being the ratio between the number of policy areas in which reform efforts have been undertaken and the total policy areas identified by the OECD. In the 2017 report<sup>22</sup>, a slowdown in the reform responsiveness rate can be observed when comparing the 2015-2016 and the 2013-2014 time periods, even

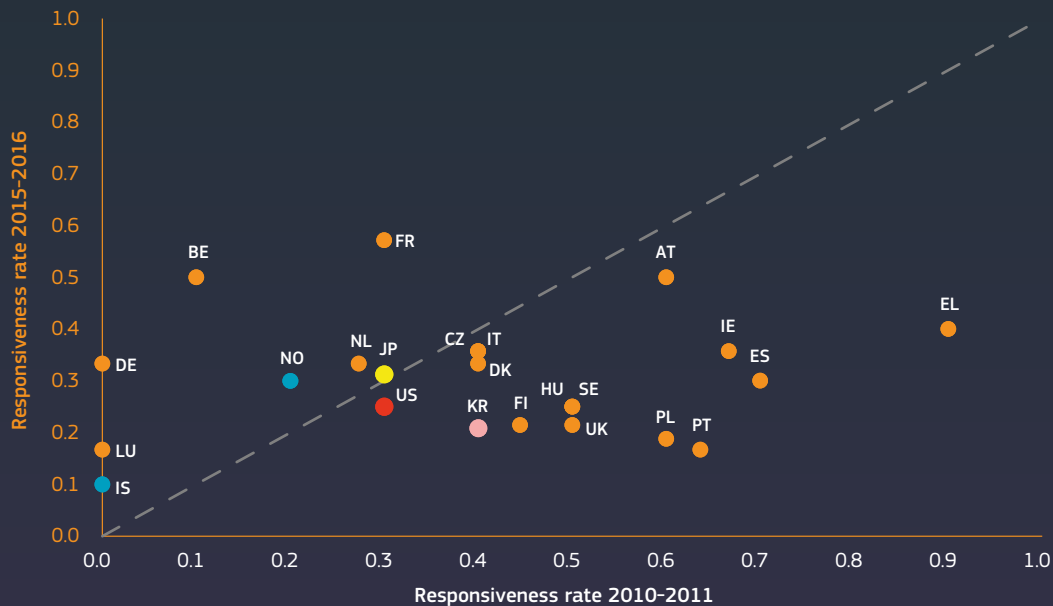
though once again significant differences and opposite trends are visible across the Member States (Figure A). The slowdown is more prominent among those countries which have made the greatest efforts in recent years, such as Greece, Ireland, Portugal, Poland and Spain. However, an acceleration in reform progress can even be seen in some central European countries (Belgium, Austria and France), as well as in Italy. While the negative trend could be due to the efforts needed to implement some of the more cumbersome reforms, it might also hint at more general reform fatigue in some Member States. This can be shown by comparing the responsiveness rates computed in the 2012 OECD report<sup>23</sup> in the period 2010-2011 with those observed in 2015-2016.

Figure B shows that most Member States' efforts have declined compared to the years closer to the crisis, as have those of countries such as the United States and South Korea. Similarly, most of those countries which increased their efforts had a relatively low responsiveness rate in 2010-2011. Now that the perceived pressure on governments to implement changes has declined, it is even more important for the Member States to continue to improve business conditions, enabling an efficient allocation of resources towards the more productive companies and sectors.

22 OECD (2017a), Economic Policy Reforms 2017: Going for Growth, OECD Publishing, Paris: <http://dx.doi.org/10.1787/growth-2017-en>

23 OECD (2012a), Economic Policy Reforms 2012: Going for Growth, OECD Publishing, Paris: <http://dx.doi.org/10.1787/growth-2012-en>

**Figure A** Responsiveness to *Going for Growth* priorities and fiscal consolidation effort, 2010-2011 and 2015-2016



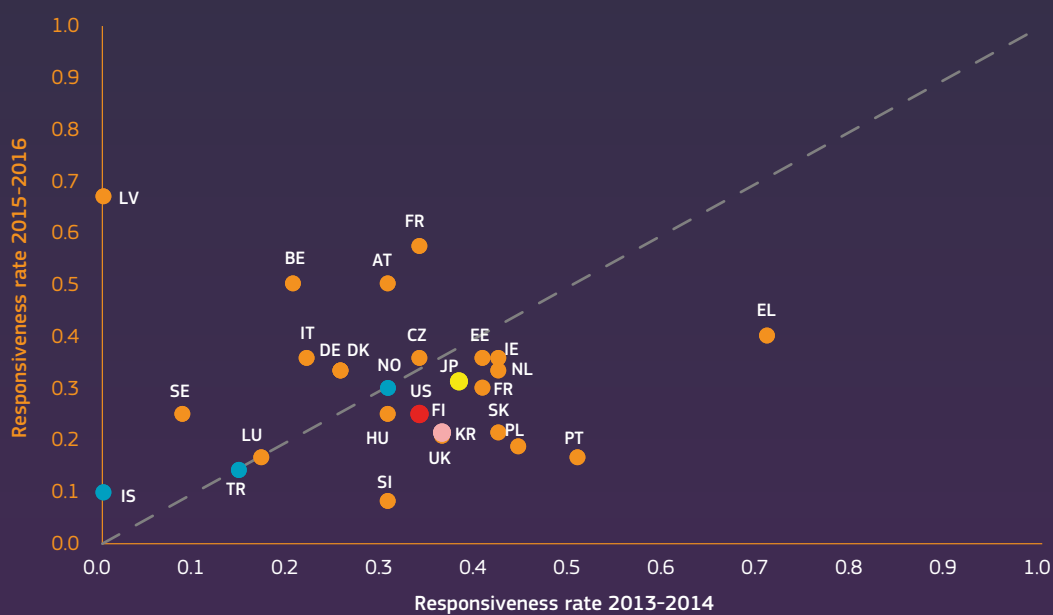
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policy

Data: OECD

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/figure-a.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/figure-a.xlsx)

**Figure B** Responsiveness to *Going for Growth* priorities and fiscal consolidation effort, 2013-2014 and 2015-2016



Science, Research and Innovation performance of the EU 2018

Source: OECD

Data: OECD

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/figure-b.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/figure-b.xlsx)

### Financial markets and access to capital

*After the crisis, access to capital was singled out as a particularly important barrier for innovation and entrepreneurship in the EU. Even though significant efforts have been carried out by the European Central Bank (ECB) and other institutions since the crisis began, capital markets have still not entirely recovered, and imperfections seem to have increased.*

While the liquidity of markets has increased significantly and recently SMEs are reporting that access to finance is no longer their most important concern, micro- and small and medium-sized enterprises in particular, amongst other start-ups and riskier business projects, remain at a disadvantage compared to large enterprises, and scale-up capital remains scarce<sup>24,25,26</sup>. Given that the core of the European economy comprises more than 90% of SMEs, it is paramount to get a deeper understanding of the European capital markets and access to financing<sup>27</sup>.

*Due to the efforts of the ECB and other European institutions, access to banking loans has significantly improved since the outbreak of the financial and sovereign crises.*

As can be seen from the 'ease of access to loan index' provided by the World Economic Forum, in the height of the crisis in 2012-2013, many companies considered access to loans was severely restrained (black line in Figure I.5-B.5) and has yet to recover to pre-crisis levels in some EU Member States. While the United States, Japan and China report values that even exceed those from 2007, the EU as a whole has yet to recover completely. When looking at the trends in individual Member States, no clear geographical pattern emerges, with the biggest recoveries, exceeding even 2007 levels, reported in, e.g. the Czech Republic, Poland, Germany, Hungary and Austria, while countries such as, e.g. Greece, Ireland, Cyprus, Denmark, the Netherlands and Slovenia report values well below pre-crisis levels.

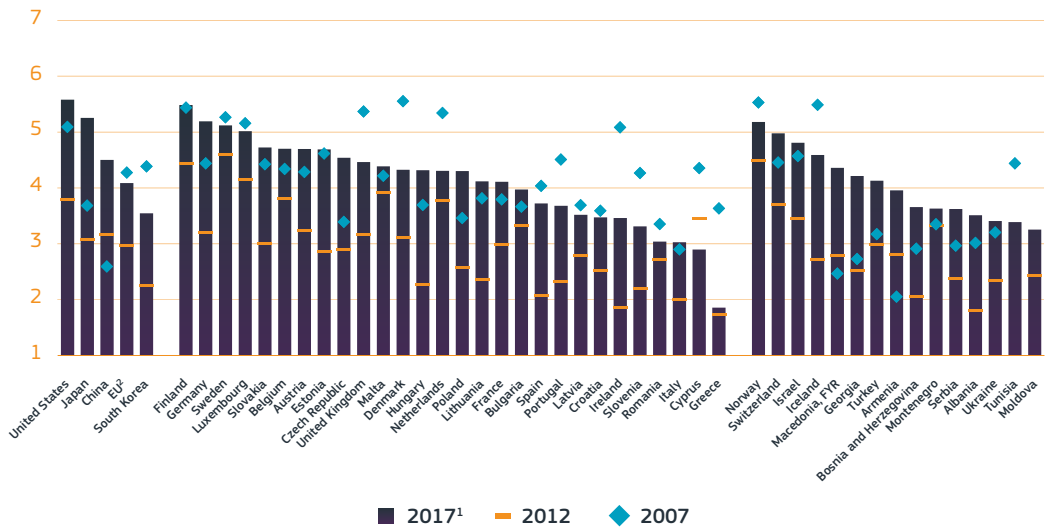
24 European Central Bank (2017). Survey on the Access to Finance of Enterprises in the euro area - October 2016 to March 2017.

25 OECD (2017b). Financing SMEs and Entrepreneurs 2017: An OECD Scoreboard. OECD Publishing.

26 Duruflé, G., Hellmann, T.F. and Wilson, K.E. (2017). From start-up to scale-up: examining public policies for the financing of high-growth ventures. Bruegel Working Papers.

27 European Investment Bank (2016). Investment and Investment Finance in Europe: Financing productivity growth. EIB Economics Department.

Figure I.5-B.5 Global Competitiveness Index - ease of access to loans, 2007, 2012 and 2017 values are on a scale of 1 to 7 (best)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: World Economic Forum. The Global Competitiveness Index dataset 2017-2018

Note: <sup>1</sup>MT: 2016. <sup>2</sup>EU is the unweighted average of the values for the EU Member States.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_5.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_5.xlsx)

**Interest rates that are paid for loans have fallen, although large spreads across countries and types of companies persist.**

While interest rates for new loans have continued to fall in most countries since 2007, reflecting the exceptionally low and even negative interest rates charged by the ECB, the additional charges for SMEs as compared to large firms have increased. This difference might be linked to a perceived higher risk and a lack of

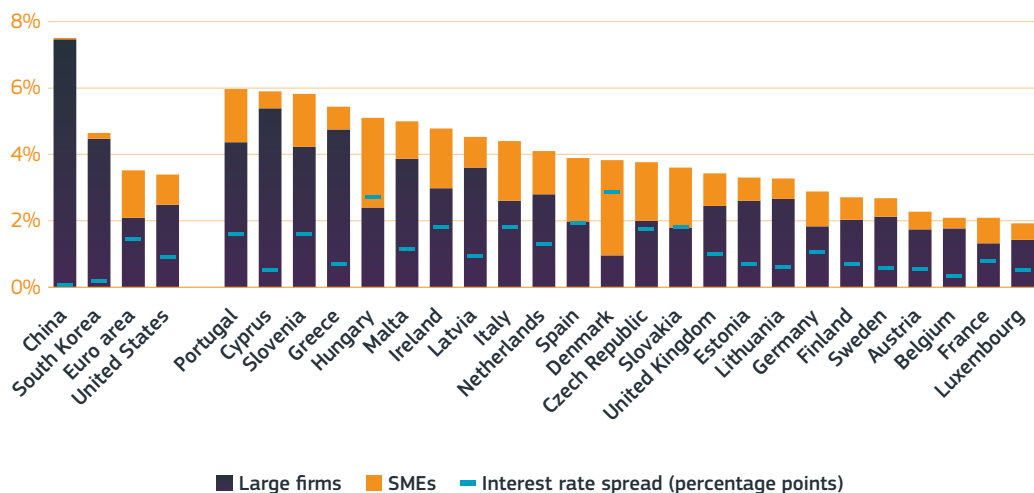
transparency associated with SMEs, since, for example, unlike large firms, they are not bound to publish their reports and accounts. However, the increase in the spread since the crisis suggests that there might be imperfections in the market<sup>28,29</sup>. The fall in interest rates coupled with a rise in the spread suggests that the liquidity that has been pumped into the markets might mainly benefit larger companies, pointing towards a concentration of capital in a minority of firms<sup>30</sup> (Figures I.5-B.6 and I.5-B.7).

28 PwC (2015). Capital Markets Union: Integration of Capital Markets in the European Union.

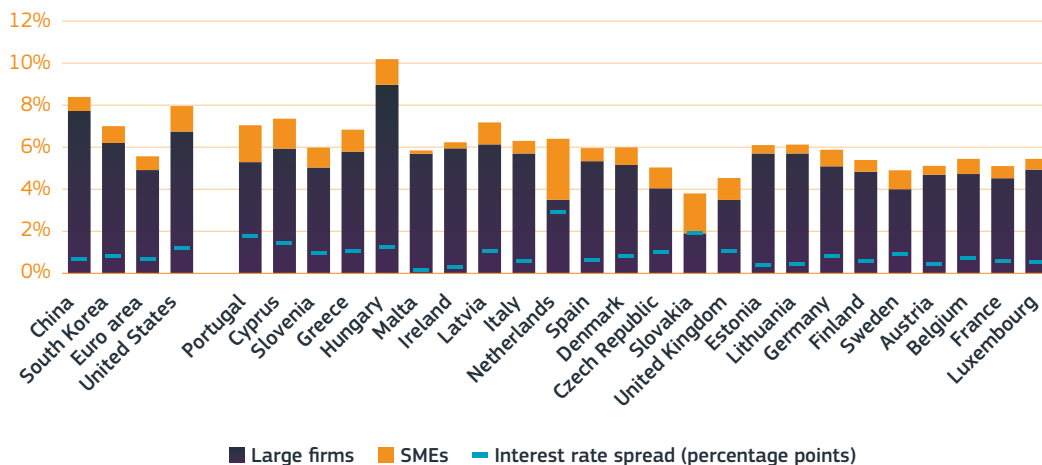
29 See European Investment Bank (2016).

30 OECD (2014). Financing SMEs and Entrepreneurs 2014: An OECD Scoreboard. OECD Publishing, and European Investment Bank (2016).

**Figure I.5-B.6** Average interest rates charged to SMEs and large firms, 2014<sup>1</sup>



**Figure I.5-B.7** Average interest rates charged to SMEs and large firms, 2007<sup>2</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD, ECB

Notes: <sup>1</sup>SK: 2013, LU: 2015. <sup>2</sup>CY, UK: 2008; NL: 2011; SK: 2012; CN: 2013.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_6\\_and\\_f\\_i\\_5-b\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_6_and_f_i_5-b_7.xlsx)

***The European market is still highly banking driven, and has yet to take full advantage of the opportunities arising from the capital markets.***

While this is opposite to the situation in the United States, being a more capital-market-driven economy, past surveys suggest that even in the United States bank loans are the main external financing source for SMEs<sup>31</sup>.

The impact the imperfections perceived in the loans market might have on entrepreneurial activities in the EU is particularly important given the heavy reliance of European companies on bank funding<sup>32</sup>. While bank loans alone already make up more than 50% of European companies' external financing source, this becomes even clearer when adding other kinds of bank finance, totalling more than 65% of their external financing sources (Figure I.5-B.8). However, clear differences are evident across the EU. As expected, UK companies rely to a much greater extent on other sources of financing, such as leasing and hire purchase, with only slightly more than 35% of bank loans appearing in their financing structure. The importance of grants as a financing source in some Eastern European countries, e.g. Hungary, Estonia, Romania, Poland, Lithuania as well as Croatia, and to a lesser extent Greece, shows that these countries still rely more on public support, such as from EU funds, for instance. The underlying data reveals that, while SMEs rely more on bank loans, both large companies and SMEs use banks as a source of external finance for more than 60%

of their investment needs<sup>33</sup>. While the heavy reliance on bank funding is not an issue per se, alternative sources of financing are needed in the EU to support entrepreneurship and improve access to finance for micro and high-growth companies. This has proved particularly relevant since the crisis, considering that access to credit was severely restrained and banks were particularly reluctant to finance SMEs<sup>34</sup>.

The crisis unveiled weaknesses in the European banking and financial sector, mainly due to insufficient liquidity and capital reserves and a pro-cyclical effect of financial regulation. This called for the introduction of regulatory reforms to increase the sector's resilience and led to, amongst others, the higher capital requirements of Basel III, implemented in the EU via the CDR IV package<sup>35,36</sup>.

However, while more restrictive capital requirements are needed to increase the resilience of the European banking sector, this may reduce the incentives for the regulated financial institutions to invest in SMEs<sup>37</sup>. Investing in SMEs, start-ups and innovation requires an appetite for risk and specific knowledge. Therefore, it is important to foster the common capital markets in the EU to provide more alternative funding choices for Europe's businesses and SMEs<sup>38</sup>. In this regard, venture capital companies play an important role in providing financing to start-ups and risky projects. However, the European venture capital market remains extremely less developed compared to that in the United States and, for example, Israel<sup>39</sup>.

31 Board of Governors of the Federal Reserve System (2012). Report to the Congress on the Availability of Credit to Small Businesses. Federal Reserve Board.

32 See European Investment Bank (2016).

33 European Investment Bank (2017). EIBIS 2016/2017: Surveying Corporate Investment Activities, Needs and Financing in the EU. EIB Economics Department.

34 See European Investment Bank (2016).

35 European Banking Authority: <http://www.eba.europa.eu/regulation-and-policy/implementing-basel-iii-europe>

36 The Basel Committee on International Banking Supervision (2010): The Basel Committee's response to the financial crisis: report to the G20; ISBN 92-9197-851-5.

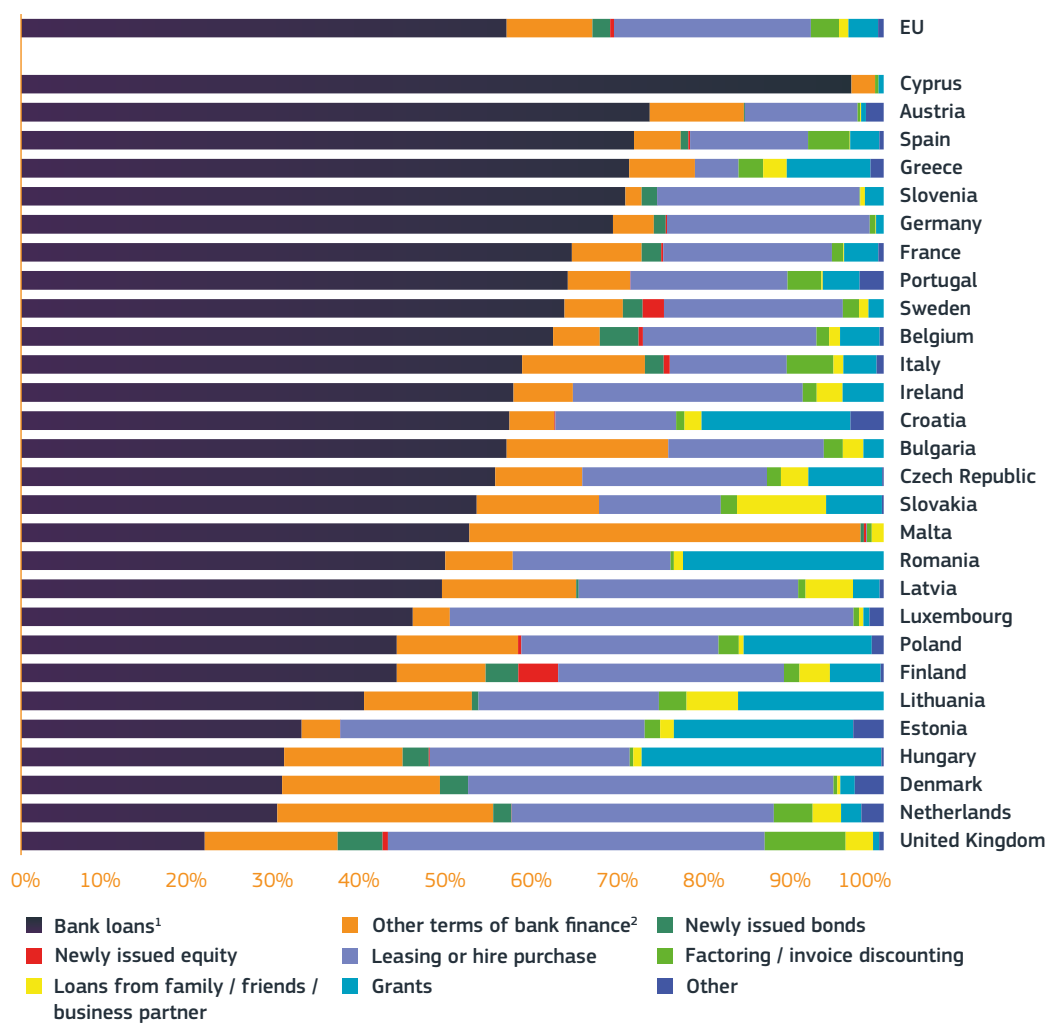
37 OECD (2012b), Financing SMEs and Entrepreneurs 2012: An OECD Scoreboard, OECD Publishing, <http://dx.doi.org/10.1787/9789264166769-en>

38 European Commission (2015b). Action Plan on Building a Capital Markets Union. COM(2015) 468 final.

39 OECD (2016b). Entrepreneurship at a Glance 2016. OECD Publishing, Paris: [http://dx.doi.org/10.1787/entrepreneur\\_aag-2016-en](http://dx.doi.org/10.1787/entrepreneur_aag-2016-en)



Figure I.5-B.8 Composition of external instment finance by source, 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: EIB

Notes: <sup>1</sup>Bank loans excluding subsidised bank loans, overdrafts and other credit lines. <sup>2</sup>Other terms of bank finance including overdrafts and other credit lines.

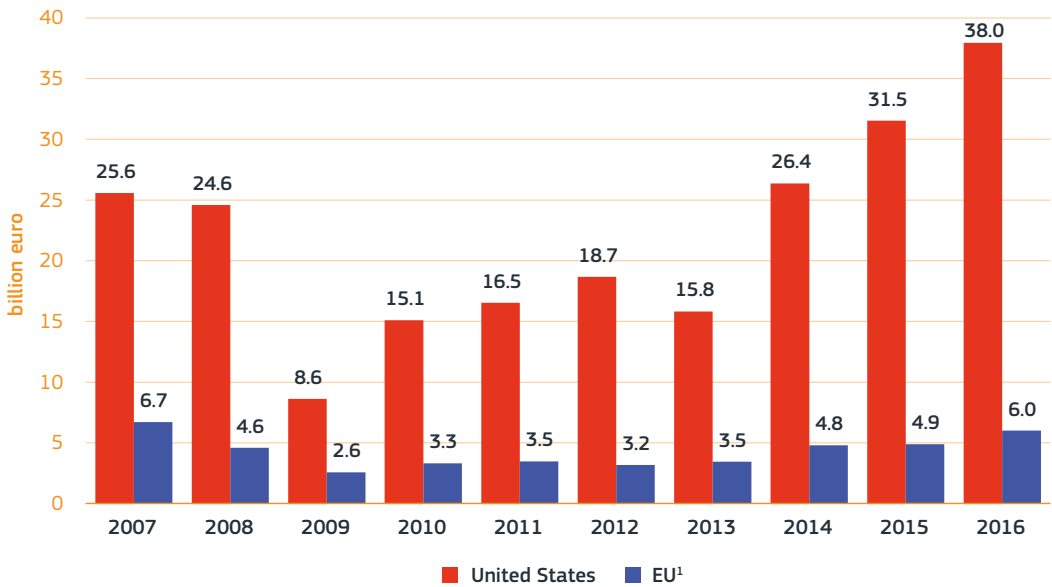
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_8.xlsx)

*The European venture capital market, crucial for providing risk capital for innovation, remains less developed compared to the United States. While the market has almost recovered since the crisis, later-stage financing in particular remains restricted.*

While the venture capital market has not only recovered in the United States, but even far exceeds its pre-crisis levels, the European venture capital market recovery is more modest, as can

be seen in Figure I.5-B.9. Indeed, even though the recovery is clearly visible, the EU's venture capital market still lags far behind that in the United States. While, in 2007, EU venture capital companies attracted EUR 6.7 billion in funding from various investors, compared to EUR 25.57 billion in the United States, this amount dropped to its lowest level at EUR 2.57 billion in 2009, followed by an unstable rise, reaching EUR 6.01 billion in 2016, while the United States attracted EUR 38 billion in the same year (Figure I.5-B.9).

**Figure I.5-B.9** Venture capital funds raised (billion euro) in the EU and in the United States, 2007-2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Invest Europe, NVCA / Pitchbook

Note: <sup>1</sup>EU does not include HR, CY, MT, SI, SK.

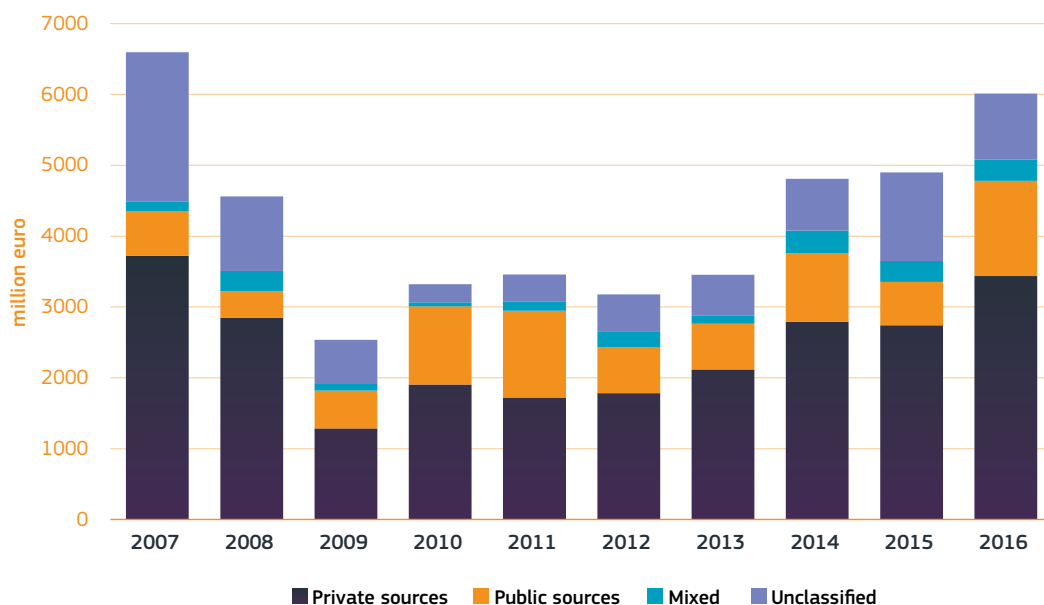
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_9.xlsx)

*The public sector has been a resilient source of venture capital in the EU, supplementing the volatility of private sources, and even slightly increasing its share during the years following the crisis.*

From Figure I.5-B.10 it is clear that public funding sources play an important role for venture capital in the EU. Indeed, funding provided by public sources to venture capital proved resilient and relatively stable and increased its volume compared to the ear-

ly years of the crisis. This is in contrast to the share of private funding which has been more volatile and has declined in value compared to 2007. The large fluctuations after the crisis are also linked to both the small size and concentration of the market, which is characterised by a relatively small amount of large venture capital funds (over EUR 100 million) providing a large share of the overall funding (80% of the total amount)<sup>40</sup>, and therefore not sufficiently diversified and more prone to volatility.

**Figure I.5-B.10** Venture capital in the EU<sup>1</sup> - new funds raised by source (million euro), 2007-2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Invest Europe

Note: <sup>1</sup>EU does not include HR, CY, MT, SI, SK.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_10.xlsx)

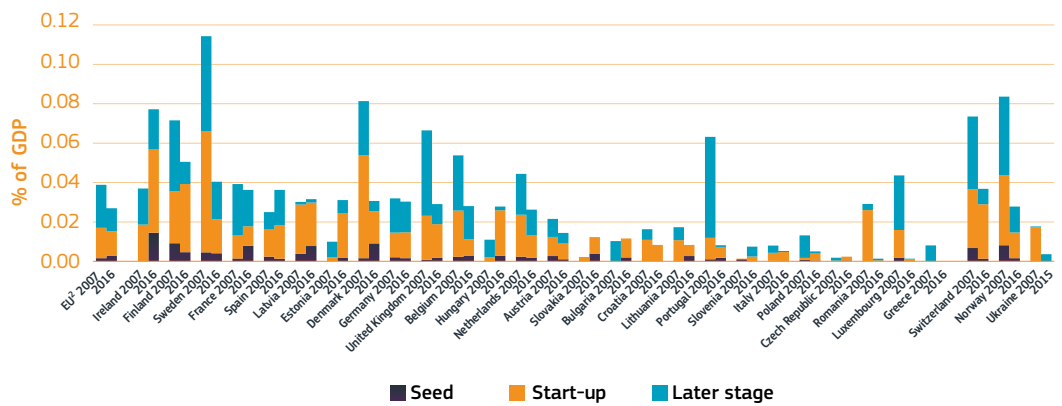
40 Invest Europe (2016). 2016 European Private Equity Activity: Statistics on Fundraising, Investments and Divestments: <https://www.investeurope.eu/media/651727/invest-europe-2016-european-private-equity-activity-final.pdf>.

*Since the crisis, funding for the scaling up<sup>41</sup> of companies has become scarcer, with later-stage financing accounting almost entirely for the overall fall in venture capital funding, as opposed to the visible recovery of the seed and start-up funding.*

As shown in Figure I.5-B.11, a shift can also be observed when looking at the stages of companies in which venture capital funds are investing<sup>42</sup>. a drop in venture capital funding from 0.039% to 0.027% can be seen following

the crisis. When taking a closer look at the evolution of financing by company stages, it becomes clear that later-stage financing has suffered the most, with seed financing exceeding pre-crisis levels and start-up funding showing some recovery (0.012% in 2016 as compared to 0.015% in 2007) whilst later-stage financing remains considerably lower. The opposite is true in the United States, where not only the overall amount of venture capital financing, but also the share of later-stage financing in overall venture capital funding has increased.

**Figure I.5-B.11 Venture capital (market statistics) by stage as % of GDP, 2007 and 2016<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Invest Europe, Eurostat

Notes: <sup>1</sup>UA: 2015. <sup>2</sup>EU does not include CY, MT.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_11.xlsx)

41 Please note that for scale-ups, normally both later-stage venture capital funding and growth or expansion equity capital are used; however, as the section focuses in particular on venture capital markets and in order to ensure consistency and the comparability of data across countries, we focus on later-stage financing in this analysis.

42 Duruflé, G., Hellmann, T. and Wilson, K. (2017). From start-up to scale-up: examining public policies for the financing of high-growth ventures. Bruegel Working Papers.

## Fulfilling the European single market

***The EU single market has shaped business, consumption and everyday life activities for all EU citizens for the last 25 years. It concerns the removal of barriers and regulatory obstacles to the free movement of goods, services and people.***

Such a process stimulates competition and trade, an efficient allocation of resources and investment flows across Europe and increases the opportunity spectrum for business and consumers alike. Overall, a functioning single market contributes strongly to enhancing the framework conditions for investment in innovative activities, as described in this section, with a positive effect on convergence, productivity and economic growth in the EU.

The road towards a complete functioning single market includes initiatives such as the Single Market Act I (2011) and II (2012) and the most recent Single Market Strategy (2015), in order to create more opportunities for business and consumers and to foster modernisation and innovation in Europe. The latter strategy aims to reduce uncertainty for business, especially SMEs and innovative start-ups, identifying regulatory requirements and countering the lack of access to finance. Most importantly, the Better Regulation framework provides the tool needed to assess the possible impacts on innovation of new policy proposals and to identify existing barriers and possible ways to remove them<sup>43,44</sup>.

Progress towards a fully integrated single market since 1995 is shown in Figure I.5-B.12.

The graph plots an average index resulting from the aggregation of 14 indicators representing the rate of integration, convergence and exchange across Member States. These include import and export of goods and services, foreign direct investment flows, the adoption of EU Directives, convergence in labour costs, interest rates, taxes, purchasing power and per-capita GDP between Member States. The larger the index value, the more integrated the EU market<sup>45</sup>.

***A steady rising trend can be observed, with an acceleration in 2003 for the EU-25. The EU was around 30% more integrated in 2015 than in 1995, with the trend also holding after the last crisis.***

Progress towards a fully functioning single market with no barriers to innovative investment depends on the rate of correct transposition of EU Directives by Member States. Figure I.5-B.13 shows the deficit in transposition, i.e. the rate of EU Directives yet to be adopted, and the compliance deficit, i.e. the share of incorrectly adopted Directives, in the EU. Only eight countries have respected the 1% target set for the transposition deficit. Such a deficit has doubled in the last year, with 20 Member States now above the threshold. Malta is the only Member State respecting the threshold, which was originally proposed in the Single Market Act in 2011 (0.5%). Significant progress has been made by Italy, having been in last position for 18 months. A similar scenario holds for incorrectly transposed Directives, with only nine countries below the 0.5% threshold, although five are very close to it. Malta and Estonia notably have achieved a perfect score (0%), the former for the fourth time<sup>46</sup>.

43 See European Commission (2015c). Upgrading the Single Market: more opportunities for people and business.

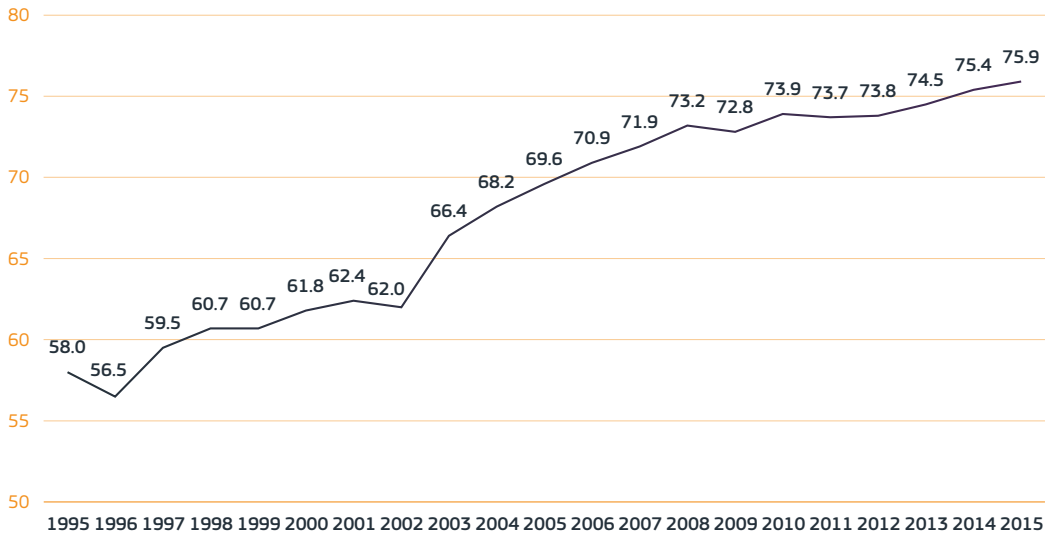
<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2015%3A550%3AFIN>, p.6.

44 The assessment and monitoring of framework conditions for growth and investment is also done for all Member States by the European Commission in the European Semester process. See: [https://ec.europa.eu/info/strategy/european-semester\\_en](https://ec.europa.eu/info/strategy/european-semester_en).

45 The index takes a value of 0 in case of no integration, while no upper limit is set. For more details about its composition, see: LE Europe (2017). The EU Single Market: Impact on Member States.

46 See the Single Market Scoreboard for further details: [http://ec.europa.eu/internal\\_market/scoreboard/performance\\_by\\_governance\\_tool/transposition/index\\_en.htm](http://ec.europa.eu/internal_market/scoreboard/performance_by_governance_tool/transposition/index_en.htm).

Figure I.5-B.12 Summary Index of Single Market integration<sup>1</sup> in the EU, 1995-2015



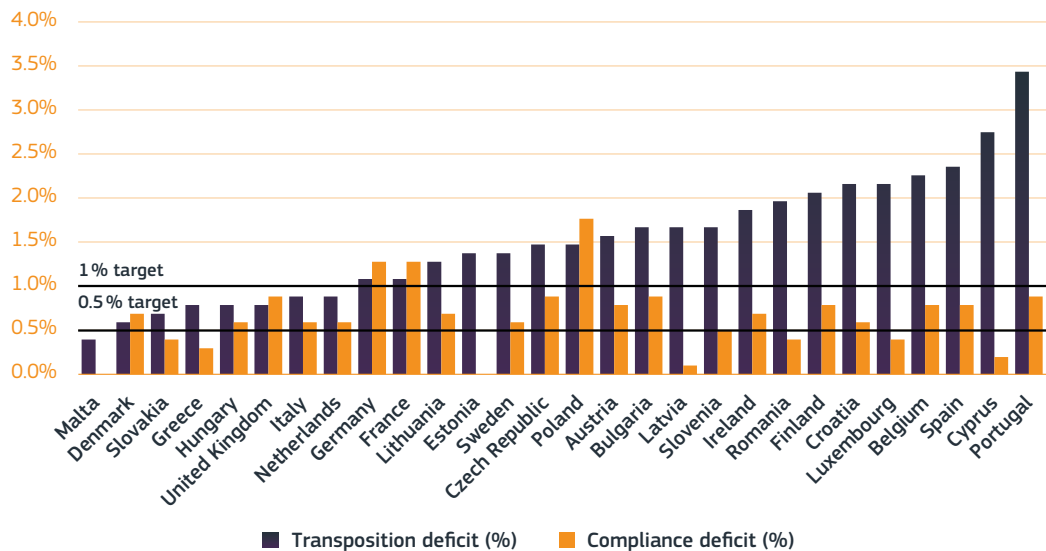
Science, Research and Innovation performance of the EU 2018

Source: London Economics, 2017

Note: <sup>1</sup>The indicator combines information on different aspects of the Single Market freedoms, the adoption of EU legislation by Member States and the extent to which the economic performance of individual Member States matches the EU economy overall. Although the minimum value of the index is zero (representing no integration at all), the index has no upper limit because the indicators of FDI and trade in goods and services included in the summary index have no upper limits.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_12.xlsx)

**Figure I.5-B.13** Transposition deficit<sup>1</sup> and compliance deficit<sup>2</sup> in EU Member States, 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: DG Internal market, Industry, Entrepreneurship and SMEs (Single Market Scoreboard, July 2017)

Notes: <sup>1</sup>The transposition deficit is the gap between the number of Single Market directives adopted by the EU and those transposed in Member States (the % refers to the % of all directives not transposed). <sup>2</sup>The compliance deficit is the number of incorrectly transposed directives (the % is the % of all directives transposed incorrectly).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-b\\_13.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-b_13.xlsx)

## CHAPTER I.5-C: FRAMEWORK CONDITIONS AND ZOMBIE FIRMS

*As a result of persisting rigidities that affect the well-functioning of the markets, 'zombie' firms<sup>47</sup> continue to 'capture' capital and labour resources that could otherwise be redirected towards innovative, more productive activities, thereby hindering Europe's innovation performance.*

The misallocation of resources, including credit, barriers to entry and inefficient product and labour markets ease the survival of less-productive firms which would otherwise have exited the market. Consequently, the economy is characterised by a wider distribution of productivity among firms, with a larger gap between the laggards and the most-productive companies.

*The reduction of exit rates of non-sustainable firms has both a direct and an indirect effect on labour productivity. As long as these companies survive by draining resources from the economy, the reallocation of resources towards more innovative and productive activities will be hampered. Capital, labour force and credit will be locked-in around non-productive activities and unable to be reallocated towards more-productive companies. In addition, this will directly slow down productivity growth by making a zero or negative contribution to the overall economic performance.*

Recent evidence by the OECD<sup>48</sup> has estimated that the survival of zombie firms triggers the indirect effect of *congesting* the market and draining resources from the most-productive firms.

Zombie companies are firms that survive on the market without being profitable in the long run, being artificially kept alive via a misallocation of external support and being too weak to stay on the market on their own. Their survival is due to the inefficiencies presented in this chapter, most notably those in the product market which reduce the entry rates of competitors, the erosion of exit margins, and the misallocation of credit towards non-productive activities.

*Since the start of the crisis, the number of such companies and the share of employment and capital stock locked in them have been increasing across countries, with the exception of France and the UK.*

Since the last economic crisis, estimates by the Bank of International Settlements indicate that the median share of zombie firms increased by around 10.5% in 2015, more than double the pre-crisis level<sup>49</sup>. The increase is most significant in Italy and Spain, especially in terms of capital stock. Figure I.5-C.1 is drawn from OECD (2017) and shows the increase in the number of zombie firms and their share of capital and employment in the overall economy. The capital stock share in 2013 is reported in Figure I.5-C.2.

*Improving framework conditions and stimulating a proper allocation of credit to the most innovative and productive activities is crucial to revert the trend and boost productivity growth in the EU and other advanced economies.*

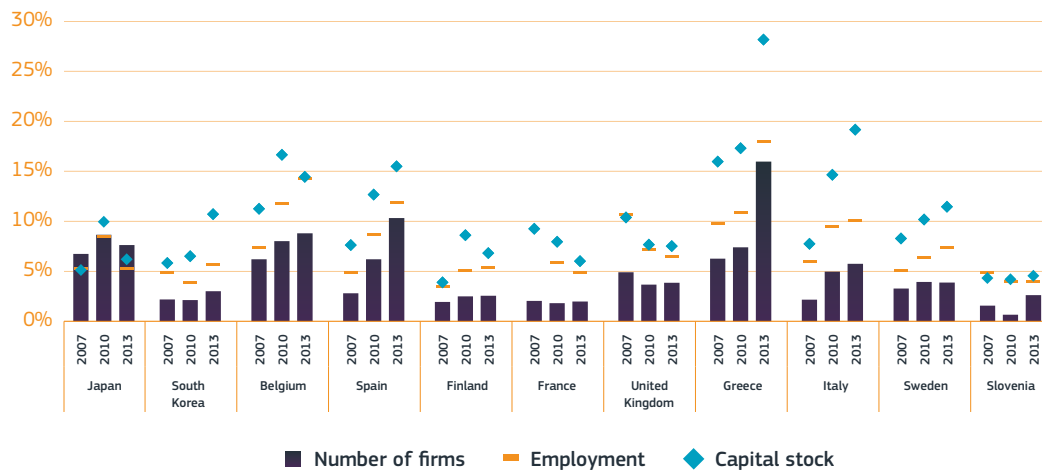
47 Here, zombie firms are defined as those companies with a ratio of operating income to interest expenses of less than one-third for three consecutive years, following McGowan, M.A., Andrews, D. and Millot, V. (2017). *The walking dead? Zombie firms and productivity performance in OECD countries* (No. 1372). OECD Publishing.

48 See McGowan et al. (2017).

49 See Bank for International Settlements (2017). 87th Annual Report, which applies a slightly different definition of zombie firms and a different sample of countries. The report considers zombie firms as listed firms with a ratio of earnings before interest and taxes to interest expenses below one, in a firm aged 10 years or more. The reported finding shows the median for the following countries: Austria, Belgium, Canada, Switzerland, Germany, Denmark, Spain, France, the UK, Italy, Japan, the Netherlands, Sweden and the United States.



**Figure I.5-C.1** Zombie firms<sup>1</sup> -% share in total firms, capital and employment 2007, 2010 and 2013



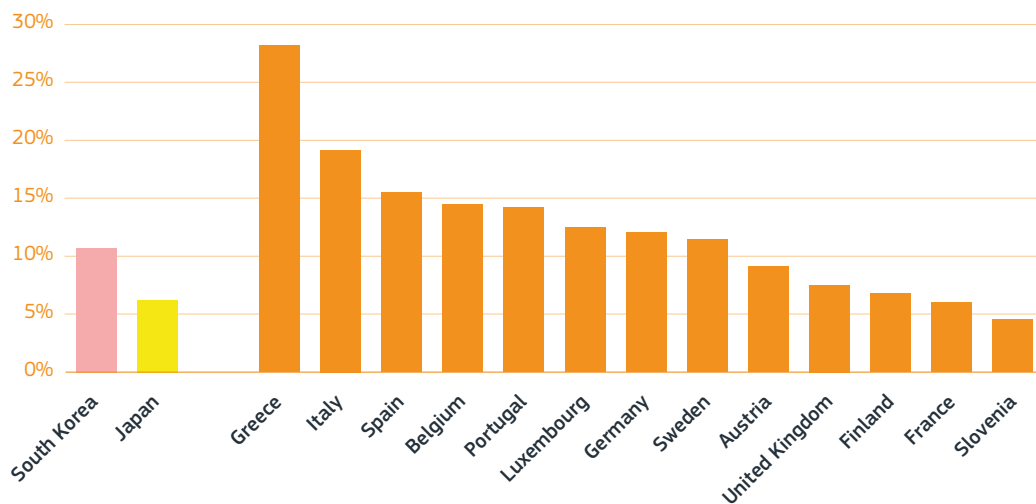
Science, Research and Innovation performance of the EU 2018

Source: OECD (Adalet McGowan, Andrews and Millot, 2017)

Note: <sup>1</sup>Zombie firms are firms aged  $\geq 10$  years and with an interest coverage ratio  $< 1$  over three consecutive years. Capital stock and employment refer to the share of capital and labour sunk in zombie firms. The sample excludes firms that are larger than 100 times the 99th percentile of the size distribution in terms of capital stock or number of employees.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-c\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-c_1.xlsx)

**Figure I.5-C.2** % share of capital sunk in zombie firms<sup>1</sup>, 2013



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD (Adalet McGowan, Andrews and Millot, 2017)

Note: <sup>1</sup>Zombie firms are firms aged  $\geq 10$  years and with an interest coverage ratio  $< 1$  over three consecutive years. The sample excludes firms that are larger than 100 times the 99th percentile of the size distribution in terms of capital stock or number of employees.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_5\\_figures/f\\_i\\_5-c\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_5_figures/f_i_5-c_2.xlsx)

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# CHAPTER

# I.6

# ENTREPRENEURSHIP AND STRUCTURAL CHANGE

Dynamic business environments that enable the birth and growth of innovative firms as well as the orderly exit of non-performing companies are crucial for innovation to flourish and be scaled up. Entrepreneurship, notably transformational entrepreneurship<sup>1</sup>, allows innovations to be brought on to the market to transform our economies by making them more productive. Flourishing innovation systems should support profound changes in our economic structures towards more productive, knowledge-based activities, enabling the economic and social impacts that support higher levels of prosperity in society.

Against this backdrop, this chapter assesses Europe's ability to build innovation-led transformational entrepreneurship as well as to shift its economic structure towards more productive, knowledge-intense activities.

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1 Transformational entrepreneurship relates to those new businesses which, from the outset, have the ambition to become big, which provide "disproportionally large contributions to net job creation" (Haltiwanger, 2014), and that invest proportionally more in R&D than older ones (Surowiecki, 2016).

## CHAPTER I.6-A: TRANSFORMATIONAL ENTREPRENEURSHIP

*Transformational entrepreneurship contributes to upgrading the economic structure and fosters economic and productivity growth, competitiveness and job creation.*

Start-ups, especially technology-enabled ones, are based on new and innovative business models that introduce product and process innovations<sup>2</sup> and hence bring new ideas and products on to the market. Due to their innovation-led nature, these young firms tend to grow much faster than other companies and contribute disproportionately to net employment creation (Criscuolo et al., 2014). Moreover, they also stimulate economic dynamism by increasing competition in the markets where they operate by forcing their competitors to adapt or exit the market through an efficient resource-allocation process of labour and capital that has the potential to increase productivity growth in the overall economy ('creative destruction'<sup>3</sup>). However, the creation and scale-up of start-ups is very dependent on certain framework conditions, such as the regulatory and administrative framework, access to risk finance, the existence of networks and collaborative arrangements to access knowledge, the availability of highly skilled human capital, and a vibrant entrepreneurial culture underpinning the development of these activities (OECD, 2014).

In this section, we assess whether innovation-led entrepreneurship is flourishing in Europe and leading to structural change. A comparative analysis of business dynamism and high-growth, scale-up and the 'transformational' potential of European firms relative to other major economies is provided alongside an assessment of the main barriers hampering innovative entrepreneurship in Europe and the most suitable policy responses to overcome them<sup>4</sup>.

*Despite significant differences across Member States, Europe fares well in traditional measures of entrepreneurship, such as start-up rates.*

Figure I.6-A.1 shows the start-up rates in 2009 and 2015 (or latest available year), i.e. the number of new and young companies (up to two years old) relative to the total number of employer enterprises in those given years. In addition, start-up rates in the overall economy are compared to those in high- and medium-high-tech sectors as well as in knowledge-intensive services (KIS) relative to the employer enterprises in those sectors.

In the latest available year, start-up rates associated with both the overall economy and knowledge-intensive services (KIS)<sup>5</sup> were higher in the EU than in the United States<sup>6</sup>,

2 EC Communication (2016).

3 Schumpeter (1942).

4 Some caveats in this analysis include the rapid pace of change, the impact of the crisis, availability of data for comparison purposes, and data issues related to the measurement of entrepreneurship, including in knowledge-intensive sectors.

5 Knowledge-intensive sectors include high-tech and medium-high-tech manufacturing and knowledge-intensive services in NACE Rev. 2 at the two-digits level. Please refer to the Annex for a more details.

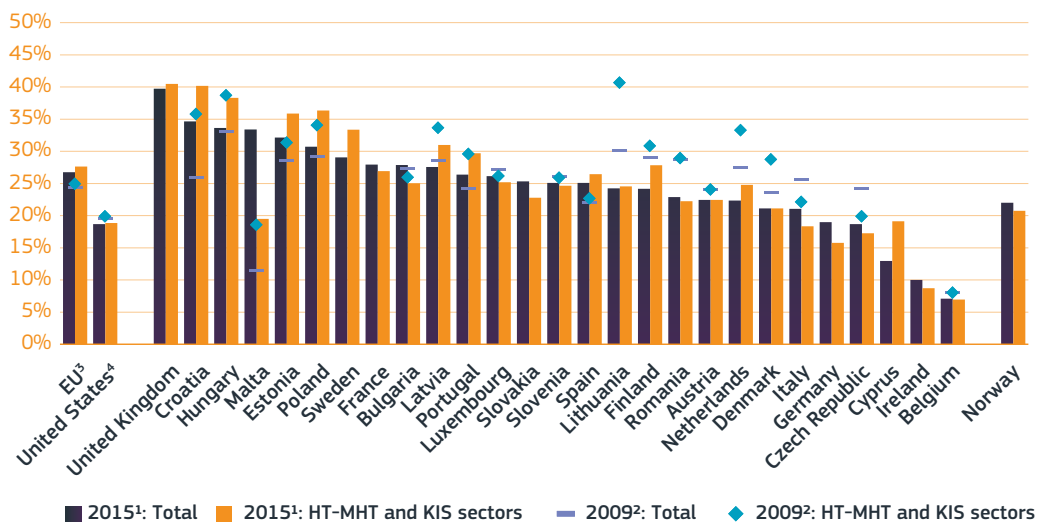
6 For the EU Member States, either 2012, 2014 or 2015; for the United States, 2012. However, Kauffman Foundation's 'Index on Start-up activity' points to a recovery in enterprise creation in the United States since 2013

(see: <http://www.kauffman.org/kauffman-index/profiles?loc=US&name=united-states&breakdowns=growth|overall,start-up-activity|overall,main-street|overall#indicator-panel-se-index>).

while start-up rates in KIS were slightly above those in the overall EU economy (25.9% vs. 23.6%). This points to the dynamism of this sector in terms of enterprise creation and to its potential to foster structural change. However, there are different patterns in the evolution of start-up rates between 2009 and 2015 (or latest available year): some Member States, such as Croatia, Malta, Estonia, Po-

land, Portugal and Spain managed to increase their start-up rates between 2009 and 2015; in others, such as Hungary and Belgium, start-up rates remained relatively stable; and most EU Member States actually contracted their share of share of start-ups in knowledge-intensive sectors during this period. This was particularly the case in Lithuania, the Netherlands, Denmark and Romania.

**Figure I.6-A.1 Start-ups (0 to 2 years old) as % of employer enterprises, 2009 and 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>BG, CZ, DE, ES, FR, HR, IT, LV, HU, AT, PL, SK, SE, NO: 2014; BE, DK: 2013; CY, US: 2012. <sup>2</sup>BE, BG, HR, LU, MT, PL, FI: 2012; DK, HR, LU, MT, PL, FI: 2012. <sup>3</sup>EU was estimated by DG Research and Innovation. <sup>4</sup>US: OECD ISIC3 classification was used.

<sup>5</sup>Data refer to employer enterprises statistics.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_1.xlsx)

*However, the share of new companies in knowledge-intensive sectors has been declining in most EU Member States, with some notable exceptions.*

The crisis seems to have interrupted the path of structural change led by more innovative entrepreneurship, albeit with some signs of recovery more recently. As mentioned above, higher start-up rates in knowledge-intensive sectors compared to the overall economy could induce economic transformation in Europe. Nevertheless, Figure I.6-A.1 shows that these start-up rates have declined in most EU Member States, most probably due to the negative impact of the crisis. This is somehow corroborated by Figure I.6-A.2 where the share of enterprise births in knowledge-intensive sectors in total enterprise births is depicted before and after the onset of the economic and financial crisis<sup>7</sup>.

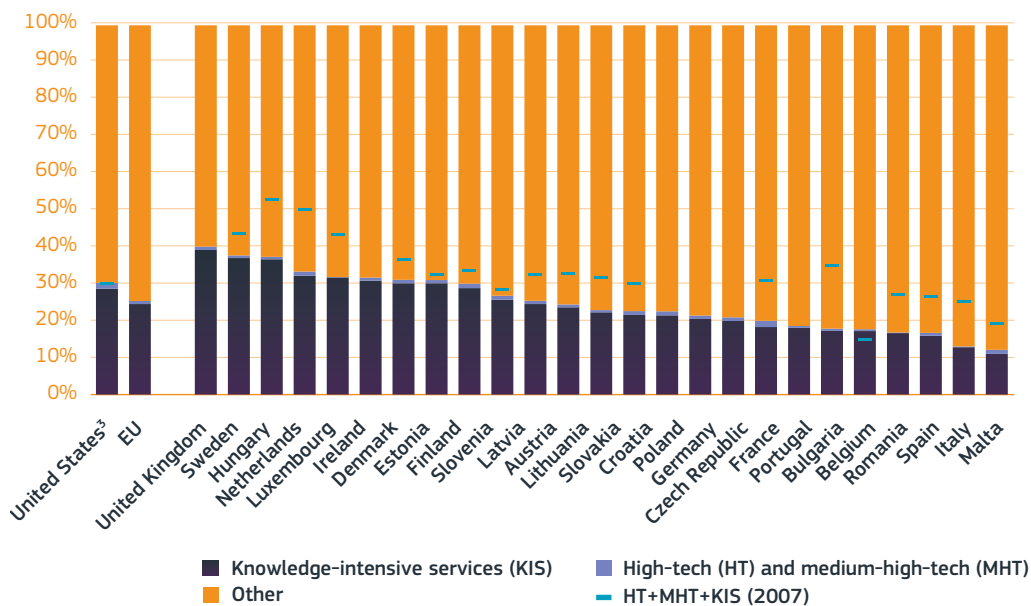
With a few exceptions among EU Member States, the majority experienced a decline in the share of births in knowledge-intensive sectors after 2007, although most also seem to show some signs of recovery in 2015 with an increase in the proportion of births in knowledge-intensive sectors. Since the service sector is typically more dynamic than manufacturing, it is not surprising that the bulk of innovative births were markedly concentrated around knowledge-intensive services, since they are typically more dynamic and have less fixed costs than manufacturing. The Czech Republic and Finland had the highest birth shares in high-tech and medium-high-tech sectors in 2015. Overall, the United Kingdom, Sweden and Hungary stand out as EU Member States where the share of births in knowledge-intensive sectors was above 35% of total enterprise births in 2015. New firms in knowledge-intensive sectors seem to be flourishing more in the United States than in the EU, including in high-tech and medium-high-tech sectors<sup>8</sup>.

7 Please note that in 2007 there was a break in series so this analysis needs to be done bearing that in mind.

8 Note that for the United States, employer enterprise statistics were used, while for EU Member States the data concern total active enterprises so the results should be assessed with caution when making comparisons.



**Figure I.6-A.2** Employer enterprise births by type of enterprise as % of total employer enterprise births, 2015<sup>1</sup> (and for 2007<sup>2</sup> total HT+MHT+KIS)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>US: 2012; BE, DK: 2013; BG, CZ, DE, ES, FR, HR, IT, LV, HU, AT, PL, SK, SE, EU: 2014. <sup>2</sup>US: 2008; BG, DK, MT: 2006.

<sup>3</sup>US: OECD ISIC3 classification was used. <sup>4</sup>Elements of estimation were involved in the compilation of the data.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_2.xlsx)

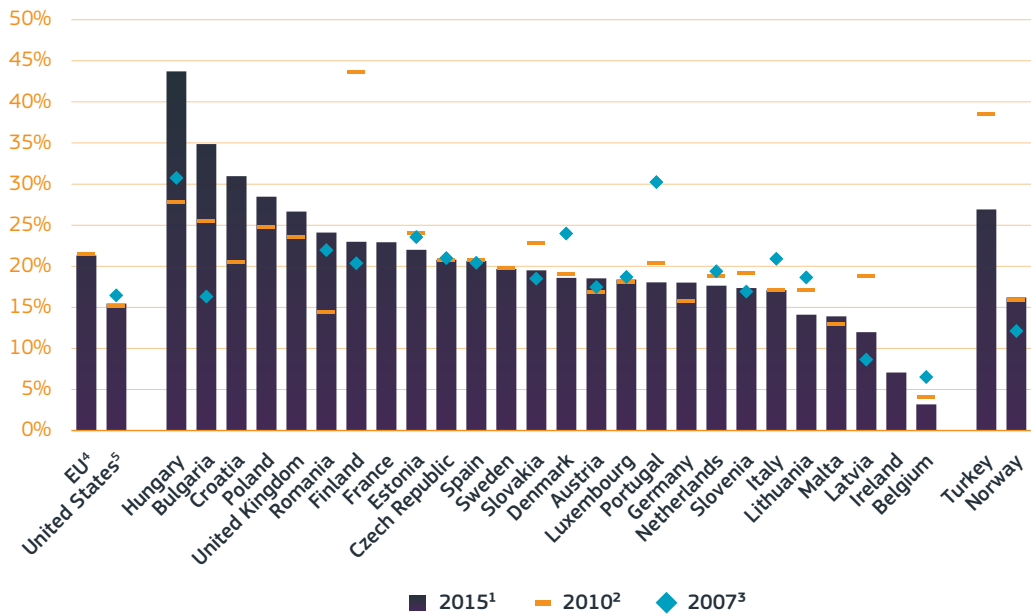
*The EU also scores well in business dynamism, including in KIS.*

Figure I.6-A.3 depicts the evolution of business churn in both the EU and the United States since 2007 related to employer enterprises. Churn rates correspond to the sum of company birth and death rates in a given country relative to the total number of employer enterprises. This measure of ‘economic dynamism’ shows how often new firms are created and existing enterprises closed, which can be associated with the so-called Schumpeterian process of ‘creative destruc-

tion’ whereby resources (i.e. capital and labour) are allocated to the most efficient firms which increases overall productivity growth.

On average, business dynamism in the EU remained relatively stable between 2010 and 2014 and above the United States in the latest year available (EU: 18.6%; United States<sup>9</sup>: 15.5%). However, the range of variation across EU Member States remains large, with Hungary (43.7%), Bulgaria (34.9%) and Croatia (31%) registering the highest churn rates, and the lowest business churn being in Belgium (3.2%), Ireland (7.1%) and Latvia (12%).

**Figure I.6-A.3** Churn rates (birth rate plus death rate) of employer enterprises, 2007, 2010 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>US: 2012; BE, DK, PL: 2013; BG, CZ, DE, ES, FR, HR, IT, LV, HU, MT, AT, SK, SE, NO, TR: 2014. <sup>2</sup>BE, BG, DK, DE, HR, MT, PL, SK, FI, SE, UK, NO, TR: 2012. <sup>3</sup>BG, DK, NO: 2005; EE, ES, LV, NL, SK, FI: 2006; US: 2008. <sup>4</sup>EU was estimated by DG Research and Innovation. <sup>5</sup>US: OECD ISIC3 classification was used.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_3.xlsx)

9 Due to data availability issues, data for the United States corresponds to 2012 so some caution is needed when assessing this result.

Figure I.6-A.4 highlights the fact that business churn also seems to be higher in Europe than in the United States when it comes to

high-, medium-high-tech and knowledge-intensive services sectors.

**Figure I.6-A.4** Employers' enterprise churn rates (birth rate plus death rate) - EU and the United States

Churn rates	EU <sup>1</sup>							
	2008	2009	2010	2011	2012	2013	2014	2015
Total economy	:	:	:	:	:	:	21.4	21.3
High-tech, medium-high-tech and knowledge intensive services	:	:	:	:	20.0	20.3	20.7	:

Churn rates	United States <sup>1,2</sup>							
	2008	2009	2010	2011	2012	2013	2014	2015
Total economy	16.5	14.9	15.1	15.5	15.5	:	:	:
High-tech, medium-high-tech and knowledge intensive services	15.9	14.4	14.6	15.1	15.3	:	:	:

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Estimates were included in the compilation of the data. <sup>2</sup>US: OECD ISIC3 classification was used.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_4.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_4.xlsx)

***Europe outperforms the United States in the share of high-growth firms.***

Figure I.6-A.5 shows that, according to the most recent data available, European firms have managed to foster their high-growth potential more significantly relative to American firms when it comes to growth of 20% or more in employment. This share was 4.3% in the EU and 2.9% in the United States for the overall economy, and is estimated to be 7.2% in the EU and 4.5% in the United States specifically in knowledge-intensive sectors in the latest year available. Indeed, according to the Kauffman Foundation (2016)<sup>10</sup>, high-growth entrepreneurship seems to have slowed down in the United States although some signs of recovery were reported in 2013<sup>11</sup>.

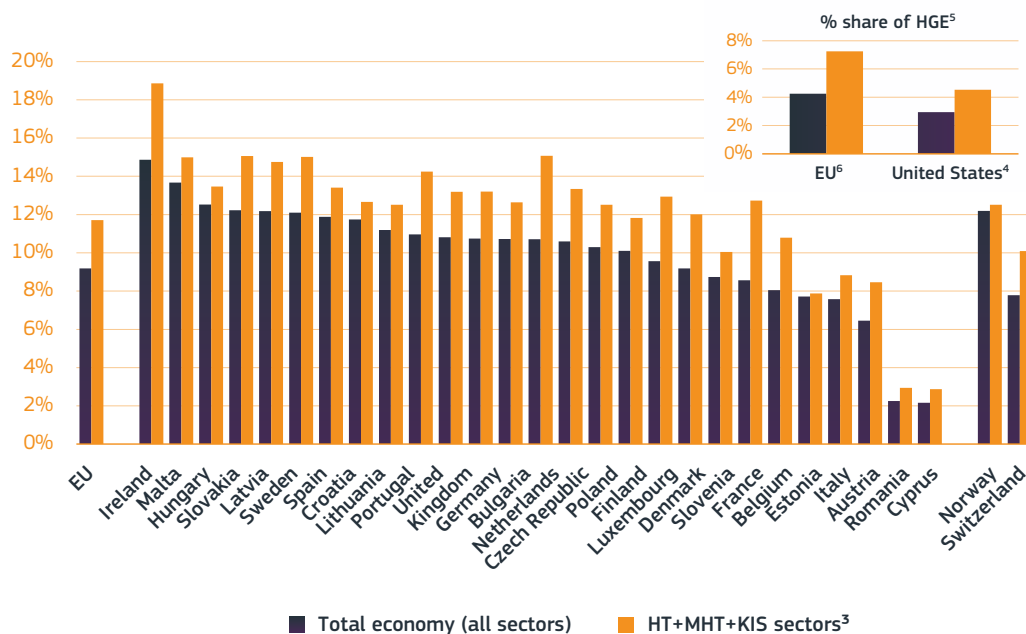
Almost 1 in 10 enterprises in the EU verified high-growth of 10% or more in employment in 2015.

While the EU's knowledge-intensive sectors seem to be producing a higher share of high-growth firms overall, there are substantial intra-EU differences. For instance, while high-growth firms in knowledge-intensive sectors seem to be quite well represented in Ireland, Slovakia, Malta, the Netherlands and Sweden, companies in these sectors in Romania and Cyprus (and also in the economy overall) seem to struggle to grow as fast as they do in other EU Member States.

10 Morelix et al. (2016).

11 Accordingly, the share of 'scale-ups' – defined as the number of companies that grow to employ at least 50 people in the first 10 years after creation as a percentage of all employer firms of 10 years and younger – rose in 2013.

**Figure I.6-A.5** % share of high-growth enterprises (HGE)<sup>1</sup> in total active enterprises - total economy and total high-tech (HT) plus medium-high-tech (MHT) plus knowledge-intensive services (KIS) sectors, 2015<sup>2</sup>



Science, Research and Innovation performance of the EU 2018  
 Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat, OECD

Notes: <sup>1</sup>Enterprises with at least 10 employees and with average annualised employment growth of 10% or more per annum over a three year period. <sup>2</sup>DK, CY, MT: 2014; US: 2012. <sup>3</sup>MT: 2013. <sup>4</sup>US: OECD ISIC3 classification was used. <sup>5</sup>The values for high-growth enterprises in the EU-US comparison refer to enterprises with at least 10 employees and with average annualised employment growth of 20% or more per annum over a three year period. <sup>6</sup>EU was estimated by DG Research and Innovation.  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_5.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_5.xlsx)

***This is also the case for young high-growth firms (gazelles), where Europe, and notably some Central and Eastern European countries continue to outperform the United States.***

Young, high-growth companies are typically R&D-intensive, tend to introduce disruptive innovations in the market, and even a small share contributes disproportionately to job creation. As a result, they play a major role in promoting innovation-driven economies and economic dynamism. Haltiwanger et al. (2016) analysed the pace of business dynamism and entrepreneurship in the United States over time and found that, since 2000, the decline in dynamism and entrepreneurship in the country has been accompanied in particular by a decline in high-growth young firms. This is substantiated in Figure I.6-A.6 which also shows that the share of European gazelles – young firms less than five years old with high-growth in employment of 20% or more – was significantly higher than the share of American gazelles in total high-growth enterprises in 2012. In addition, while there was a slight fall in this share in the United States between 2009 and 2012, in the EU the percentage of young high-

growth firms has increased. In absolute terms, the EU<sup>12</sup> also outperformed the United States in 2012; in fact, France alone outnumbered the United States in gazelles. However, there are significant intra-EU disparities with some economies ‘in transition’, such as Romania, Bulgaria and Lithuania, registering the highest shares of gazelles in high-growth firms.

This apparent “reduction in the ability of (American) companies to scale in a meaningful and systematic way”<sup>13</sup> could be partly explained by the greater power of established incumbents<sup>14</sup> and hence the concentration of benefits around a few so-called ‘superstar’ companies which are successfully mastering information technology<sup>15</sup>. According to Hathaway and Litan (2014), this concentration has increased substantially in the United States over the last three decades, which may have reduced the overall chances of new firms in the marketplace to grow as fast as they might expect, including in more innovative sectors. This could explain why, as Haltiwanger et al. (2016) put it: “the likelihood of a young firm being a high-growth firm has declined” in the country.

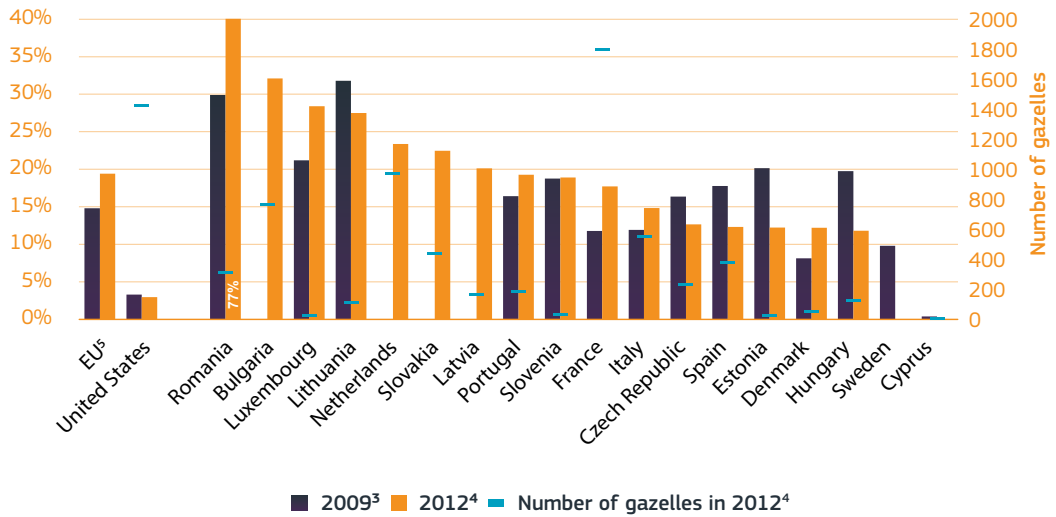
12 The EU absolute value is the sum of the number of gazelles for the EU Member States for which data are available which poses some limitations in the comparison with the United States.

13 Stern et al. (2016).

14 MIT Technology Review (2016).

15 Harvard Business Review (2017).

Figure I.6-A.6 % share of gazelles<sup>1</sup> in high-growth enterprises<sup>2</sup>, 2009 and 2012



Science, Research and Innovation performance of the EU 2018  
 Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Eurostat, OECD SDBS database

Notes: <sup>1</sup>Gazelles are enterprises up to 5 years old with at least 10 employees and with an average annualised employment growth greater than 20% per annum over a three year period. <sup>2</sup>High-growth enterprises: all enterprises with at least 10 employees and with average annualised employment growth greater than 20% per annum over a three year period.

<sup>3</sup>SE: 2008; CY, LT: 2010. <sup>4</sup>DK, LT, LU, SI: 2011. <sup>5</sup>EU was estimated by DG Research and Innovation.

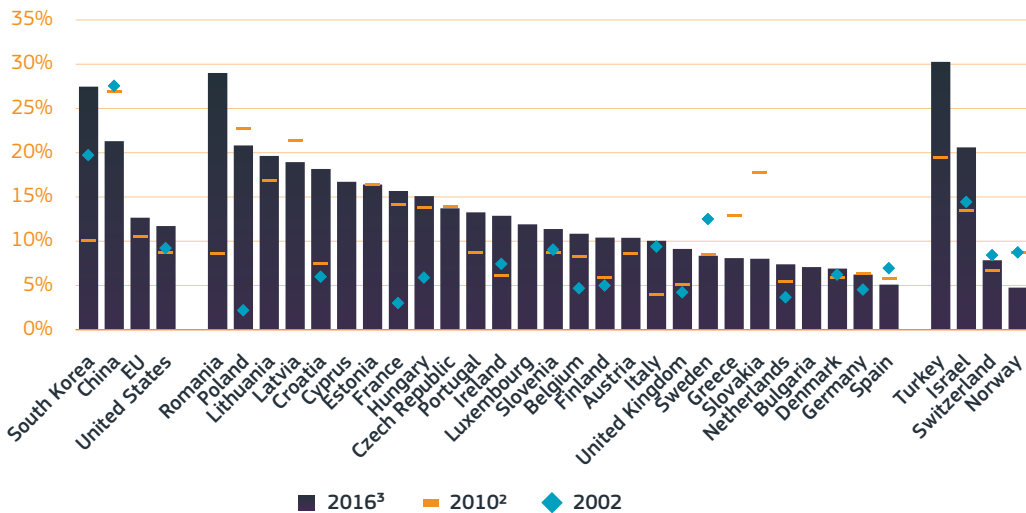
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_6.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_6.xlsx)

**Moreover, entrepreneurial intention is on the rise in Europe.**

According to the Global Entrepreneurship Monitor (GEM) which looks into ‘entrepreneurial behaviour and attitudes’, based on GEM’s adult population survey, entrepreneurial intention – the percentage of adults who intend to start a business within three years – rose in most EU countries between 2010 and 2016 (Figure I.6-A.7) with many reporting a greater intention to become entrepreneurs than in the United States, but all (except Romania) below China and South Korea in 2016. In 2016, the seven EU Member States where entrepreneurial intention

was the highest are all from the most recent enlargement processes (2004, 2010 and 2013). In relative terms, these are at an economic ‘transition stage’, and with the enlargement process they gained access to a wider market with more opportunities for business expansion (including e.g. access to new financing/funding instruments) and with more knowledge and technological diffusion to these countries, which may have made entrepreneurship more ‘appealing’. In addition, self-employment may be seen as an interesting option when compared to the existing job opportunities (and job quality) there. These may be two possible explanations although there are certainly others, too.

**Figure I.6-A.7 Entrepreneurial intention<sup>1</sup> by country, 2002, 2010 and 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Global Entrepreneurship Monitor

Notes: <sup>1</sup>Percentage of population aged 18-64 (not including individuals involved in any stage of entrepreneurial activity) who are latent entrepreneurs and who intend to start a business within three years. <sup>2</sup>CZ, LT, PL, SK, NO: 2011, EE, AT: 2012. <sup>3</sup>DK, LT: 2014; BE, RO, NO: 2015.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_7.xlsx)



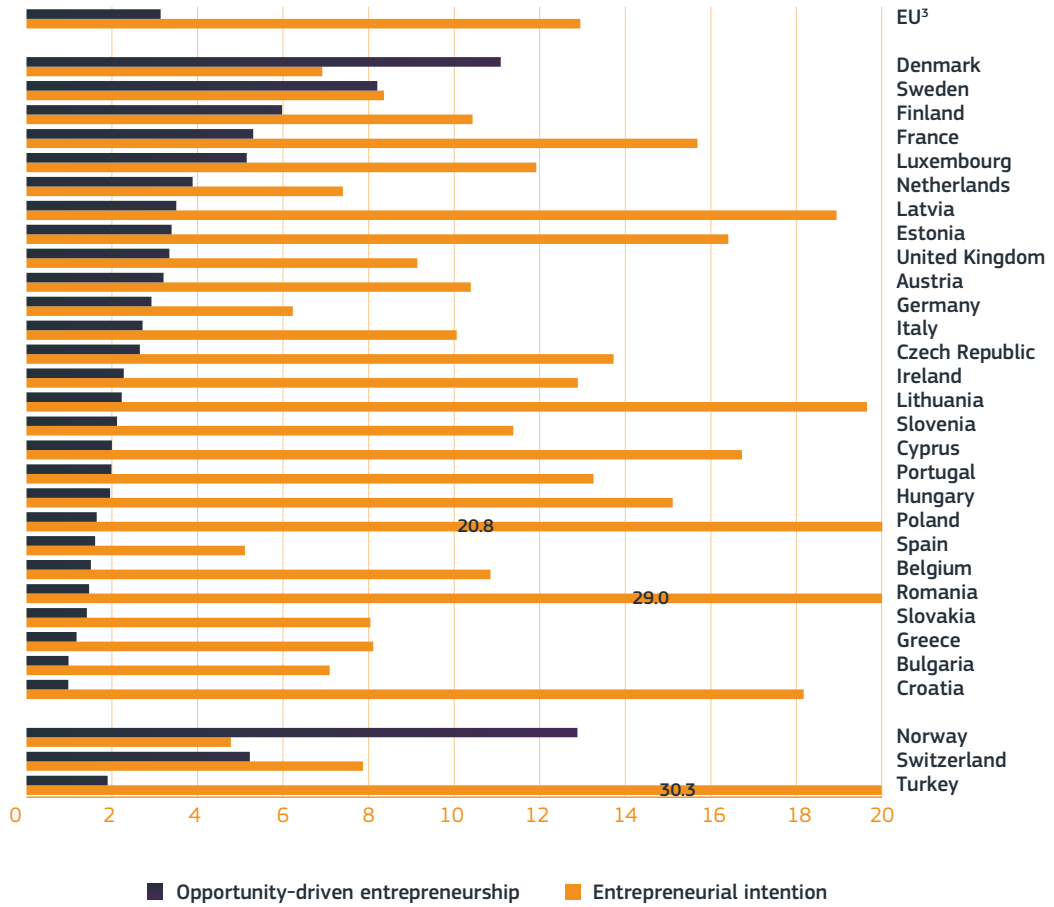
*However, there seems to be different intra-EU motivations driving the interest to become an entrepreneur: from subsistence to transformational.*

Entrepreneurial intention is depicted in Figure I.6-A.8 together with the opportunity-driven entrepreneurship indicator calculated as the ratio between the share of people involved in improvement-driven entrepreneurship and the share of those involved in necessity-driven entrepreneurship. Broadly speaking, this indicator can be seen as a motivational index in the sense that it attempts to capture whether the intention to become an entrepreneur in a given country is mainly driven by the existence of business opportunities in the market, or whether this intention is more necessity-driven because, for example, there are no better choices for work. Bholá et al. (2006) also found that necessity entrepreneurs are driven by push motivations and opportunity entrepreneurs mostly by pull motivations. In addition, they have concluded that for opportunity-driven entrepreneurs, administrative complexity and the unfavourable economic climate negatively influence their intention to become entrepreneurs, while this is not the case for necessity-driven entrepreneurs.

In line with the findings of the EIS (2017), Figure I.6-A.8 shows that countries with a high relative prevalence of improvement-driven opportunity entrepreneurship appear primarily to be more advanced<sup>16</sup>, innovation-driven economies. In these countries, opportunities may be expected to be more abundant, and individuals may have more alternative ways to make a living. Therefore, while Member States such as Romania, Poland and Croatia verify in relative terms very high entrepreneurial intention, as mentioned before, in these countries the opportunity-driven entrepreneurship ratio is at the same time very low, which seems to indicate that in these countries the motivation to become an entrepreneur might be, in relative terms, mainly linked to unemployment situations or higher dissatisfaction with their jobs. Denmark, Sweden and Finland, the three EU 'innovation leaders' in the EIS 2017, have the highest opportunity-driven entrepreneurship ratios (only outperformed by Norway) even though overall their entrepreneurial intention is markedly below other EU Member States.

16 Wennekers et al. (2006) also found that the ratio of opportunity to necessity entrepreneurship seems to be higher in countries with higher per-capita income.

**Figure I.6-A.8 Entrepreneurial intention<sup>1</sup> and opportunity-driven entrepreneurship<sup>2</sup> by country, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Global Entrepreneurship Monitor, European Innovation Scoreboard 2017

Notes: <sup>1</sup>Percentage of population aged 18-64 (not including individuals involved in any stage of entrepreneurial activity) who are latent entrepreneurs and who intend to start a business within three years. <sup>2</sup>The opportunity-driven entrepreneurship index is calculated as the ratio between the share of people involved in improvement-driven entrepreneurship and the share involved in necessity-driven entrepreneurship; three year averages were used (EIS2017). <sup>3</sup>EU does not include Malta.

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***However, in terms of the transformational impact of entrepreneurship, Europe trails behind the United States.***

In 2013, Aileen Lee – an American seed investor – analysed the start-up and tech ecosystem<sup>17</sup> and spotted a rapidly expanding group of 39 start-ups valued at more than US\$ 1 billion which she coined as ‘unicorns’ due to their “rarity”. Four years later, this has become an ‘increasingly crowded club’ (CB Insights, 2017<sup>18</sup>) with an accumulated number of 261 unicorns as of July 2017, including exits through IPOs or acquisitions (Box 7). In addition, the boom in the evolution of the NASDAQ-100 Index<sup>19</sup>, shown in the graph, illustrates one of the main reasons behind the “technological hype” and explosion in the number of unicorns mainly between 2009 and 2015 – the presence of “vibrant public markets

fuelling optimism” in the tech sector. However, it seems that in the last two years, the number of new unicorns has slowed down, even though the NASDAQ-100 has risen.

Despite the growing number of unicorns since 2009, these companies remain part of an ‘exclusive group’ in relative terms – for example, Lee (2015) calculated that in 2015 only 0.14% of software and internet companies funded in the past decade reached the unicorn status (2014: 0.07%) although, accordingly, calculating unicorn probability with accuracy is difficult.

The general characteristics of unicorns are summarised in Box 7 based mainly on a study performed by the European Commission’s Joint Research Centre (JRC) on a sample of exited unicorns<sup>20</sup>.

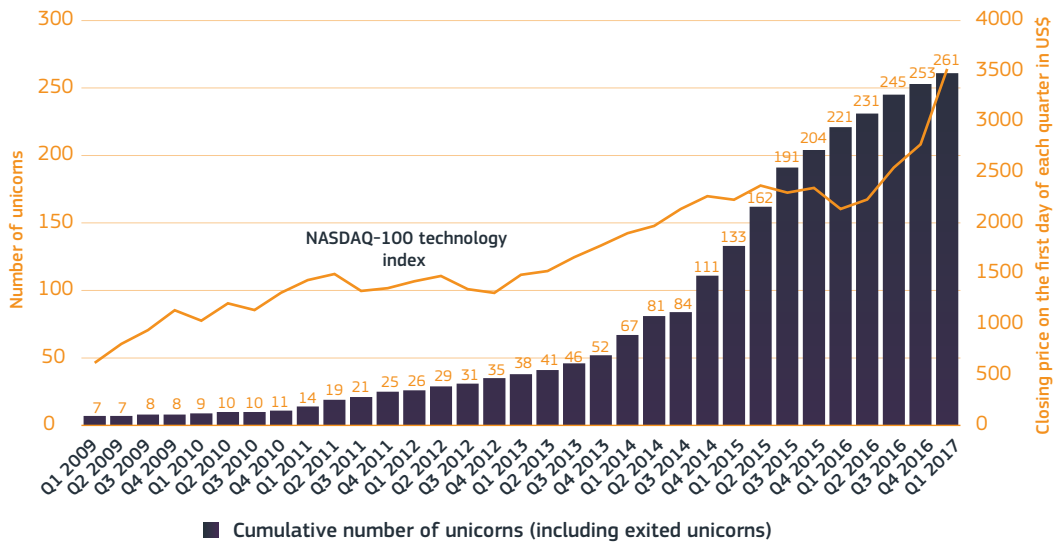
17 Aileen Lee (2013), ‘Welcome to the Unicorn Club: Learning from Billion-dollar Start-ups’, Contribution to TechCrunch.

18 <https://www.cbinsights.com/research/increasingly-crowded-unicorn-club/>

19 The NASDAQ-100 Index is an equal-weighted index based on the securities of the NASDAQ-100 Index that are classified as technology according to the Industry Classification Benchmark (ICB) classification system.

20 Jean Paul Simon (2016).

**Figure I.6-A.9** Cumulative number of unicorns (including exited unicorns)<sup>1</sup> and the closing price of the NASDAQ-100 technology index, 2009-2017 (by quarter)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Graph generated based on NASDAQ data - <http://www.nasdaq.com/symbol/ndx/interactive-chart>; Crunchbase data on unicorns (as of July 2017).

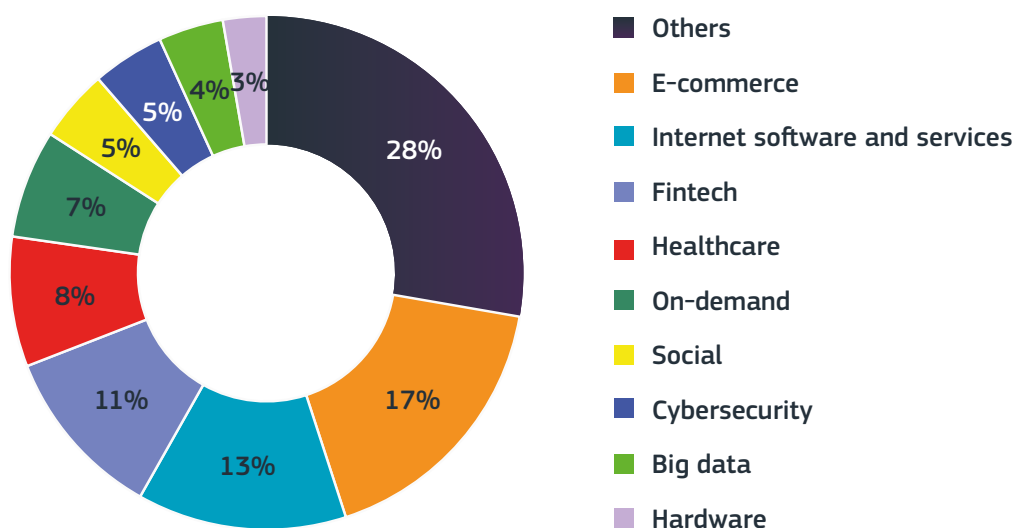
Note: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation at more than US\$ 1 bn. Exited unicorns are no longer private unicorns due to acquisition or IPO.

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## BOX 7: Main common characteristics of Unicorns

- ▶ IT-centred: E-commerce, internet software and services, and Fintech dominate (Figure I.6-A.10)
- ▶ Often young global companies that match unsatisfied demand with supply through the provision of innovative and usually affordable services and products with a high scaling-up potential
- ▶ Part of the mobile internet wave, relying on connectivity (high-speed networks, mobile and fixed)
- ▶ Rely on new devices (e.g. smartphones and tablets) and the opportunities they bring
- ▶ such as through apps. The launch of the iPhone (in 2007) and the Android (in 2008) have contributed to this trend
- ▶ Based on network effects, demand-side economies of scale and scope
- ▶ Highly dependent on a favourable business environment, and in particular on access to venture capital
- ▶ The competition for funding can generate impressive (i.e. inflated) valuations
- ▶ Can be disruptive for other sectors and firms

Figure I.6-A.10 Private unicorn companies<sup>1</sup> by sector - % shares, December, 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: CBinsights

Note: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation of more than US\$ 1 bn.

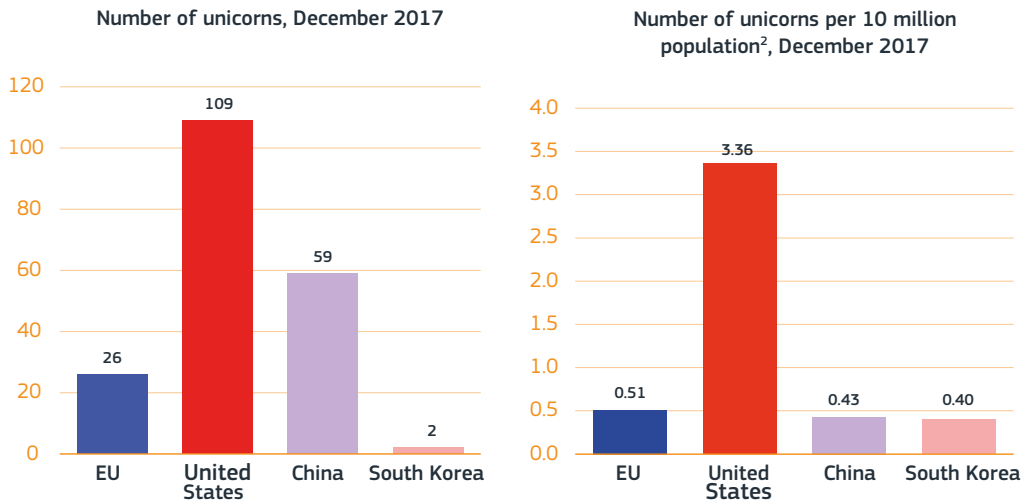
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_10.xlsx)

*The number of private unicorn companies is much lower in Europe than in the United States or China.*

However, Figure I.6-A.11 shows that Europe is still lagging behind in terms of the number of companies reaching the unicorn status of more than US\$ 1 billion in post-money valuation, while the United States is remarkably leading the production of private unicorns. In fact, at the end of 2017, there were 26 private unicorns in the EU compared to 109 in the United States and 59 in China which is quickly catching up. When

controlled for the size of the population, the EU remains a weak player but compares similarly with China, while the United States maintains its pronounced leading position. Hence, despite the relatively lower overall high-growth performance of companies in the United States, as mentioned above, according to new research by Stern and Guzman (2016)<sup>21</sup> on entrepreneurial growth potential, it would appear that 'high-quality' and highly-ambitious American start-ups are still being set up and are shaping the United States economy with their high R&D investments and radical innovations.

**Figure I.6-A.11 Private unicorns<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: CBInsights, OECD, Eurostat

Notes: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation of more than US\$ 1 bn.

<sup>2</sup>Population data refer to 2016.

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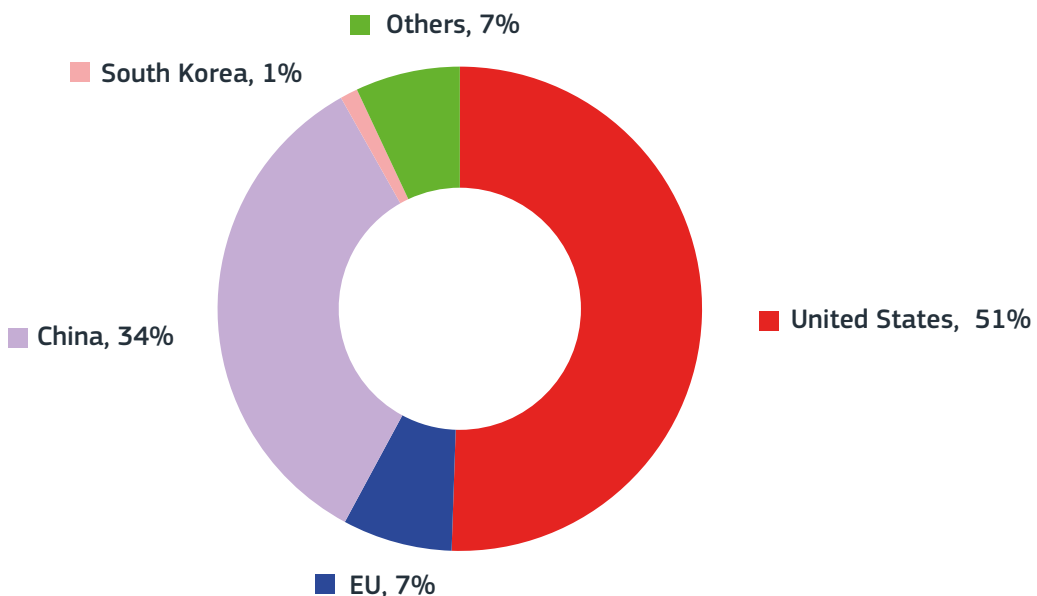
21 Stern and Guzman (2016).

*The company valuation of private unicorn companies in Europe is also much lower than in the United States or China.*

Figure I.6-A.12 enhances the United States' superiority in terms of 'excellence' in entrepreneurship, as measured by the share of each

major economy in total private valuation of unicorns, with American companies aggregating more than half of this valuation while the EU's share is only 7%. China has also managed to increase the quality of its entrepreneurial performance and currently has a share slightly above one-third of the total unicorn valuation.

**Figure I.6-A.12** Total valuation of private unicorns<sup>1</sup> - geographical distribution (%), December, 2017



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: CBInsights

Note: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation of more than US\$ 1 bn. Exited unicorns, due to acquisition or IPO, are not included.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_12.xlsx)

***Likewise, unicorn companies' R&D investment is much lower in Europe than in the United States.***

Some unicorns are also highly R&D-intensive, especially those in the software and computer services sector which have either exited through an IPO or were acquired. Out of the 186 unicorn exits<sup>22</sup>, almost 25% were in the top 2500 global companies ranked by R&D according to the 2017 EU Industrial R&D Scoreboard<sup>23</sup>. Most companies in Figure I.6-A.13 are

from the United States, with just two from the EU (out of the 20 European unicorns that have *exited* since 2009)<sup>24</sup>. Moreover, together these companies contribute significantly to job creation with Facebook having the largest number of employees. However, it is important to note that of the 40 companies represented in the table below, only 7 were profitable which raises questions on the sustainability of unicorns and whether their previous valuations may have been over-inflated.

22 According to CBInsights' 'Unicorn Exits Tracker', accessed on 4 December 2017. Exits include IPOs, acquisitions, corporate majority, mergers and reverse mergers.

23 This excludes companies that do not disclose information on R&D investments publicly. This concerns, for instance, Alibaba (China) which, however, is reputed to invest heavily in R&D. In fact, the company is expected to invest US\$ 15 billion in R&D labs (see: <https://www.ft.com/content/774080c4-1a34-3998-b787-87c029c3cf36>).

24 This includes exited unicorns from Germany (Delivery Hero, Hello Fresh, Rocket Internet, Zalando, Ganymed Pharmaceuticals), Finland (Rovio Entertainment, Supercell), United Kingdom (Skyscanner, O3B Networks, Novocure, Adaptimmune, Markit, Just Eat, Betfair), the Netherlands (Takeaway.com, Acerta Pharma, Dezima Pharma), France (Criteo), Ireland (King Digital Entertainment) and Denmark (Sitecore) that have exited through an IPO, were acquired or went through a corporate majority.



**Figure I.6-A.13 Exited unicorns<sup>1</sup> that went public after 2009 and are in the world top 2500 companies as ranked by total R&D investment**

Rank	Company	Country	Sector	R&D intensity <sup>2</sup> (%)	Profitability (%)	Number of employees
19	FACEBOOK	United States	Software & Consumer Services	21.4	45.0	17,000
174	TWITTER	United States	Software & Computer Services	33.1	-14.5	3,600
175	TESLA	United States	Automobiles & Parts	11.9	-9.5	17,800
206	WORKDAY	United States	Software & Computer Services	43.4	-25.0	6,600
353	PALO ALTO NETWORKS	United States	Software & Computer Services	19.7	-10.2	4,600
366	GOPRO	United States	Leisure Goods	28.3	-31.5	1,600
376	FITBIT	United States	Healthcare Equipment & Services	15.0	-5.2	1,800
380	ZYNGA	United States	Software & Computer Services	43.2	-15.4	1,700
403	TABLEAU SOFTWARE	United States	Software & Computer Services	36.6	-16.9	3,200
410	SPLUNK	United States	Software & Computer Services	31.1	-36.2	2,700
427	FIREEYE	United States	Software & Computer Services	40.3	-58.4	2,900
431	SERVICENOW	United States	Software & Computer Services	20.5	-11.0	4,800
442	ARISTA NETWORKS	United States	Software & Computer Services	24.2	21.6	1,500
449	SQUARE	United States	Software & Computer Services	15.8	-7.0	1,900
458	JUNO THERAPEUTICS	United States	Pharmaceuticals & Biotechnology	333.0	-329.0	500
462	YANDEX	Russian Federation	Software & Computer Services	20.9	17.5	6,300
484	PURE STORAGE	United States	Technology Hardware & Equipment	33.8	-29.5	1,700
599	SNAP	United States	Software & Computer Services	45.4	-128.7	1,900
718	FIBROGEN	United States	Pharmaceuticals & Biotechnology	80.7	-29.9	400
736	IRONWOOD PHARMACEUTICALS	United States	Pharmaceuticals & Biotechnology	50.9	-18.8	700
761	LENDINGCLUB	United States	Financial Services	11.4	-12.6	1,500
868	CRITEO	France	Media	6.5	6.7	2,500
869	NUTANIX	United States	Software & Computer Services	15.2	-55.7	:
877	BOX	United States	Software & Computer Services	29.1	-37.8	1,500
949	CLOUDERA	United States	Software & Computer Services	39.2	-71.8	1,500
981	VEEVA SYSTEMS	United States	Software & Computer Services	17.9	19.8	1,800
1056	TWILIO	United States	Mobile & Telecommunications	32.1	-14.9	700
1170	SHOPIFY	Canada	Software & Computer Services	20.3	-9.5	1,900
1196	NANTHEALTH	United States	Software & Computer Services	75.9	-160.9	900
1269	UBIQUITI NETWORKS	United States	Technology Hardware & Equipment	8.0	33.5	700
1288	ETSY	United States	General Retailers	18.5	4.8	1,000
1309	CHEGG	United States	Software & Computer Services	26.1	-16.2	800
1329	NEW RELIC	United States	Software & Computer Services	24.7	-23.3	1,100
1570	QUOTIENT TECHNOLOGY	United States	Software & Computer Services	18.6	-9.5	700
1688	NOVOCURE	United Kingdom	Pharmaceuticals & Biotechnology	55.7	-131.4	500
1696	GOGO	United States	Fixed Line Communications	7.7	-4.5	1,200
1746	OKTA	United States	Software & Computer Services	27.5	-51.8	900
1873	CASTLIGHT HEALTH	United States	Software & Computer Services	39.8	-58.0	400
1958	ADURO BIOTECH	United States	Pharmaceuticals & Biotechnology	73.1	-141.8	200
2096	MEITU	China	Software & Computer Services	14.8	-39.4	1,300
2124	MULESOFT	United States	Software & Computer Services	17.5	-25.8	800

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EU Industrial R&D Investment Scoreboard 2017 and CBinsights (exited unicorns since 2009), accessed on 04 December 2017

Notes: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation of more than US\$ 1 bn. <sup>2</sup>The ratio between the company's R&D investment and net sales.

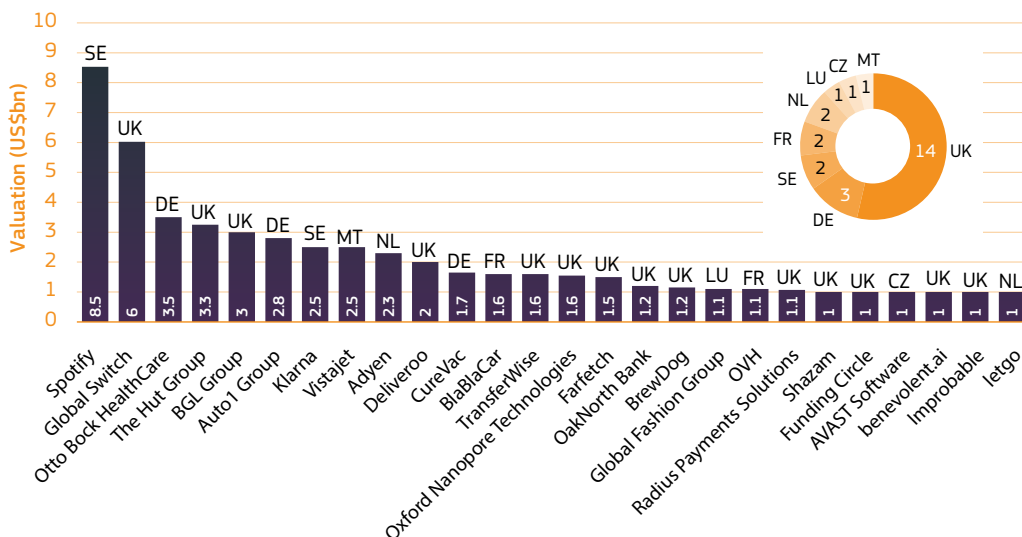
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*Within Europe, there is a high concentration of unicorn firms in core countries, with only one in Southern Europe and another one in Central and Eastern Europe.*

When looking into intra-EU performance, the number of unicorns is very concentrated in the UK which is ‘home’ to more than 50% of the EU unicorns. Germany comes next with three unicorns, France, Sweden and the

Netherlands with two each and Luxembourg, Malta and the Czech Republic with one unicorn each (Figure I.6-A.14). The significant gap in valuation between EU and American unicorns is also evident from the difference in valuation at the top – while the Union’s most valuable unicorn, Spotify, reached US\$ 8.5 billion, Uber’s 2017 valuation of US\$ 68 billion positions the company as the leading private unicorn in the United States.

**Figure I.6-A.14 Private unicorns<sup>1</sup> in EU Member States with valuation in US\$bn, December 2017**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: CBInsights, as of 4 December 2017

Note: <sup>1</sup>A unicorn is a private company with a post-money (i.e. ‘after funding’) valuation at more than US\$ 1 bn.

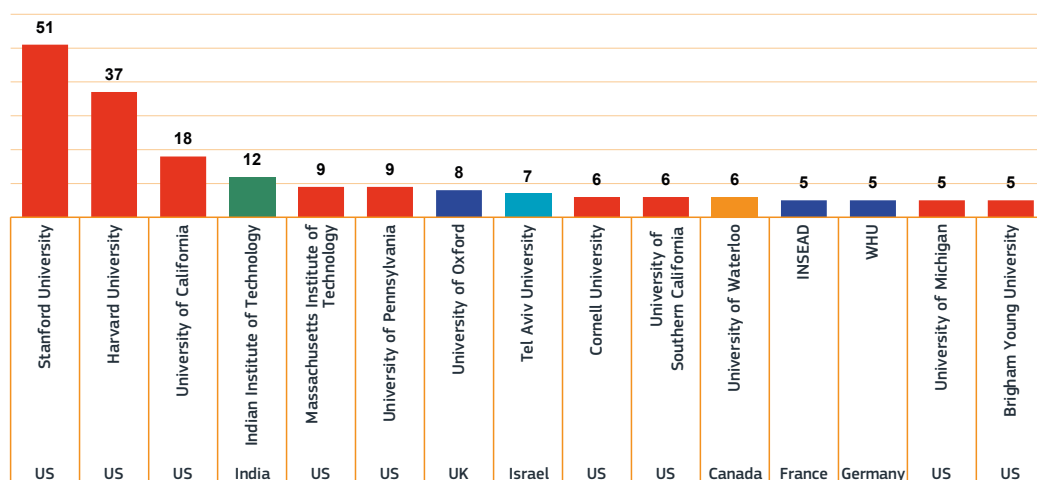
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*A similar geographical pattern exists when analysing the higher education institutions from which unicorn founders graduated.*

When looking into where “transformational entrepreneurs” (i.e. unicorn founders) went to college<sup>25</sup>, American universities emerge as the most popular, with Stanford University, Harvard

University and the University of California in the lead (‘top 3’). In total, 146 unicorn founders were alumni in nine US universities. Eighteen unicorn founders graduated from three universities in the EU (as of January 2017), namely Oxford University (UK), INSEAD (France) and the WHU – Otto Beisheim School of Management (Germany) (Figure I.6-A.15).

**Figure I.6-A.15** Universities producing the most unicorn<sup>1</sup> founders



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Sage

Notes: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation at more than US\$ 1 bn. <sup>2</sup>All data are up to date as of January 2017.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_15.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_15.xlsx)

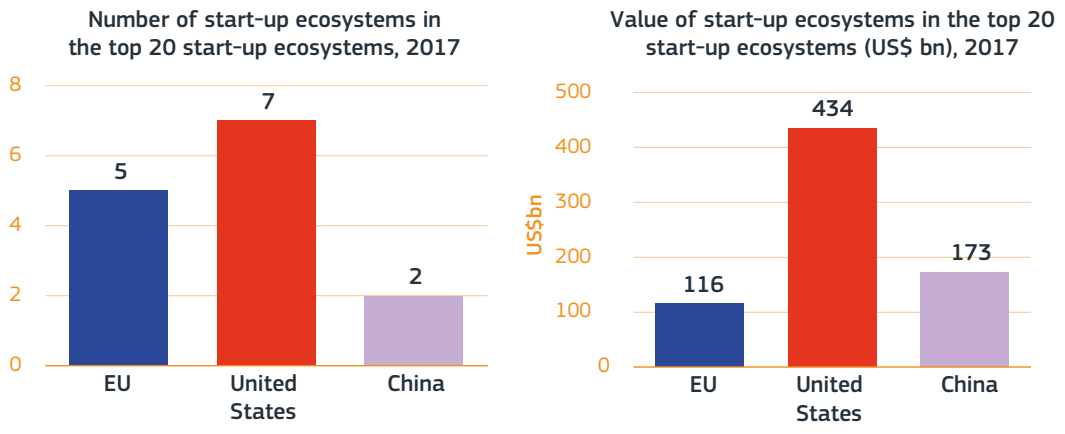
<sup>25</sup> According to Sage research on the Unicorn League.

*This seems to indicate that the EU lags behind in the creation of vibrant entrepreneurial ecosystems.*

Entrepreneurial ecosystems play a key role in the innovation cycle by acting as a platform for start-up ideas, developing products and services and making them grow in the market. In parallel, these powerful, well-connected 'technical hubs' contribute to economies of scale and agglomeration since they are the 'meeting point' between skilled entrepreneurs, suppliers, supportive services and infrastructure, and institutional structures such as financial intermediaries (Martin et al., 2001). For this reason, start-ups tend to emerge in hubs built around first-class universities that act as key players in developing a dynamic entrepreneurial environment because they are a source of talent which includes students and academics. This support to ecosystem building around top universities is the approach chosen by the European Institute of Innovation and Technology (EIT). The EIT

model aims at bringing together actors in the knowledge triangle of education, research and business in vibrant innovation ecosystems operating across the entire value chain of innovation. In this context, the 'Global Startup Ecosystem Report 2017' by Startup Genome follows a multidimensional approach to analyse "in which ecosystems does an early-stage start-up have the best chance of building a global success". This approach comprises five main dimensions, namely performance, funding, market reach, talent and start-up experience of the ecosystems. Figure I.6-A.16 shows that, according to the above-mentioned report, the EU had five entrepreneurial ecosystems in the top 20 start-up ecosystems. This compares with seven ecosystems in the United States and two in China. Furthermore, the accumulated value of the top EU ecosystems – London, Berlin, Paris, Stockholm and Amsterdam – is accordingly significantly below that of both the United States and China (EU: US\$ 116 billion, United States: US\$ 434 billion, China: US\$ 173 billion).

**Figure I.6-A.16 Start-up ecosystems**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Global Startup Ecosystem Report, 2017

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_16.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_16.xlsx)

Figure I.6-A.17 indicates the relative strengths of the top-performing world entrepreneurial ecosystems. Silicon Valley appears as the clear leader, followed by New York and London, the latter being the EU's top start-up ecosystem. Berlin also stands out in particular as a hub capable of at-

tracting highly talented entrepreneurs and for its global and local connectedness. Paris' top relative strength rests on the existence of strong and effective networks to access knowledge, while Stockholm performs relatively well in market reach, and Amsterdam in terms of overall ecosystem value.

**Figure I.6-A.17** World top 20 start-up ecosystems, 2017

RANKING 2017		Performance <sup>1</sup>	Funding <sup>2</sup>	Market reach <sup>3</sup>	Talent <sup>4</sup>	Start-up experience <sup>5</sup>
1	Silicon Valley					
2	New York					
3	London					
4	Beijing					
5	Boston					
6	Tel Aviv					
7	Berlin					
8	Shanghai					
9	Los Angeles					
10	Seattle					
11	Paris					
12	Singapore					
13	Austin					
14	Stockholm					
15	Vancouver					
16	Toronto-Waterloo					
17	Sydney					
18	Chicago					
19	Amsterdam					
20	Bangalore					

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Global Startup Ecosystem Report 2017, Startup Genome

Notes: <sup>1</sup>Performance includes start-up output, exits, valuations, early-stage success, growth-stage success, and overall ecosystem value. <sup>2</sup>Funding concerns growth in early-stage investments, and funding quality through the presence of experienced VC firms. <sup>3</sup>Market reach is linked to global connectedness and global and local reach, based on the start-ups' proportion of foreign customers and the national GDP. <sup>4</sup>Talent-access, cost, and quality of talent. <sup>5</sup>Start-up experience: team experience and ecosystem experience in terms of knowledge and networks available from which start-ups can develop.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-a\\_figures/f\\_i\\_6-a\\_17.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-a_figures/f_i_6-a_17.xlsx)

***Several factors may affect the lower rate of transformational entrepreneurship in Europe, including lower access to growth financing in Europe relative to the United States.***

Access to finance has a key role to play in supporting the pre-launch, launch and early-stage development phases of a business<sup>26</sup>. Venture capital is especially relevant in the case of young innovative companies in deep-tech sectors that have high growth and a disruptive potential and may even contribute to creating new markets. However, due to both the high uncertainty and investments required, they have difficulty in accessing traditional finance since some sort of collateral is needed. For this reason, banking finance should be complemented by diverse and flexible funding sources with a focus on the development of the venture capital industry to support transformational entrepreneurship in Europe.

As mentioned in Chapter 1.4<sup>27</sup>, after the crisis, venture capital investments as a percentage of GDP contracted substantially in Europe and currently represent only a fraction of those in the United States. This is particularly true for accessing growth-stage funding. With less later-stage funding available to thrive and scale-up, European tech start-ups favour earlier revenue generation to the detriment of fast growth to be compete for capital from less risk-taking investors available in Europe (in comparison to the United States). GP Bullhound's research (2016) argues that, overall, European private tech unicorns are growing sustainably "on

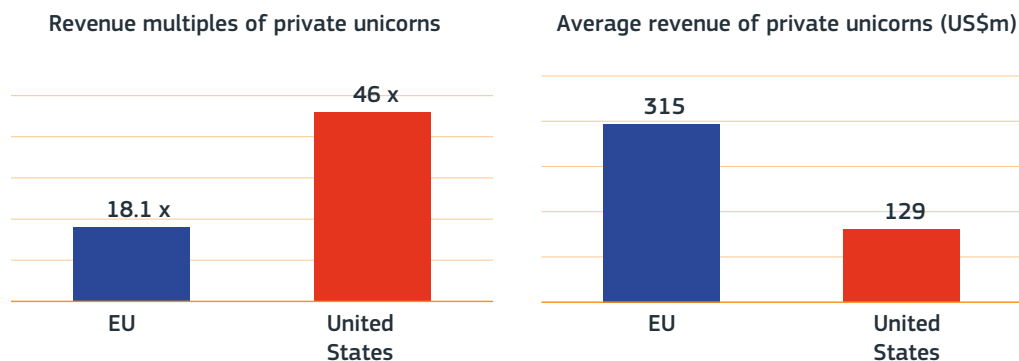
a base of profit and revenue". They compare valuations and actual revenue in a sample of European and American private unicorns in 2016. Figure I.6-A.18 shows that in the United States, on average, unicorn valuations are 46 times the revenues generated, while in the EU this number is much lower, at 18 times. However, when comparing the average revenue between EU and American private unicorns in the sample, they found that European unicorns have almost three times the average revenue obtained by the American unicorns in the sample. As a result, this research seems to indicate that "investors in the European Union request a "stronger track record of revenues and profits for billion-dollar valuations".

In line with these findings, Lee (2015) highlights in her analysis the growth of the so-called "paper unicorns" which are those with considerable low capital efficiency. While she admits that some of these new unicorns are due to "fantastic market fundamentals", she believes that this trend is linked mainly to the combination of a perception of "winner-takes-all markets" related to the importance of branding and the establishment of extensive networks, and private capital to fuel a company's growth which makes companies prioritise the idea of "getting big fast" instead of generating sufficient cash flow earlier. Recently, this conclusion has also been substantiated by Gornall and Strebulaev (2017) who show that, on average, these companies report values about 51% above what they are actually worth – and what public markets would give them.

26 InvestEurope.

27 For further reference to access to risk capital, please see Chapter 1.4 on 'Framework conditions'.

**Figure I.6-A.18 Private unicorns<sup>1</sup> - revenues<sup>2</sup> in the EU and the United States**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: GP Bullhound Research - European Unicorns 2016

Notes: <sup>1</sup>A unicorn is a private company with a post-money (i.e. "after funding") valuation of more than US\$ 1 bn. <sup>2</sup>Sourced latest revenue and valuation data available, revenue data is one year older than valuation data. Sample set size: 12 EU unicorns and 20 US unicorns, as of April 2016.

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***All in all, removing barriers for transformational, innovative start-ups to thrive and scale-up could boost technological dynamism and productivity growth in Europe.***

As mentioned above, a lack of sufficient access to financing for innovation is a major barrier for innovative entrepreneurship to flourish in Europe since it limits the growth and scale-up potential of young, innovative and talented European firms. Despite recent progress in reversing the significant decline of venture capital investments in Europe as a result of the crisis<sup>28</sup>, more needs to be done to further develop the venture capital industry in Europe. According to the European Investment Fund (EIF)<sup>29</sup>, hostile regulations for equity investments persist, as well as some degree of market fragmentation and complexity, which hinders the creation of a critical mass of companies and venture capital investors. The Pan-European Venture Capital Fund-of-Funds intends to tackle these issues, together with exploring alternative sources of financing such as crowdfunding and business angels. Moreover, according to the European Commission's 'Start-

up and Scale-up Initiative'<sup>30</sup>, completing and deepening the Digital Single Market is extremely relevant for innovative start-ups which, by expanding to other EU Member States, typically face considerable regulatory and administrative barriers inherent in cross-border situations. In addition, other framework conditions, such as fostering faster insolvency procedures, simplifying tax procedures, and propelling an entrepreneurial culture that does not penalise failure and allows for a 'second chance', have also been identified as important elements to enable a more innovation-driven European economy. The European Innovation Council (EIC) pilot provides bottom-up support targeting market-creating innovations with the potential to scale-up globally and which are of a 'high risk-high gain' nature for investors. This includes, for instance, six 'EIC Horizon Prizes' under the Horizon 2020 Work Programme 2018-2020. Fostering high-quality technical hubs throughout Europe, combining access to knowledge, capital, talent and infrastructure in a synergetic fashion, would also contribute to promoting transformational entrepreneurship.

28 Source: InvestEurope (2017) 'The Acceleration point: Why now is the time for European venture capital'.

29 European Investment Fund – presentation at the SEP Investors Forum Workshop 2015 – 'European Venture Capital. The Facts', by Patric Gresko.

30 EC Communication (2016).



## CHAPTER I.6-B: STRUCTURAL CHANGE

In the current context of slowing productivity worldwide, and especially in the EU, it becomes even more important to understand why some economies manage to be more productive than others. As will be shown in this chapter, knowledge-intensive activities enjoy the highest productivity levels, have the largest productivity growth, and lay the foundations for productivity-enhancing innovations to materialise.

This chapter analyses how the economic structure of the EU and its Member States has evolved in recent years and assesses whether there has been a structural economic shift towards more knowledge intensive sectors. While knowledge intensity is in itself difficult to measure, it is common practice to use R&D intensity as a reasonable proxy, i.e. the share of investment in R&D of a sector's total value added. Economies that manage to invest and expand in those sectors with the highest productivity become more productive. Labour productivity tends to be especially high in high-tech manufacturing and high-tech knowledge-intensive services, followed by medium-high-tech manufacturing. These three macro-sectors are referred to in this chapter as knowledge-intensive activities or sectors.

### Economic structure in the EU and its Member States

*In the context of a global productivity growth slowdown presented in Chapter 1 of this Report, the gap between the EU vis-à-vis its main competitors, in particular the United*

*States, can be tracked down to two main factors: (i) lower specialisation in knowledge-intensive activities, and (ii) lower productivity within each of these sectors.*

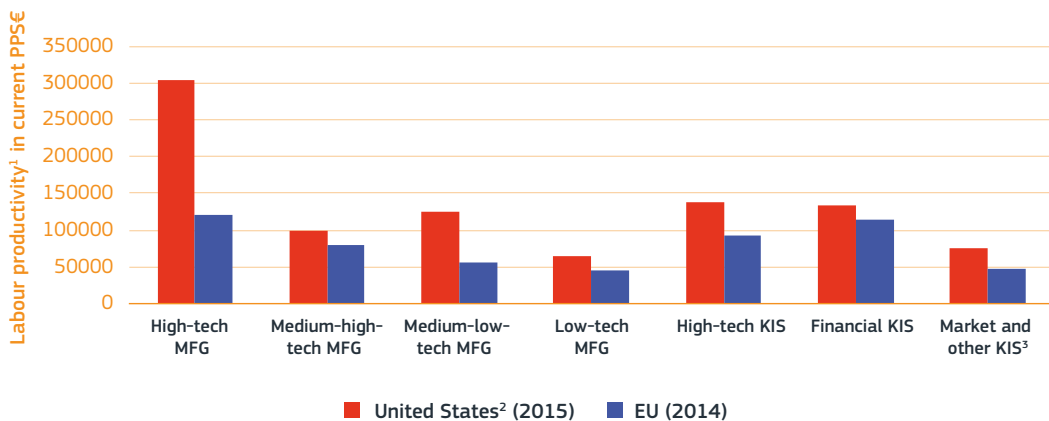
Figure I.6-B.1 compares labour productivity in the EU and the United States. While knowledge-intensive activities are the most productive sectors both in the EU and the United States, labour productivity in the EU is lower across all sectors. Such a gap is particularly significant in high-tech manufacturing, in medium-low-tech manufacturing and knowledge-intensive services (KIS), although most notably in high-tech sectors<sup>31</sup>.

*Economic specialisation across countries is linked to sectoral productivity levels that in turn define the competitiveness of the sectors in the global economic landscape. Economies where productivity in specific sectors is higher tend to enjoy higher value-added shares in those sectors, compared to other countries.*

Figure I.6-B.2 plots labour productivity in knowledge-intensive services, high-tech and medium-high-tech manufacturing against the share of value added in the same sectors, revealing the existence of a positive relationship: countries tend to have higher specialisation in sectors where their productivity is higher in comparative terms. Labour productivity in knowledge-intensive activities in the United States is higher than in the EU, and the share of these activities in total value added is also larger.

31 The classification of manufacturing and services is based on NACE Rev. 2 at the two-digits level. In particular, HT manufacturing includes basic pharmaceutical products and preparations; computer, electronic and optical products. MHT manufacturing includes chemicals and chemical products; electrical equipment, machinery and equipment; motor vehicles, trailers and semi-trailers; and other transport equipment. KIS include a large range of activities, such as water and air transport; publishing activities; computer programming; telecommunications; and others (section J); financial and insurance activities; legal and accounting activities; market research; scientific research and development; and others (section M); security and investigation; public administration and defence, compulsory social security; education; human health and social work activities; arts, entertainment and recreation. See: <http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF>.

**Figure I.6-B.1 Labour productivity<sup>1</sup> of manufacturing (MFG) and knowledge-intensive services (KIS) by type of sector - EU and the United States**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPS€. <sup>2</sup>US: (i) Medium-low-tech MFG does not include repair and installation of machinery and equipment; (ii) High-tech KIS does not include scientific research and development and telecommunications (iii) Market and other KIS does not include employment activities. <sup>3</sup>Market and other KIS does not include investigation activities due to unavailability of data.

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**Figure I.6-B.2** Labour productivity<sup>1</sup> of high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT) plus knowledge-intensive services (KIS)<sup>2</sup> and % share of value added in HT plus MHT plus KIS, 2015<sup>3</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPS€. <sup>2</sup>KIS does not include security and investigation activities due to unavailability of data. <sup>3</sup>MT: 2013; BE, DE, IE, ES, FR, HR, IT, CY, LV, LT, PL, PT, RO, SE, EU, NO, JP: 2014. <sup>4</sup>EE, LU, US, JP: KIS does not include employment activities. <sup>5</sup>LU, JP: KIS does not include water transport and air transport. <sup>6</sup>IS: KIS does not include water transport. <sup>7</sup>EE, HR, MT, PL: KIS does not include air transport. <sup>8</sup>IE, MT, NO: Manufacture of coke and refined petroleum products is included in MHT. <sup>9</sup>EE: Manufacture of basic pharmaceutical products and pharmaceutical preparations is not included in HT. <sup>10</sup>Elements of estimation were involved in the compilation of the data.

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***The EU landscape is heterogeneous in terms of both its structural composition and its sectoral productivity.***

Two main groups of countries can be identified in Figure I.6-B.2. On the bottom left, the Eastern European economies are characterised by low specialisation in knowledge intensive sectors and relatively low labour productivity levels within these sectors, while on the upper right, Western and Northern European countries dominate. Southern European countries score in-between, with average levels of productivity and knowledge-intensive shares. Luxembourg, Ireland and Malta stand out as exceptions. Luxembourg and Malta's high shares of value added in knowledge intensive sectors are driven almost completely by their specialisation in KIS: 59.9% out of 61.2% and 53.7% out of 57.6% respectively, while little of the contribution is due to manufacturing activities. In Luxembourg, this pattern is mirrored by labour productivity levels which are higher than in the United States. Finally, Ireland is placed in the top right of Figure I.6-B.2, mainly due to very high labour productivity and value added share in KIS and, unique in the EU, in high-tech manufacturing. The relevance of knowledge-intensive sectors

is shown in Figure I.6-B.3 below, where labour productivity in knowledge-intensive sectors is plotted against the value-added share of the sector. The sector accounts for a relevant part of the economic structure of EU countries, ranging from 24.6% in Lithuania to around 60% in Luxembourg, with an EU average of 39%. The chart also highlights the peculiarity of Luxembourg in terms of structural specialisation and labour productivity, as well as the labour productivity gap between the United States and EU economies, with the exception of Ireland<sup>32</sup>.

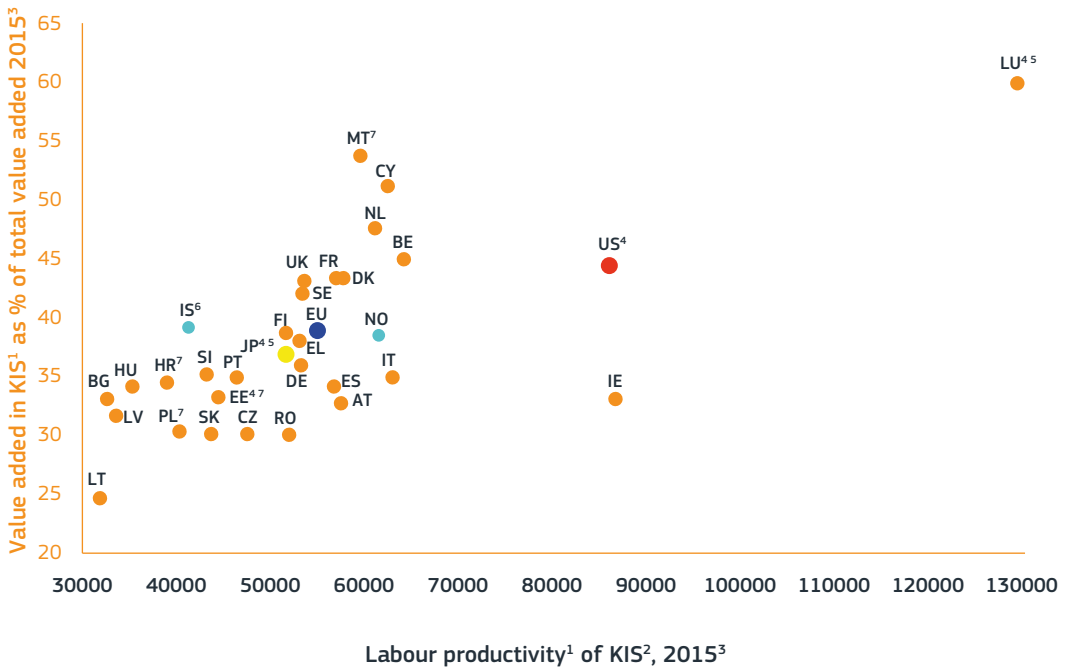
Countries' productivity levels, technological change and the presence of more or less favourable framework conditions for businesses and innovative investments<sup>33</sup> are all very closely linked to the evolution of an economy's economic structure. Furthermore, differences in R&D investments are key in explaining the divergences observed between Member States and between the EU and the United States. Figures I.6-B.4 and I.6-B.5 clearly show a positive relationship between the intensity of R&D investments and both value added and labour productivity in high-tech and medium-high-tech manufacturing sectors<sup>34</sup> in these countries.

32 See Figures I.6-B.9 and I.6-B.15 below. Overall, in what follows, Ireland and Luxembourg stand as consistent outliers. This is due to sectoral specialisations in high-tech manufacturing and KIS, as described in this paragraph.

33 For further details, see Chapter I.5 on Framework conditions for innovation.

34 R&D intensity in KIS will not be considered in the analysis due to the insufficient availability of data for most services activities. Therefore, only manufacturing sectors will be analysed for consistency.

**Figure I.6-B.3** Labour productivity<sup>1</sup> of knowledge-intensive services (KIS)<sup>2</sup> and % share of value added in KIS, 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD

Notes: <sup>1</sup>Value added in KIS per person employed in KIS, current PPS€. <sup>2</sup>KIS does not include security and investigation activities due to unavailability of data. <sup>3</sup>MT: 2013; BE, DE, ES, FR, HR, IT, CY, LV, LT, PL, PT, RO, SE, EU, NO: 2014. <sup>4</sup>EE, LU, US, JP: KIS does not include employment activities. <sup>5</sup>LU, JP: KIS does not include water transport and air transport. <sup>6</sup>IS: KIS does not include water transport. <sup>7</sup>EE, HR, MT, PL: KIS does not include air transport. <sup>8</sup>Elements of estimation were involved in the compilation of the data.  
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-b\\_figures/f\\_i\\_6-b\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-b_figures/f_i_6-b_3.xlsx)

*Overall, the EU has a slightly higher value added in medium-high and high-tech manufacturing sectors, but much lower R&D intensity than the United States. Within the EU, countries with low value added in high-tech and medium-high-tech sectors, namely the Southern and Eastern European Member States, also invest less in R&D in these sectors.*

Figure I.6-B.4 shows that the EU has slightly higher value added in high-tech and medium-high-tech manufacturing than the United States, despite the lower R&D intensity. This can be explained by two main factors. First, investment in R&I takes time to translate into the production of new goods, and might therefore only show a significant effect on shares of value added with a time lag. Secondly, it can be explained by the structural composition of the EU versus that of the United States. As will be shown in Figures I.6-B.9 and I.6-B.10, the EU has a higher share of value added in medium-high-tech manufacturing sectors, which are traditionally more established sectors like automotive and chemicals, while the United States has a higher share in high-tech manufacturing, which includes frontier sectors such as pharmaceuticals and ICT. Since high-tech manufacturing is usually characterised by larger R&D investments than medium-high-tech manufacturing, the United States has a higher R&D intensity for both sectors combined.

*The difference in R&D intensity, and consequently the sectoral composition of the EU and the United States, contributes explain why*

*the EU reports considerably lower productivity levels in knowledge intensive sectors.*

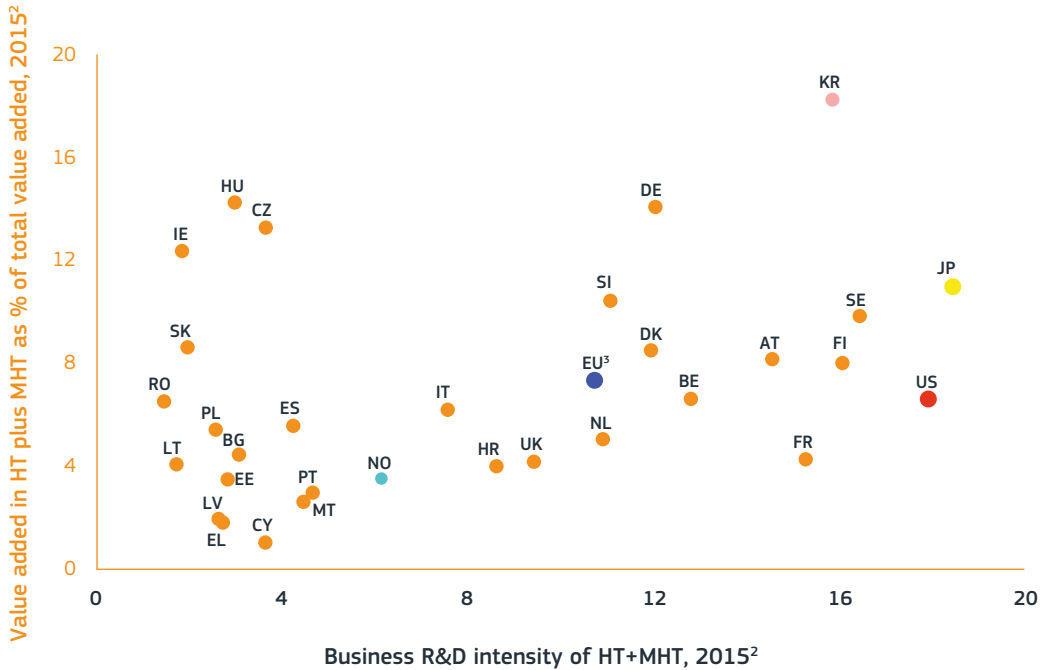
Figure I.6-B.5 shows clearly not only an even stronger positive relationship between investment and labour productivity (than for investment and value added), but also that the United States far outperforms the EU, as can also be seen in Figure I.6-B.1. Again, an intra-EU divide can be seen, with the Eastern and Southern European countries reporting low productivity levels paired with low R&D intensity in medium-high and high-tech manufacturing sectors. The positive correlation between R&D intensity and labour productivity levels is higher than with value added but, as outlined above, given that economies tend to specialise in their most productive sectors, it is to be expected that the value-added shares in the United States will increase in the future<sup>35</sup>.

R&I policies are fundamental levers to drive R&D investment trends and to shape the transformation of a country's economic structure and, eventually, its productivity performance.

The following sections will analyse the dynamics of the structural composition of the EU and its Member States. First, the upward shifts in the importance of knowledge-intensive activities in the added value of an economy will be analysed. Then, labour productivity trends within these sectors will be explored. Finally, the evolution of business R&D intensity will be explored.

<sup>35</sup> This may also explain why the productivity slowdown seems to affect the EU more than the United States, the former investing and therefore specialising less in high-tech manufacturing sectors.

**Figure I.6-B.4 Business R&D intensity<sup>1</sup> and % share of value added in high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT), 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

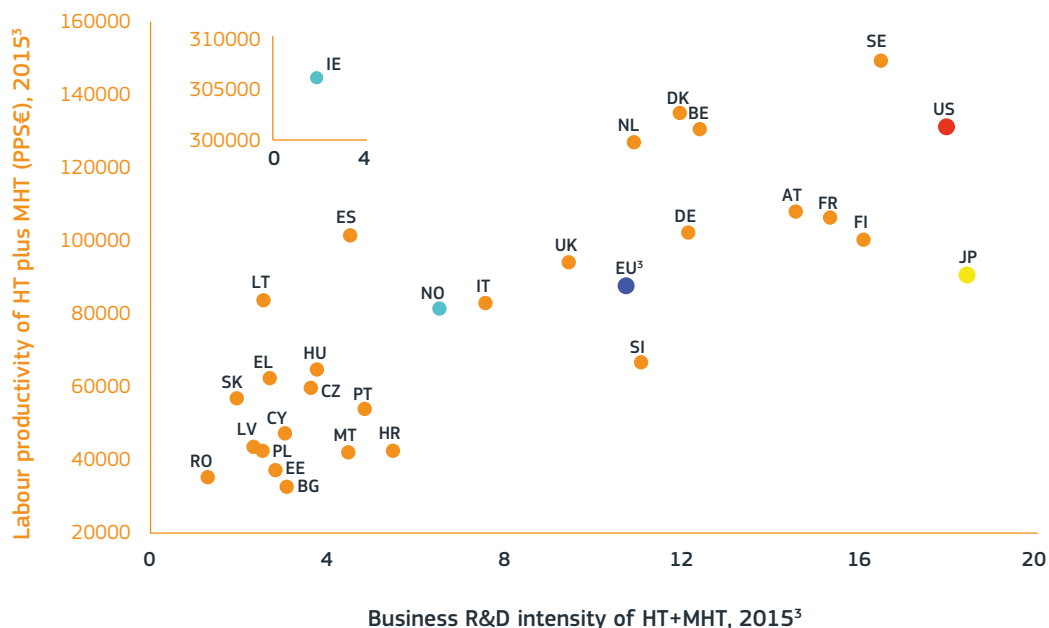
Data: Eurostat, OECD

Notes: <sup>1</sup>Business enterprise expenditure on R&D (BERD) as % of value added in HT+MHT sectors. <sup>2</sup>IE, FR, SE: 2013; PL, EU, JP: 2014.

<sup>3</sup>EU was estimated by DG Research and Innovation and does not include Luxembourg. <sup>4</sup>Elements of estimation were involved in the compilation of the data.

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**Figure I.6-B.5 Business R&D intensity<sup>1</sup> and labour productivity<sup>2</sup> of high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT), 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Business enterprise expenditure on R&D (BERD) as % of value added in HT+MHT sectors. <sup>2</sup>Value added per person

employed in current PPSE. <sup>3</sup>IE, FR, SE: 2013; BE, DE, ES, HR, CY, LT, HU, PL, PT, RO, EU, NO, JP: 2014. <sup>4</sup>EU was estimated by DG

Research and Innovation and does not include Luxembourg. <sup>5</sup>Elements of estimation were involved in the compilation of the data.

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### Shifts in the economic structure of the EU and its Member States

Structural change is defined as the long-term evolution of the economy's composition, measured as the variation in production and/or employment shares. Such a transformation is growth enhancing if employment and production are progressively reallocated towards more knowledge-intensive and productive sectors. In addition, increased R&D investment within sectors also contributes to the growth of sectoral and eventually aggregate productivity, as the variables are closely interrelated. Analysing the growth rates of value-added shares in knowledge-intensive services, high-tech and medium-high-tech manufacturing informs on the direction of the shifts within the economic structure.

*Overall, the EU has experienced a process of structural change towards more knowledge intensive sectors. The growth rate of value-added shares in these sectors is higher in the EU than in the United States, Japan or Switzerland. However, this positive trend is not enough to close the gap with those countries and a more rapid shift is needed. South Korea was the most knowledge-intensive economy in 2015, also enjoying the fastest growth-enhancing structural change worldwide.*

The EU trend is driven by high heterogeneity among Member States. Figure I.6-B.6 below

plots the share of value added of the aggregate of the three sectors in 2015 against its compound annual growth rate in the period 2000-2015. At the top of the graph are the countries which have been increasingly shifting the composition of their economies towards more knowledge-intensive activities, by growing at rates between 1% and 2% per year. Bulgaria, Romania, Slovakia, Estonia and the Czech Republic have still an aggregate lower share than the EU average, but they managed to reduce or close the gap with countries like Austria, Italy, Portugal and Croatia whose structure has remained relatively unchanged over the 15 years observed. Malta and Cyprus have been shifting their structure at a high speed and are among the most knowledge-intensive countries in the EU at the end of the period. Denmark, the Netherlands, Belgium and Ireland have been increasing the value-added share of knowledge-intensive activities more slowly but are still far above the EU average. Conversely, Latvia, Portugal, Poland and Lithuania have experienced a decline in value-added shares, moving towards less-knowledge intensive sectors. The rest of the Member States stand in an intermediate position, with growth rates around or below the EU average, with the exception of Greece and Spain which still lagged behind in 2015.

**Figure I.6-B.6** Share of value added in high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT) plus knowledge-intensive services (KIS)<sup>1</sup>, 2015 and compound annual growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KIS does not include security and investigation activities due to unavailability of data. <sup>2</sup>MT, KR: 2013; BE, DE, IE, ES, FR, HR, IT, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2014. <sup>3</sup>MT, KR: 2000-2013; BE, DE, IE, ES, FR, HR, IT, CY, LV, LT, PT, SE, EU, NO, CH: 2000-2014; PL: 2003-2014. <sup>4</sup>LU, CH, US, JP, KR: KIS does not include employment activities. <sup>5</sup>LU, CH, JP, KR: KIS does not include water transport and air transport. <sup>6</sup>IS: KIS does not include water transport. <sup>7</sup>HR, MT, PL: KIS does not include air transport. <sup>8</sup>IE, MT, NO, CH: Manufacture of coke and refined petroleum products is included in MHT. <sup>9</sup>Elements of estimation were involved in the compilation of the data.

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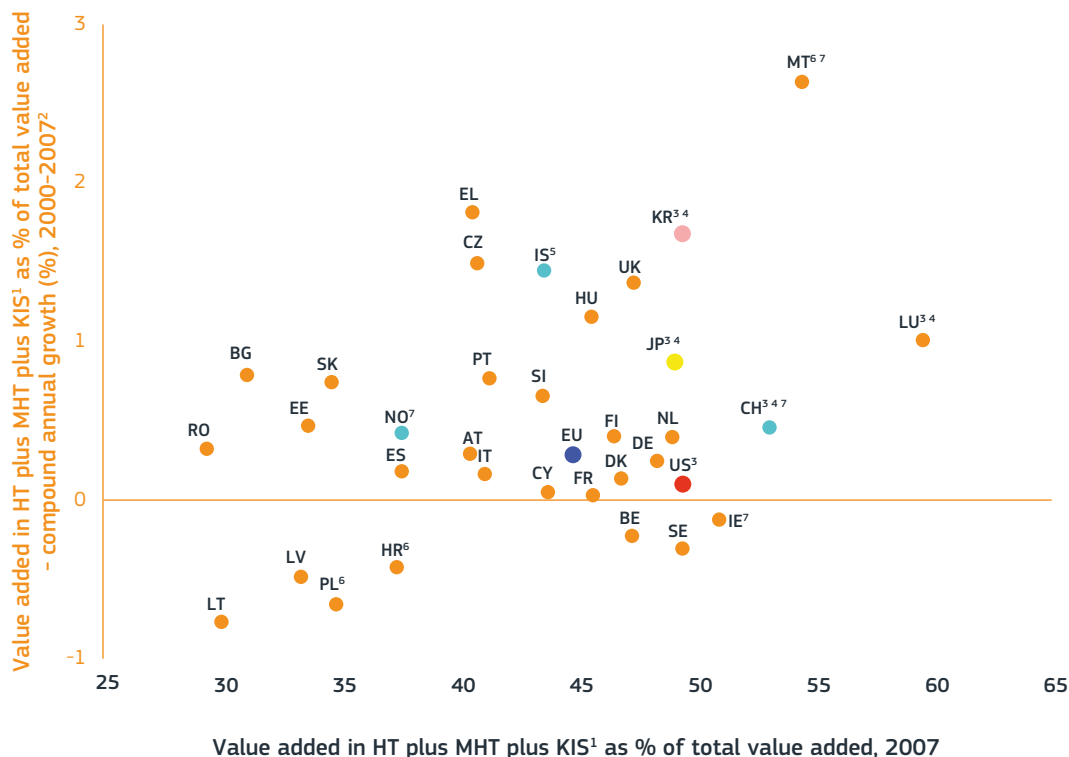
*The crisis has not hampered the process of structural change in the EU or the United States. On the contrary, a slight increase can be seen in the speed of change.*

In both cases, the annual growth rate in the aggregate shares of value added in knowledge intensive sectors increased by 0.3% per year in the period 2008-2015 with respect to 2000-2007 (Figures I.6-B.7 and I.6-B.8 below). This is in contrast to the slowdown in South Korea (from 1.7% to 0.4% per year), in Japan (from 0.9% to -0.1% per year) and, to a lesser extent, in Switzerland.

*However, the process has not been homogeneous among countries and different trends can be observed within the EU itself.*

Starting in 2008, Greece and Portugal have inverted the shift towards knowledge-intensive activities, while Bulgaria, Romania, Slovakia and Cyprus have doubled or more than doubled the speed of change, also suggesting a possible positive effect generated by their accession to the EU. Denmark, Belgium and the Netherlands have accelerated the structural upgrade process, while the UK has slowed it down to a growth rate close to zero.

**Figure I.6-B.7** Share of value added in high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT) plus knowledge-intensive services (KIS)<sup>1</sup>, 2007 and compound annual growth, 2000-2007<sup>2</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KIS does not include security and investigation activities due to the unavailability of data. <sup>2</sup>PL: 2003-2007. <sup>3</sup>LU, CH, US, JP, KR: KIS does not include employment activities. <sup>4</sup>LU, CH, JP, KR: KIS does not include water transport and air transport. <sup>5</sup>IS: KIS does not include water transport. <sup>6</sup>HR, MT, PL: KIS does not include air transport. <sup>7</sup>IE, MT, NO, CH: Manufacture of coke and refined petroleum products is included in MHT. <sup>8</sup>Elements of estimation were involved in the compilation of the data.

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**Figure I.6-B.8** Share of value added in high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT) plus knowledge-intensive services (KIS)<sup>1</sup>, 2015 and compound annual growth, 2008-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KIS does not include security and investigation activities due to unavailability of data. <sup>2</sup>MT, KR: 2013; BE, DE, IE, ES, FR, HR, IT, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2014. <sup>3</sup>MT, KR: 2008-2013; BE, DE, IE, ES, FR, HR, IT, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2000-2014. <sup>4</sup>LU, CH, US, JP, KR: KIS does not include employment activities. <sup>5</sup>LU, CH, JP, KR: KIS does not include water transport and air transport. <sup>6</sup>IS: KIS does not include water transport. <sup>7</sup>HR, MT, PL: KIS does not include air transport. <sup>8</sup>IE, MT, NO, CH: Manufacture of coke and refined petroleum products is included in MHT. <sup>9</sup>Elements of estimation were involved in the compilation of the data.

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The above trends are the result of the aggregation of diverse trajectories in the different sectors. Hence, what follows is an analysis of the growth rates in value-added shares of KIS, high-tech and medium-high-tech manufacturing separately, providing a deeper perspective on the drivers of structural change. This is relevant given the technology content of the diverse economic activities in the three groups, as can be seen from each Member State's different specialisation and productivity figures in Figure I.6-B.2.

***The EU as a whole is not as specialised in high-tech manufacturing activities as the United States, Japan, South Korea and Switzerland. Most of the EU countries have less than 2% of value added in the sector. This share has been decreasing overtime, suggesting that the gap between the EU as a whole and the other leading economies has been widening.***

While such a shift away from high-tech manufacturing is also observed in the United States and Japan, the gap with the EU is growing in

a sector which is crucial for innovation and productivity growth (Figure I.6-B.9). Ireland is a notable exception with around 9% of value added in high-tech manufacturing, despite a negative growth rate. Only a handful of countries have been increasing their specialisation in the sector, most notably Cyprus, Denmark, Latvia and the Czech Republic. Switzerland and South Korea are the countries most specialised in high-tech manufacturing outside of the EU, by far, and are increasing their specialisation over time. More interestingly, Finland and Malta have experienced a significant shift away from the sector, at a growth rate of -6.1% and -7.7% respectively, with spikes of -11% and -10.2% after 2008.

**Figure I.6-B.9** Share of value added in high-tech manufacturing (HT), 2015 and compound annual growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KR: 2013; DE, IE, ES, HR, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2014; MT: 2016. <sup>2</sup>KR: 2008-2013; DE, IE, ES, HR, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2008-2014; MT: 2008-2016; TR: 2010-2015. <sup>3</sup>LU, MT: MHT is included in HT. <sup>4</sup>MT: Manufacture of coke and refined petroleum products is included in MHT. <sup>5</sup>SE: Manufacture of chemicals and chemical products is included in HT. <sup>6</sup>NO: Manufacture of basic pharmaceutical products and preparations is not included in HT. <sup>7</sup>Elements of estimation were involved in the compilation of the data.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-b\\_figures/f\\_i\\_6-b\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-b_figures/f_i_6-b_9.xlsx)

*The EU is more specialised in medium-high-tech manufacturing, which has been on a slightly declining trend since 2000 (-0.4% per year), although this decline is happening at a slower pace than in the United States (-1.1%). Overall, the gap with South Korea and Japan has been increasing during the period.*

In 2015, the medium-high-tech manufacturing sectors accounted for 5.7% of total value added, compared to 4.2% in the United States and 4.1% in Switzerland. Germany is the Member State with the largest share (11.8%), higher than South Korea (11.4%) and Japan (8.8%),

followed by the Czech Republic (11.5%) and Hungary (10.9%). Overall, high heterogeneity in value added shares can be observed throughout the EU. Between 2000 and 2015, a structural change towards medium-high-tech manufacturing activities took place mainly in eastern economies, together with Greece, Austria and Germany. All the other countries experienced negative growth rates, in particular Malta and Cyprus. This negative trend has been partially reversed since 2008, due to a positive shift for countries like Spain, Portugal, Ireland and the UK and stable and positive growth rates in Germany, Hungary and the Czech Republic.



**Figure I.6-B.10** Share of value added in medium-high-tech (MHT) manufacturing, 2015 and compound annual growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KR: 2013; DE, IE, ES, HR, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2014; MT: 2016. <sup>2</sup>KR: 2000-2013; DE, IE, ES, HR, CY, LV, LT, PT, SE, EU, NO, CH: 2000-2014; MT: 2000-2016; PL: 2003-2014. <sup>3</sup>LU, MT: HT is included in MHT. <sup>4</sup>SE: Manufacture of chemicals and chemical products is not included in MHT. <sup>5</sup>NO: Manufacture of basic pharmaceutical products and pharmaceutical preparations is included in MHT. <sup>6</sup>IE, MT, NO, CH: Manufacture of coke and petroleum products is included in MHT. <sup>7</sup>Elements of estimation were involved in the compilation of the data.

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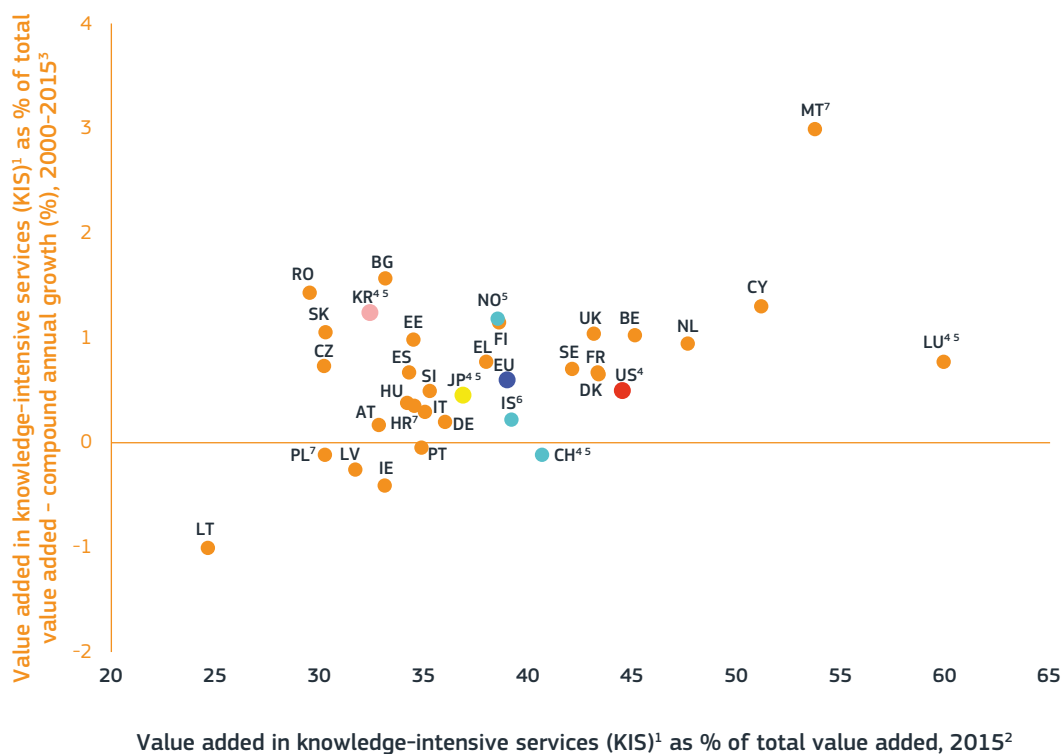
*Moreover, over the last two decades, the EU has been transforming its economic structure, shifting more and more towards knowledge-intensive services, with an average growth rate of 0.6% per year. Positive growth in the sector has been driving the positive shift towards knowledge-intensive activities for the EU as a whole.*

With a share of value added at 39% in 2015, the EU's degree of specialisation in KIS is higher than in Japan and South Korea, but lower than in the United States. Only a few countries have experienced a shift away from KIS, namely Poland, Latvia, Lithuania, Portugal and Ireland, the latter at an accelerated pace following the crisis in 2008. The structural composition of Malta is the fastest growing towards the sector. The years 2008-2015 show no change in

the overall pattern. However, a reversion of the trend can be observed for some Member States, in particular Greece and Hungary, while an acceleration of the already negative growth rates occurred in Portugal, Latvia and Lithuania. Conversely, Slovakia and Cyprus increased the pace of shift towards the sector in the same period.

Given the above structural shifts and the differences in productivity presented in Figure I.6-B.1, this chapter also investigates labour productivity dynamics in the knowledge intensive sectors in the period 2000-2015 to shed further light on the performance of the EU and its Member States from a global perspective. Furthermore, understanding trends in productivity will complement the static figures presented in Figures I.6-B.2 and I.6-B.3.

**Figure I.6-B.11** Share of value added in knowledge-intensive services (KIS)<sup>1</sup>, 2015 and compound annual growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>KIS does not include security and investigation activities due to the unavailability of data. <sup>2</sup>MT, KR: 2013; BE, DE, ES, FR, HR, IT, CY, LV, LT, PL, PT, SE, EU, NO, CH: 2014. <sup>3</sup>MT, KR: 2000-2013; BE, DE, ES, FR, HR, IT, CY, LV, LT, PT, SE, EU, NO, CH: 2000-2014; PL: 2003-2014. <sup>4</sup>LU, CH, US, JP, KR: KIS does not include employment activities. <sup>5</sup>LU, CH, JP, KR: KIS does not include water transport and air transport. <sup>6</sup>IS: KIS does not include water transport. <sup>7</sup>HR, MT, PL: KIS does not include air transport.

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***On average, labour productivity in knowledge intensive sectors activities in the EU has been growing at 0.6% per year, with most Member States experiencing growth rates around or below zero, lagging behind the United States.***

The global scenario over the period has been characterised by low or negative growth worldwide, with the United States growing at 1.2% per year and Japan at -0.1%.

***Within the EU, a typical convergence pattern<sup>36</sup> can be observed for the eastern economies growing at a rate of up to five times the EU average, while most advanced economies have experienced close to zero (e.g. Germany, Austria, Spain) or negative growth (e.g. Italy, Luxembourg, Portugal).***

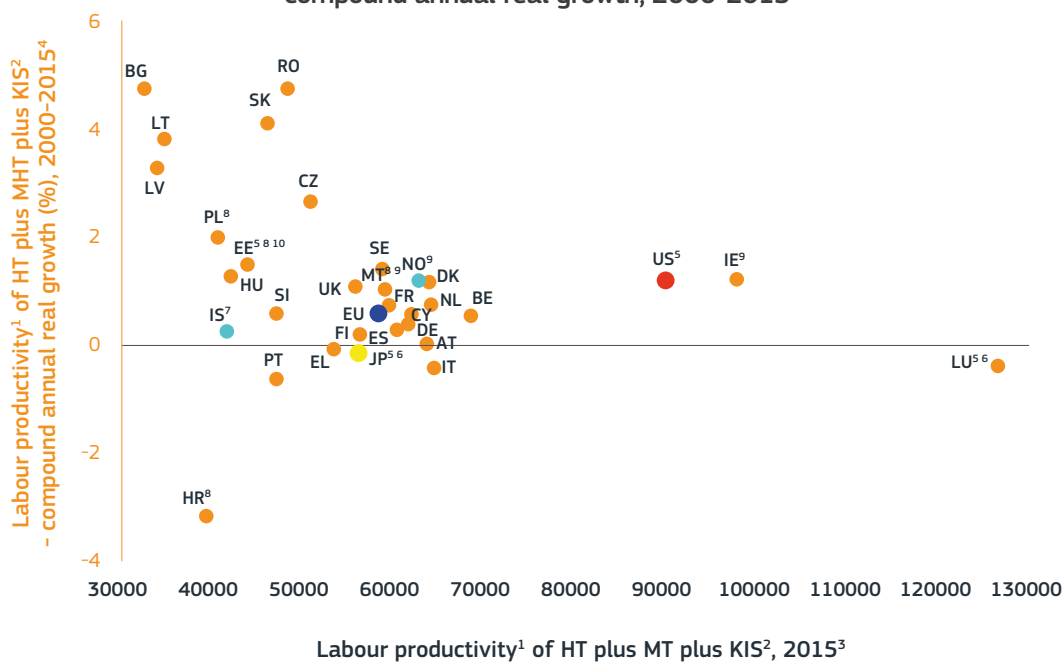
However, this convergence process does not involve southern economies, such as Italy,

Greece, Spain and Portugal. Indeed, the growth rate of labour productivity in the south of Europe has been consistently lower (and mainly negative) than in other Member States, such as Germany, France, the Netherlands or most of the Scandinavian countries, a trend which has worsened since the crisis. As a result, such countries still lag behind the EU average and more advanced Member States in terms of labour productivity levels. The only exception is Italy which, despite a negative performance over the period, has higher labour productivity in medium-high-tech, high-tech manufacturing sectors and knowledge-intensive services than Germany, Austria, Denmark and the Netherlands, only lagging behind Belgium, Ireland and Luxembourg. Overall, in 2015, EU labour productivity in knowledge intensive sectors is still only around two-thirds of the United States and this gap has been increasing over time (Figure I.6-B.12).

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<sup>36</sup> Economies are said to converge in absolute terms if those with a lower initial level of labour productivity grow faster than the most advanced ones. See, for instance, Barro, R.J. and Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy* 100(2): 223-251. Figure I.6-B.12 shows the last year (2015) on the horizontal axis rather than the initial year (2000), although the results would remain unchanged using the latter.

**Figure I.6-B.12** Labour productivity<sup>1</sup> of high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT) plus knowledge-intensive services (KIS)<sup>2</sup>, 2015 and compound annual real growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPSE. Compound annual real growth was calculated from values at 2010 prices. <sup>2</sup>KIS does not include security and investigation activities due to unavailability of data. <sup>3</sup>MT: 2013; BE, DE, IE, ES, FR, HR, IT, CY, LV, LT, PL, PT, RO, SE, EU, NO, JP: 2014. <sup>4</sup>MT: 2000-2013; PL: 2003-2014; EE: 2004-2015; HR: 2008-2014; IS: 2008-2015; BE, DE, IE, ES, FR, IT, CY, LV, LT, PT, RO, SE, NO, JP: 2000-2014. <sup>5</sup>EE, LU, US, JP: KIS does not include employment activities. <sup>6</sup>LU, JP: KIS does not include water transport and air transport. <sup>7</sup>IS: KIS does not include water transport. <sup>8</sup>EE, HR, MT, PL: KIS does not include air transport. <sup>9</sup>IE, MT, NO: Manufacture of coke and refined petroleum products is included in MHT. <sup>10</sup>EE: Manufacture of basic pharmaceutical products and pharmaceutical preparations is not included in HT. <sup>11</sup>IE, CY, RO: Breaks in series occur between 2000 and 2015; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>12</sup>Elements of estimation were involved in the compilation of the data.

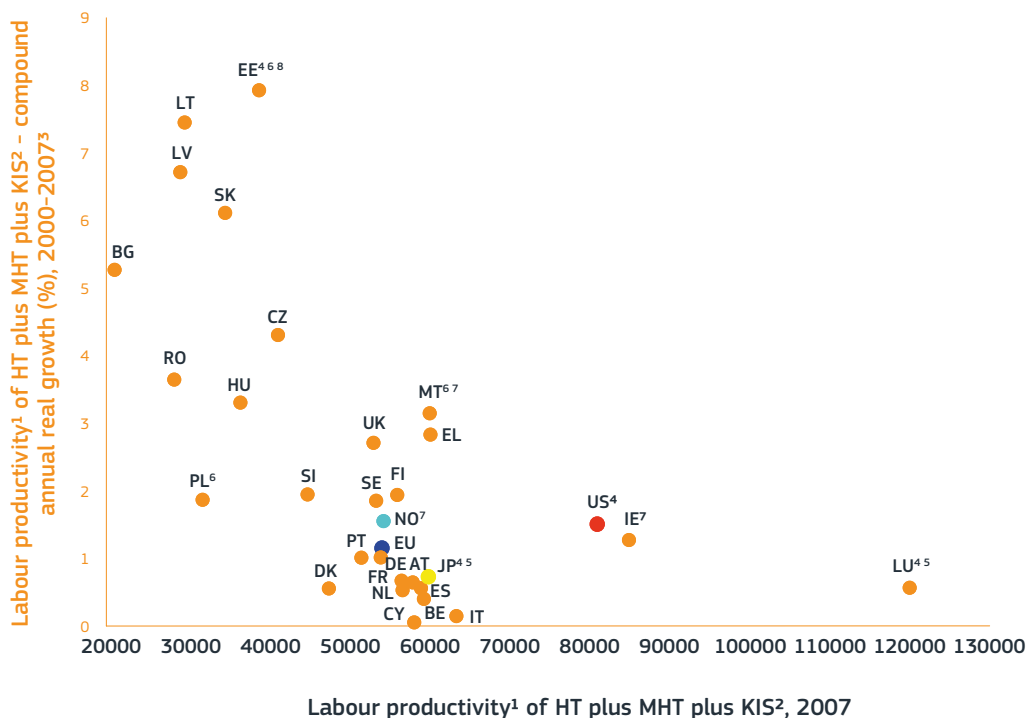
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-b\\_figures/f\\_i\\_6-b\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-b_figures/f_i_6-b_12.xlsx)

*The general productivity slowdown seems to have accentuated since the Great Recession, hitting the EU as a whole, Japan and, to a lesser extent, the United States, the latter showing some resilience and reducing its annual growth rate by only 0.2% after 2007.*

Figures I.6-B.13 and I.6-B.14 show some stylised facts concerning labour productivity dynamics before and after the surge of the crisis. First, the convergence dynamics characterising the periods 2000 and 2015 were already in place between 2000 and 2007. During this period, labour productivity growth was up to eight times higher in eastern economies than the EU average, while staying between 0% and 2% per year in most advanced Member States, the majority of them experiencing yearly growth rates below 1%. Second, despite huge heterogeneity, the growth rates in knowledge intensive sectors were positive in every EU Member State before the crisis hit, leading to an EU average growth rate of 1.2%. Third, after 2007, the crisis sharply impacted the performance of most countries,

reducing labour productivity growth rates, which became negative in southern European economies, Austria, Malta, Finland and some of the eastern economies. The impact was significantly negative in Greece, Croatia and Portugal, while Denmark, Cyprus and the Netherlands are the only countries which have continued to enjoy growing rates of productivity since 2007. Fourth, Romania, Bulgaria, Poland, Slovakia and Czech Republic have continued their convergence trend, even though it is at a slower pace than before the crisis. Conversely, the process came to a halt for Estonia, Latvia, Lithuania, Slovenia and Hungary whose growth rates turned negative and fell below the EU average. Fifth, the economies more resilient to the crisis were those with the largest R&D intensities in knowledge intensive sectors (Figure I.6-B.5), suggesting that investing in R&I improves competitiveness over the long term. Finally, the gap between the EU and the United States increased in 2015 compared to 2007, while Japan fell behind due to a worse and negative performance over the period.

**Figure I.6-B.13** Labour productivity<sup>1</sup> of high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT) plus knowledge-intensive services (KIS)<sup>2</sup>, 2007 and compound annual real growth, 2000-2007



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPS€ . Compound annual real growth was calculated from values at 2010 prices. <sup>2</sup>KIS does not include security and investigation activities due to the unavailability of data. <sup>3</sup>PL: 2003-2007; IE, ES, FR, HR, IT, CY, LV, LT, PL, PT, RO, SE, EU, NO, JP: 2014. <sup>4</sup>MT: 2000-2013; PL: 2003-2014; EE: 2004-2015; HR: 2008-2014; IS: 2008-2015; BE, DE, IE, ES, FR, IT, CY, LV, LT, PT, RO, SE, NO, JP: 2000-2014. <sup>5</sup>EE, LU, US, JP: KIS EE: 2004-2007. <sup>6</sup>EE, LU, US, JP: KIS does not include employment activities. <sup>7</sup>LU, JP: KIS does not include water transport and air transport. <sup>8</sup>EE, MT, PL: KIS does not include air transport. <sup>9</sup>IE, MT, NO: Manufacture of coke and refined petroleum products is included in MHT. <sup>10</sup>EE: Manufacture of basic pharmaceutical products and pharmaceutical preparations is not included in HT. <sup>11</sup>Elements of estimation were involved in the compilation of the data.

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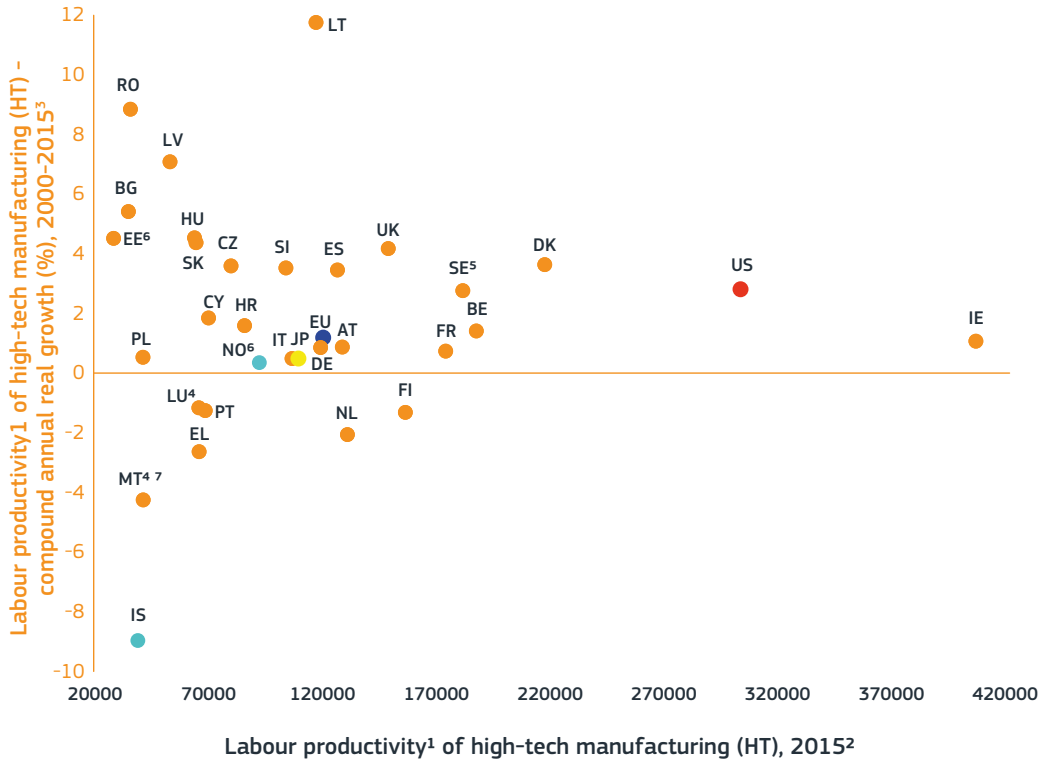


*Labour productivity in high-tech manufacturing in the EU has been growing at a faster pace than the aggregate of all the knowledge-intensive activities (1.2% against 0.6% per year). The United States still (2.8%) outperforms the EU, implying an increase in the gap between the two economies, while Japan's performance has been stuck at 0.5% growth per year.*

Within the EU, southern economies, with the exclusion of Spain, have experienced weak or negative growth over the period, together with the Netherlands, Finland, Luxembourg and Malta. Productivity has been rising in all the other countries, with the highest growth rates in Lithuania, Romania, Latvia and Bul-

garia. Overall, the United States had by far the highest productivity level in high-tech manufacturing in 2015, exceeding by a large margin even the EU countries performing well, such as Denmark, Sweden, Belgium and France. Ireland stands apart because of its exceptional labour productivity level, more than three times higher than the EU average, and also outperforming United States values despite slower growth rates (Figure I.6-B.15). The crisis had a slightly negative impact on labour productivity dynamics in high-tech manufacturing in the EU, slowing down the aggregate growth rate from 1.5% to 1.2% per year in the period 2008-2015 but not significantly affecting the overall trend.

**Figure I.6-B.15** Labour productivity<sup>1</sup> of high-tech manufacturing (HT), 2015 and compound annual real growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPSE. Compound annual real growth was calculated from values at 2010 prices. <sup>2</sup>DE, IE, ES, HR, CY, LV, LT, PL, PT, RO, SE, EU, NO, JP: 2014; MT: 2016. <sup>3</sup>DE, IE, ES, CY, LV, LT, PT, RO, SE, EU, NO, JP: 2000-2014; MT: 2000-2016; PL: 2003-2014; HR: 2008-2014; IS: 2008-2015. <sup>4</sup>LU, MT: MHT is included in HT. <sup>5</sup>SE: Manufacture of chemicals and chemical products is included in HT. <sup>6</sup>EE, NO: Manufacture of basic pharmaceutical products and pharmaceutical preparations is not included in HT. <sup>7</sup>MT: Manufacture of coke and refined petroleum products is included in MHT. <sup>8</sup>IE, CY, RO: Breaks in series occur between 2000 and 2015; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the the break in series. <sup>9</sup>Elements of estimation were involved in the compilation of the data.

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*Medium-high-tech manufacturing is the sector among knowledge-intensive activities where labour productivity has been growing at the fastest pace in the EU, experiencing an average compound growth rate of 1.6% per year in the period 2000-2015, faster than Japan (1.5%) but still slower than the United States (2.1%). Most Member States have increased their productivity levels, with only five countries (Italy, Croatia, Luxembourg, Cyprus and Malta) experiencing negative growth rates.*

Romania, Bulgaria and Lithuania<sup>37</sup> are the economies where productivity in the sector has grown the most, while the remaining countries have ex-

perienced growth rates between around 0% and 4% per year (Figure I.6-B.16). Labour productivity in Germany, the EU country with the highest specialisation in medium-high-tech manufacturing (see Figure I.6-B.10), has been growing at the same rate as the United States and their levels in 2015 were equal. Ireland is the Member State with the highest labour productivity, followed by the Netherlands, Belgium, Austria and France. The crisis had a heterogeneous effect across countries, depressing the performance of some economies (such as Austria, Malta and the Netherlands), while others have either shown resiliency or higher growth rates (such as, for instance, Denmark, Poland and Hungary).

<sup>37</sup> A positive impact of their accession to the EU may be contributing to their overall performance.

**Figure I.6-B.16** Labour productivity<sup>1</sup> of medium-high-tech manufacturing (MHT), 2015 and compound annual real growth, 2000-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPSE. Compound annual real growth was calculated from values at 2010 prices. <sup>2</sup>DE, IE, ES, HR, CY, LV, LT, PL, PT, RO, SE, EU, NO, JP: 2014; MT: 2016. <sup>3</sup>DE, IE, ES, CY, LV, LT, PT, RO, SE, EU, NO, JP: 2000-2014; PL: 2003-2014; EE: 2004-2015; HR: 2008-2014; IS: 2008-2015; MT: 2008-2016. <sup>4</sup>LU, MT: HT is included in MHT.

<sup>5</sup>SE: Manufacture of chemicals and chemical products is not included in MHT. <sup>6</sup>NO: Manufacture of basic pharmaceutical products and pharmaceutical preparations is included in MHT. <sup>7</sup>IE, MT, NO: Manufacture of coke and refined petroleum products is included in MHT. <sup>8</sup>IE, CY, RO: Breaks in series occur between 2000 and 2015; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>9</sup>Elements of estimation were involved in the compilation of the data.

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*EU labour productivity dynamics in knowledge-intensive services have slightly improved over the past 15 years despite having been negatively affected during the crisis. Growth performance in the sector, which was already the lowest among knowledge-intensive activities at 1.2% per year from 2000-2007, collapsed to 0% from 2008 to 2015, resulting in overall weak performance during the whole period.*

As a result, in 2015, EU labour productivity was higher than in Japan but lagged behind the United States, with a bigger gap as compared to 2000. This is worrying given the weight of KIS in total economic activity in modern economies. In addition, while there was a positive trend in the first half of the 2000s, the period following the last recession is characterised by declining labour productivity growth across all Member States, which turns negative for the southern economies, the UK and some Eastern European countries. This negative trend also applies to Japan and the United States, the latter nevertheless being able to maintain positive growth over time.

**Figure I.6-B.17** Labour productivity<sup>1</sup> of knowledge-intensive services (KIS)<sup>2</sup>, 2015 and compound annual real growth, 2000-2015



Science, Research and Innovation performance of the EU 2018  
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD

Notes: <sup>1</sup>Value added per person employed in current PPSE. Compound annual real growth was calculated from values at 2010 prices. <sup>2</sup>KIS does not include security and investigation activities due to the unavailability of data. <sup>3</sup>MT: 2013; BE, DE, ES, FR, HR, IT, CY, LV, LT, PL, PT, RO, SE, EU, NO: 2014. <sup>4</sup>MT: 2000-2013; BE, DE, ES, FR, IT, CY, LV, LT, PT, RO, SE, EU, NO: 2000-2014; PL: 2003-2014; HR: 2008-2014; IS: 2008-2015. <sup>5</sup>EE, LU, US, JP: KIS does not include employment activities. <sup>6</sup>LU, JP: KIS does not include water transport and air transport. <sup>7</sup>IS: KIS does not include water transport. <sup>8</sup>EE, HR, MT, PL: KIS does not include air transport. <sup>9</sup>IE, CY, RO: Breaks in series occur between 2000 and 2015; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>10</sup>Elements of estimation were involved in the compilation of the data. Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/part/i\\_6-b\\_figures/f\\_i\\_6-b\\_17.xlsx](https://ec.europa.eu/info/sites/info/files/srip/part/i_6-b_figures/f_i_6-b_17.xlsx)

*In conclusion, over the last two decades, the EU has been unable to bridge the productivity gap with the United States. Furthermore, such a divide has been widening since the last economic crisis due to zero or negative growth rates in the EU. This overall scenario can be partially explained by relatively lower R&D investment in these sectors compared to the United States and international competitors. Business R&D intensity in the EU is considerably lower than in the United States, South Korea and Japan and the trend in the years after the crisis has not led to a significant narrowing of the gap.*

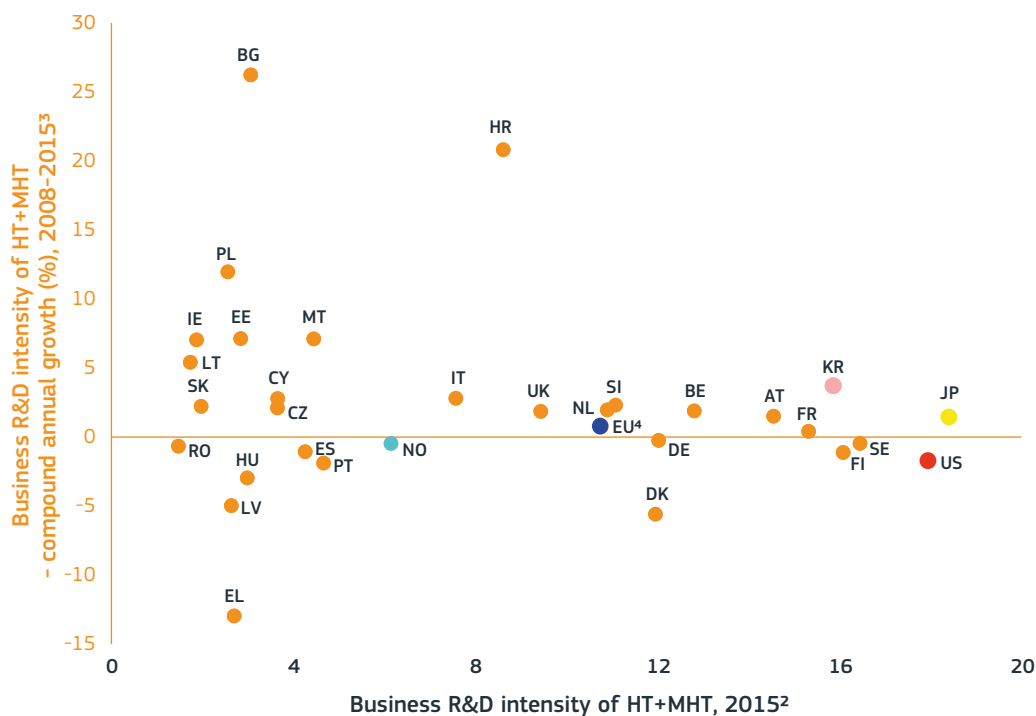
While business R&D intensity in medium-high and high-tech manufacturing has increased

slightly in the EU since 2008, the low growth rate (0.8% per year) has not been enough to bridge the gap with Japan, the United States and South Korea (Figure I.6-B.18). The latter has increased its R&D investment at a much higher pace (3.7%) than the United States (-1.7%) and Japan (1.5%). Within the EU, some eastern economies have experienced positive growth in R&D intensity, while a negative performance has been observed in particular for Greece<sup>38</sup>. In 2015, nine Member States had business R&D intensities above the EU average, and only Finland, Sweden, France and Austria are close to the rates of the main international competitors.

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<sup>38</sup> It should be noted that for some smaller economies, a relatively small variation in R&D investment at the sectoral level can have a large effect on both the growth rate and the intensity.

**Figure I.6-B.18** Business R&D intensity of high-tech manufacturing (HT) plus medium-high-tech manufacturing (MHT)<sup>1</sup>, 2015 and compound annual growth, 2008-2015<sup>3</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Business enterprise expenditure on R&D (BERD) as % of value added, in HT+MHT sectors. <sup>2</sup>IE, FR, SE: 2013; PL, EU, JP: 2014. <sup>3</sup>FR, SE: 2008-2013; PL, EU, JP: 2008-2014; BG, DK, HR: 2009-2015; EE, MT: 2010-2015; IE: 2011-2013; EL: 2011-2015; LV: 2012-2015. <sup>4</sup>EU was estimated by DG Research and Innovation and does not include LU. <sup>5</sup>NL, RO, SI: Breaks in series occur between 2008 and 2015; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>6</sup>Elements of estimation were involved in the compilation of the data. Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/parti/i\\_6-b\\_figures/f\\_i\\_6-b\\_18.xlsx](https://ec.europa.eu/info/sites/info/files/srip/parti/i_6-b_figures/f_i_6-b_18.xlsx)

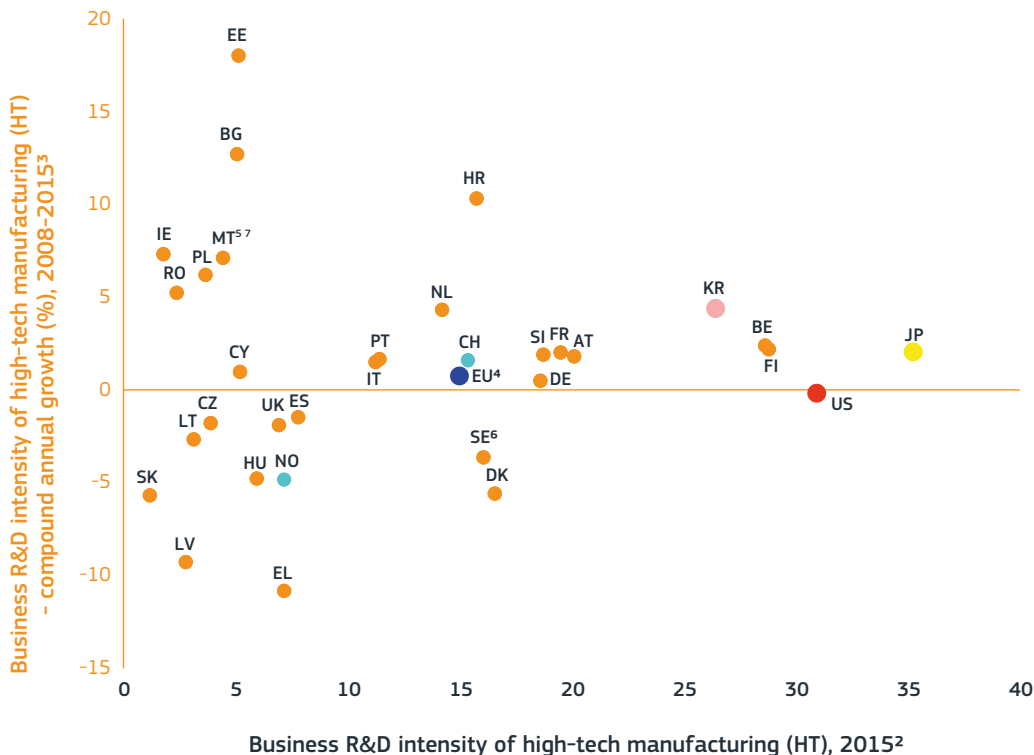
*Business R&D intensity in high-tech manufacturing has been growing slightly faster in the EU (0.8% per year) compared to the United States (-0.2%) but slower than in Japan (2.0%), while South Korea has been the largest investor over the period (4.4%). Nevertheless, the EU still invests considerably less in R&D than its international competitors.*

With an average BERD of 15 %, the EU invests less than half of what can be observed in the United States (30.9%) or Japan (35.3%), and significantly less than South Korea (26.4%). Overall, there is no trend towards significantly higher R&D investment in high-tech manufacturing in the EU since the last economic crisis (Figure I.6-B.19). The EU landscape is quite diverse, with R&D intensities ranging

from values close to zero – e.g. Slovakia, Ireland and Romania – to levels comparable to those observed in the United States – e.g. Belgium and Finland. In fact, Belgium and Finland are contributing significantly to driving the EU average up, since the majority of Member States have a remarkably lower BERD intensity. The BERD intensity has also been increasing at significant rates in some Eastern European economies and a positive performance can also be observed for Austria, France and the Netherlands among others. Conversely, some countries have been reducing the R&D investment in the sector, with Greece experiencing the lowest growth rate in the EU (-10.9% per year). Growth dynamics have also been particularly negative for Slovakia, Sweden, Latvia and Denmark.



**Figure I.6-B.19** Business R&D intensity of high-tech manufacturing (HT)<sup>1</sup>, 2015 and compound annual growth, 2008-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: <sup>1</sup>Business enterprise expenditure on R&D (BERD) as % of value added in HT sectors. <sup>2</sup>FR, IE, SE: 2013; PL, EU, JP: 2014.

<sup>3</sup>FR, SE: 2008-2013; PL, JP, EU: 2008-2014; BG, DK: 2009-2015; EE, MT, SK: 2010-2015; IE: 2011-2013; EL: 2011-2015. <sup>4</sup>EU

was estimated by DG Research and Innovation and does not include LU and MT. <sup>5</sup>MT: MHT is included in HT. <sup>6</sup>SE: Manufacture of

chemicals and chemical products and manufacture of coke and refined petroleum products are included in HT. <sup>7</sup>MT: Manufacture of

coke and refined petroleum products is included in MHT. <sup>8</sup>IE, NL, RO, SI: Breaks in series occur between 2008 and 2015; when

there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth

after the break in series. <sup>9</sup>Elements of estimation were involved in the compilation of the data.

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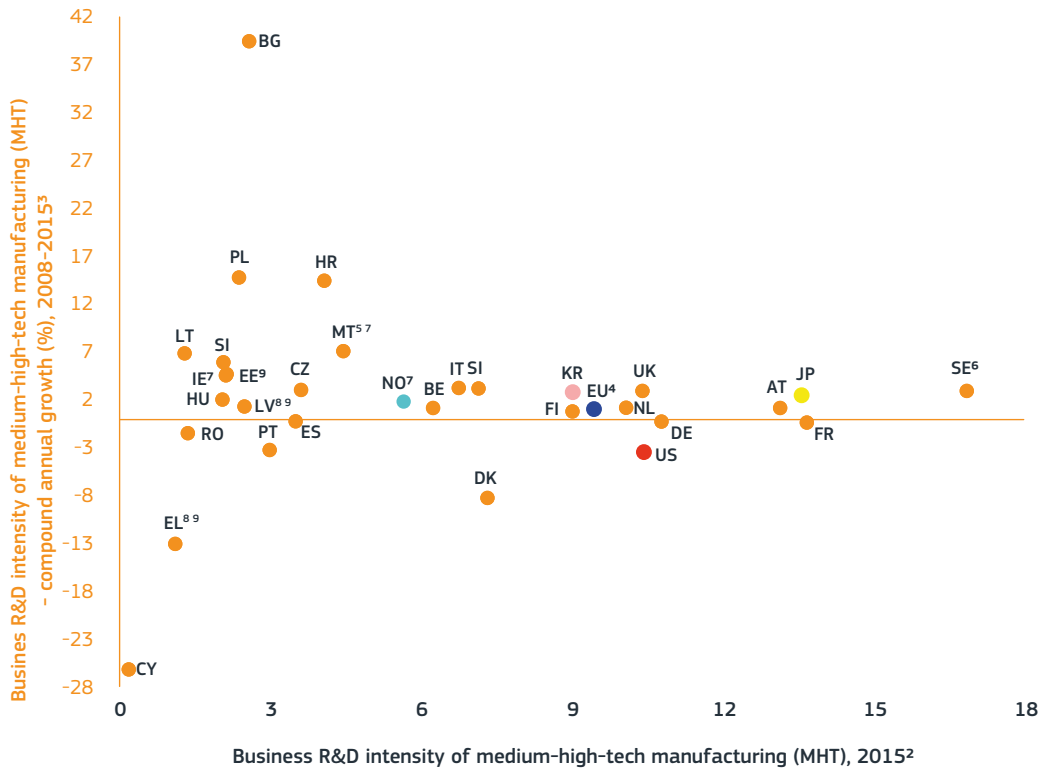
***Medium-high-tech manufacturing industries in the EU are characterised by R&D investments (BERD intensity equal to 9.5%) comparable to those in the United States (10.4%) and South Korea (9%). The investment trend has been stable since 2008, with a growth rate of 1.1% per year over the period 2008-2015, slower than in South Korea (2.9%) and Japan (2.5%), but much faster than the United States (-3.4%), implying a narrowing of the gap with the latter.***

Most Member States have been experiencing positive growth rates between 0% and 5% per year, suggesting an effort has been made to increase knowledge intensity in the sector over time (Figure I.6-B.20). Some countries, e.g. Latvia, Slovenia, Malta, Poland and Croatia, have been growing faster at rates up to 15%. Conversely, Cyprus and Greece have been going through a drastic collapse in R&D investment, with an annual negative growth rate of 26.6% and 13%, respectively. In the case of Cyprus, this trend is coupled with a shift in economic activity away from the sector and a growing specialisation in high-tech manufacturing, suggesting an upgrade in the economy's knowledge structure. Bulgaria stands as an outlier, with an exceptional annual growth rate of BERD

intensity in the sector of 39.8% since 2008. As of 2015, Sweden has the highest investment in R&D in the industry, larger (16.8%) than Japan (13.6%), followed by France (13.7%) and Austria (13.1%).

This chapter has analysed structural change in the EU and among its main competitors and has linked these trends to labour productivity dynamics. Economies with higher productivity in a sector are more competitive and, in the long term, tend to have larger shares in that sector than other countries, and are also more resilient to external shocks, such as the last economic crisis. Furthermore, R&D investments are a key factor behind labour productivity, shaping sectors' competitiveness and acting as an important lever to drive changes in economic specialisation. The EU has been slightly increasing both its specialisation in knowledge intensive sectors and business R&D intensity in those sectors. However, these trends are not sufficient to bridge the gap with the most advanced economies, most notably the United States, South Korea and Japan. Therefore, both a faster pace of structural transformation and greater R&D investments would be needed to increase labour productivity growth and EU competitiveness on the global scale.

**Figure I.6-B.20 Business R&D intensity of medium-high-tech manufacturing (MHT)<sup>1</sup>, 2015 and compound annual growth, 2008-2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Eurostat, OECD

Notes: <sup>1</sup>Business enterprise expenditure on R&D (BERD) as % of value added in MHT sectors. <sup>2</sup>IE, FR, SE: 2013. PL, EU, JP: 2014. <sup>3</sup>FR, SE: 2008-2013; PL, EU, JP: 2008-2014; BG, DK, HR, SK: 2009-2015; MT: 2010-2015; IE: 2011-2013; EL: 2011-2015. <sup>4</sup>EU was estimated by DG Research and Innovation and does not include LU and MT. <sup>5</sup>MT: HT is included in MHT. <sup>6</sup>SE: Manufacture of chemicals and chemical products is not included in MHT. <sup>7</sup>IE, MT, NO: Manufacture of coke and refined petroleum products is included in MHT. <sup>8</sup>EL, LV: Manufacture of motor vehicles, trailers and semi-trailers is not included in MHT. <sup>9</sup>EE, EL, LV: Manufacture of other transport equipment is not included in MHT. <sup>10</sup>NL, RO, SI: Breaks in series occur between 2008 and 2015; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. <sup>11</sup>Elements of estimation were involved in the compilation of the data.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/part/i\\_6-b\\_figures/f\\_i\\_6-b\\_20.xlsx](https://ec.europa.eu/info/sites/info/files/srip/part/i_6-b_figures/f_i_6-b_20.xlsx)

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# CHAPTER

# I.7

# **CONCLUSIONS AND POLICY IMPLICATIONS**

## CHAPTER I-7: CONCLUSIONS AND POLICY IMPLICATIONS

Part I of this Report has provided an overview of the research and innovation (R&I) performance in Europe, following an indicator-based analysis. It has assessed the impacts of R&I on fostering productivity growth and the changes they bring to the job market, highlighting the changing nature of innovation in a digitised economy, where the digital and physical spheres are increasingly converging.

The productivity slowdown in Europe can be traced back to increasing challenges for breakthrough innovations to be scaled up and diffused quickly in the economy, across different sectors and types of companies. This is particularly noticeable at the company level, where a limited number of leading companies, whose productivity growth has been robust in the past, contrast with the evolution of a wider set of companies in the economy, whose productivity growth has been disappointing and are lagging behind. This divergence in productivity across companies, coupled with the profound changes that many new technologies such as automation and artificial intelligence are bringing into the job market, is leading to growing polarisation of jobs and wages. The decline in routine task jobs and pressure on low and medium skill wages can have a significant impact on inequality, with the negative social, economic and political consequences associated with it.

While more analytical evidence is necessary, breakthrough innovation and innovation diffusion in Europe seems to be hampered by a combination of lower investment levels in R&I and other intangible assets and challenges in the conditions required to spur and support innovation and innovation diffusion due to weaker framework conditions. These factors seem to be hindering Europe's ability to quickly adapt to the profound and rapid changes in innovation

dynamics, with potentially serious consequences for Europe's continued prosperity.

More precisely, innovation – and notably breakthrough innovation – is increasingly linked to the convergence of several technologies, much enabled by digitalisation, that are returning to their scientific and technological roots and that are not easy to master or to obtain off the shelf. To fully reap the benefits of innovation, there is a need for a change in business models, which usually require substantial economic and, at times, financial capacity. Many breakthrough innovations are being introduced rapidly into the markets and are bringing about complete game-change scenarios in increasingly converging industries and markets. This is giving rise to new global superstar companies, notably in the United States, where the benefits from innovations tend to become highly concentrated in 'winner takes most' companies.

Against this backdrop, innovation currently requires sufficient and efficient investment in R&I and other intangible assets to support innovation creation and the ability to absorb and apply innovation, as well as redefining the conditions for innovation to flow quickly across the economy. The speed and depth of the changes we are experiencing enhances the urgency of these requirements which should be applicable to all countries, including those performing relatively well, as complacency now can lead to sleepwalking into trouble in the near future.

The Report shows that Europe remains a global R&I powerhouse, although it is failing to invest as much as other economies, notably the United States, in business R&D, education and skills development, ICT and economic competences, such as management and organisational skills – a gap that is widening over time. This affects the ability of stakeholders to build stronger knowledge



flows and impacts negatively on Europe's technological and innovation output, including the development of new emerging technologies. This hinders the ability to capitalise on Europe's scientific excellence.

In addition, the analysis shows that overall Europe suffers from weaker framework conditions for innovation and innovation-led entrepreneurship, notably in terms of more stringent conditions for labour and goods markets, less access to risk capital, and a still fragmented market in certain areas, such as digital, capital and services that hinder companies' ability to scale up innovations quickly. As a result, Europe lags behind in benefiting from new technological champions or more generally transformational entrepreneurship, i.e. disruptive innovators who reshape existing markets to become global giants.

However, this aggregate analysis masks large differences across Member States and while the innovation divide persists in Europe, it is now more nuanced, notably for investment patterns as several Member States have made significant progress towards boosting their investment levels. The analysis also shows that there are persistent challenges in transforming investment into scientific and technological outputs, as many R&I systems continue their restructuring.

Based on this analysis of R&I performance number of policy considerations follow:

### **1- Boost investment in R&I and other intangible assets in Europe**

Public investment in R&I and other intangible assets in Europe can help bridge the current investment gap against other economies. Lifelong learning aimed at developing the skills needed for a changing economy will contribute not only to spurring innovation but also to mitigating the risks associated with it in terms of potential job losses. While Member States benefit from differ-

ent fiscal spaces for public investment, those that can do so should invest more in intangible assets. In addition, this will bring spillover benefits to other countries. Those countries that have experienced low or even declining public investments should make it a priority to cement the basis of future growth on such investments. In addition, the leveraging of business investment, an area in which Europe particularly lags behind, is critical. The right framework conditions for private companies to innovate must be in place.

### **2- Urgently rethink public support for R&I today, notably for market-creating breakthrough innovations**

Europe lacks sufficient investment in market-creating breakthrough innovations, where private capital shies away. Supporting bottom-up transformative innovative projects can bridge this gap. In addition, public R&D investment will benefit from moving away from supporting specific fields towards more comprehensive trans-sectoral and trans-disciplinary mission-oriented policy approaches. Missions should have a transformative potential, set direction, maximise the impacts of public R&D, galvanise business investment and be capable of mobilising all stakeholders. Policy experimentation in these fields can help establish more robust evidence about the impacts of these changes in public R&D funding.

### **3- Improve the conditions to speed up knowledge creation and diffusion to support innovation and innovation diffusion, by opening up national science and innovation systems**

Supporting investment in R&I and other intangible assets improves an economy's absorptive capacity and its ability to diffuse knowledge. Measures to open up science and innovation systems within Europe and to the world will support faster and stronger knowledge flows, innovation outputs and their commercialisation. Against this backdrop, initiatives to boost

the conditions for open science, thanks to the opportunities offered by digital technologies, and for open innovation, including through stronger science-business, will be critical for faster and stronger innovation diffusion.

**4- Ensure innovation-friendly regulations and innovation demand policies that support breakthrough innovation and innovation diffusion across sectors**

It is crucial to develop innovation-friendly regulations that facilitate the smoother adoption of innovations, notably in relation to the myriad of opportunities that digital technologies offer, across all sectors of the economy and specifically in relation to highly regulated sectors such as education, health and transport. In addition, innovation demand policies, such as public procurement or the empowerment of consumers to develop consumer-based innovations, will be critical. These actions will speed up the creation of benefits from innovation.

**5- Rethink competition policy in a digitised economy**

While there is not yet sufficient evidence, it appears that changes in the innovation dynamics are leading to a higher concentration of innovation benefits and to the creation of potential monopolies or dominant positions in relation to the access and use of key new resources, such as data, and notably big data. This may have implications for ensuring a level playing field with equal opportunities for transformative innovations.

**6- Complete the internal market in all sectors to support the rapid scale-up of European innovation**

Europe's ability to scale up innovations is being hindered by an incomplete internal market, notably in strategic areas such as digital or services. Achieving that internal market in all areas is crucial to give innovations 'born in Europe' the opportunity to scale up and become global players.

**7- Boost adequate access to risk capital in Europe to support innovation**

Risk and patient capital, while recovering, remain very low compared to the United States. Public efforts to invest and leverage private risk capital are crucial. Initiatives like the Capital Markets Union or the creation of a Pan-European Venture Capital Fund-of-Funds which aim to make European capital markets deeper, broader, better integrated and with a greater capacity to leverage business resources will help bridge this gap.

**8- Strengthen the pace of structural reforms and improve framework conditions for the creation, growth and orderly exit of firms, to unlock resources from unproductive companies**

Continuing structural reforms that allow markets to react better and faster to the changes that innovations bring about in the markets and that facilitate the entry, but also the orderly exit of firms, will help reallocate resources towards the most innovative and productive companies, avoiding the negative lock-in of resources in unproductive and zombie companies.

**9- Raise R&I capacities across the European Union**

Bridging the innovation divide in Europe in order to build the foundations of sustained growth across all Member States and regions will require renewed efforts to sustain investments in R&I and other intangible assets and the commercialisation of products and services accruing from innovation. It will also require the design, implementation and evaluation of the necessary accompanying reforms to boost the quality, efficiency and institutional capacity in R&I. Smart specialisation strategies that are about enabling regions to turn their needs, strengths and competitive advantage into marketable goods and services are already helping in this process. The mobilisation of na-

tional and European resources towards these activities will bring scientific excellence and impactful innovation performance.

**10- Europe must capitalise on the increasingly global innovation landscape by opening up its science and innovation to the world**

As the global R&I landscape has changed profoundly with the rise of new innovation poles, Europe needs to make sure that it can capitalise on all the new knowledge that is created around the world by building strong R&I partnerships and by supporting the strengthening of R&I capacity in other countries, so that global knowledge can quickly expand and more countries can contribute to and benefit from global progress.

Finally, the current analysis has also unveiled a number of areas where we continue to lack sufficient robust evidence and that will require further research to provide better evidence-based policy input. These include:

- ▶ How can investment in intangible assets support innovation and innovation diffusion and what mechanisms are in place at the micro-economic level?
- ▶ How can R&I, ICT, skills and social policies best coordinate to ensure innovation and the wide participation of innovation benefits in society?
- ▶ How is the current concentration of innovation, notably in the United States, affecting the creation of a level playing field where incumbents and new entrants can compete fairly? What role is there for regulation and competition policy?
- ▶ How can R&I policy instruments support innovation diffusion?
- ▶ How can public R&D investment better leverage private R&D investment? What role is there for mission-led public research to mobilise increasing public and private investments?



# CHAPTER



# CHAPTER

## II.1

# **SLOW AND DIVIDED: WHAT POLICIES CAN LIFT ECONOMIES AND RESTART ENGINES OF GROWTH FOR ALL?**

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## 1. Introduction

Over the last decade, developed economies in Europe and elsewhere have faced two major trends with important implications for the well-being of their societies: a slowdown in productivity growth and increasing inequality. These trends are already affecting countries in many areas, ranging from earnings growth and inequality to the ability of governments to make good on promises to their citizens. The two trends have been mainly studied separately and from an aggregate perspective. The debate around the slowdown in global productivity tends to focus on the ability of recent technological developments, particularly in the information and communications technology (ICT) industries, to generate broad and sustained economic growth, and on measurement issues. At the same time, the debate about the potential causes of rising inequality tends to emphasise structural trends, like skill-biased technological change and offshoring, and institutional factors, such as education, unionisation, the minimum wage and top income taxation.

However, recent research points to important interconnectedness between the two types of trends and attracts attention to the need to look behind the aggregate figures (Andrews et al., 2016; Berlingieri et al., 2017). Specifically, it emphasises the role of individual firms in driving aggregate outcomes and the huge differences that exist among firms, even within the same country and narrowly defined industries. It documents a growing divergence between high-productivity firms and those lagging behind. This divergence could at least partially explain productivity slowdown and hints at some of its potentially deeper causes, namely

insufficient technological diffusion to laggard firms and an insufficiently dynamic process of ‘creative destruction’, whereby inefficient firms exit the market and resources are reallocated to innovative new firms. In addition, the divergence in productivity is found to be linked to a divergence in wages, which means that the same company-level patterns can also explain a significant part of the growing inequality in earnings (Berlingieri et al., 2017). Importantly, this implies that policy responses which can tackle the increasing productivity divergence could potentially produce a ‘double dividend’ in terms of both greater productivity growth and reduced income inequality.

The aim of this chapter is to provide an overview of this research and use it as an evidence base for designing policies that ensure productivity growth for all. It is organised as follows: Section 2 provides a brief overview of the global productivity slowdown and increasing inequality and the discussions around them. Sections 3 and 4 focus on the role of productivity differences across firms in driving these trends. Section 3 takes a global perspective and summarises evidence on the widening gap between the global frontier and the rest of the business population, and explores the potential role of policies in closing this gap. Section 4 takes a closer look at the sources of these divergences, exploring variations within countries and industries. Section 5 links productivity divergence to wage inequality and investigates the role of structural factors such as globalisation, digitalisation and labour market features on both wage inequality and its links to productivity dispersion. Section 6 concludes this chapter.



## 2. The two trends

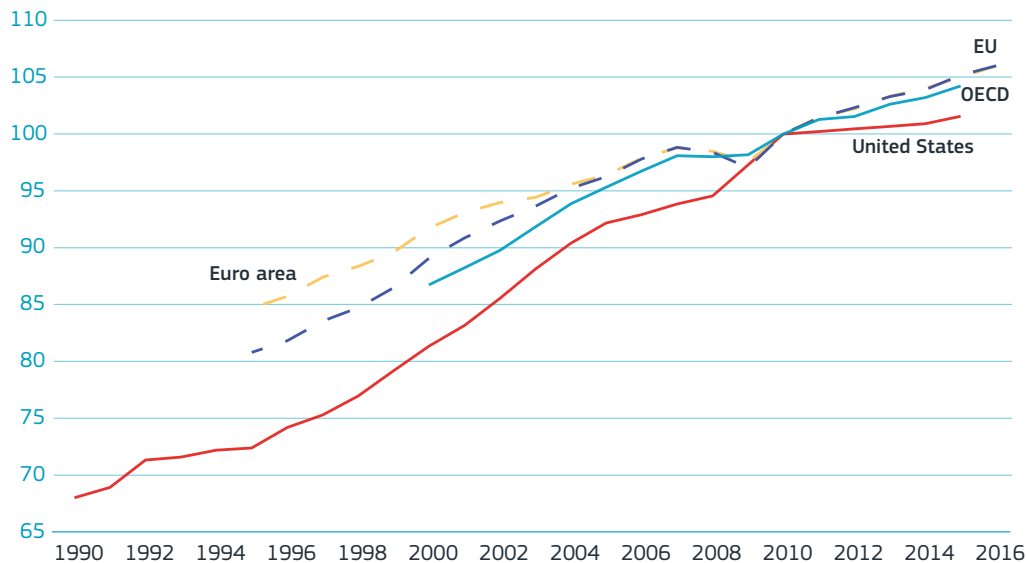
### 2.1 Global productivity slowdown

OECD and European economies have witnessed a global productivity slowdown that started well before the great recession and has worsened ever since. What is even more worrying is that the main culprit behind the pre-recession productivity slowdown is a decline in the contribution to growth by multi factor productivity (MFP), an index which measures how efficiently inputs are combined to produce output. MFP can be considered a proxy for innovation, smart organisation, good management and,

more broadly, a high level of knowledge-based capital (KBC). The slowdown in MFP growth is of concern because, in the long run, it is the main driver of economic and income growth, governments' capacity to respect their obligations vis-à-vis societies and, ultimately, people's well-being.

This slowdown in aggregate productivity and the decline in the contribution from MFP growth characterises many countries across the OECD, including Europe and the United States (Figures II.1.1 and II.1.2).

**Figure II.1.1 Real growth in GDP per hour worked<sup>1</sup>, 1990-2016**  
Index 2010 = 100



Science, Research and Innovation performance of the EU 2018

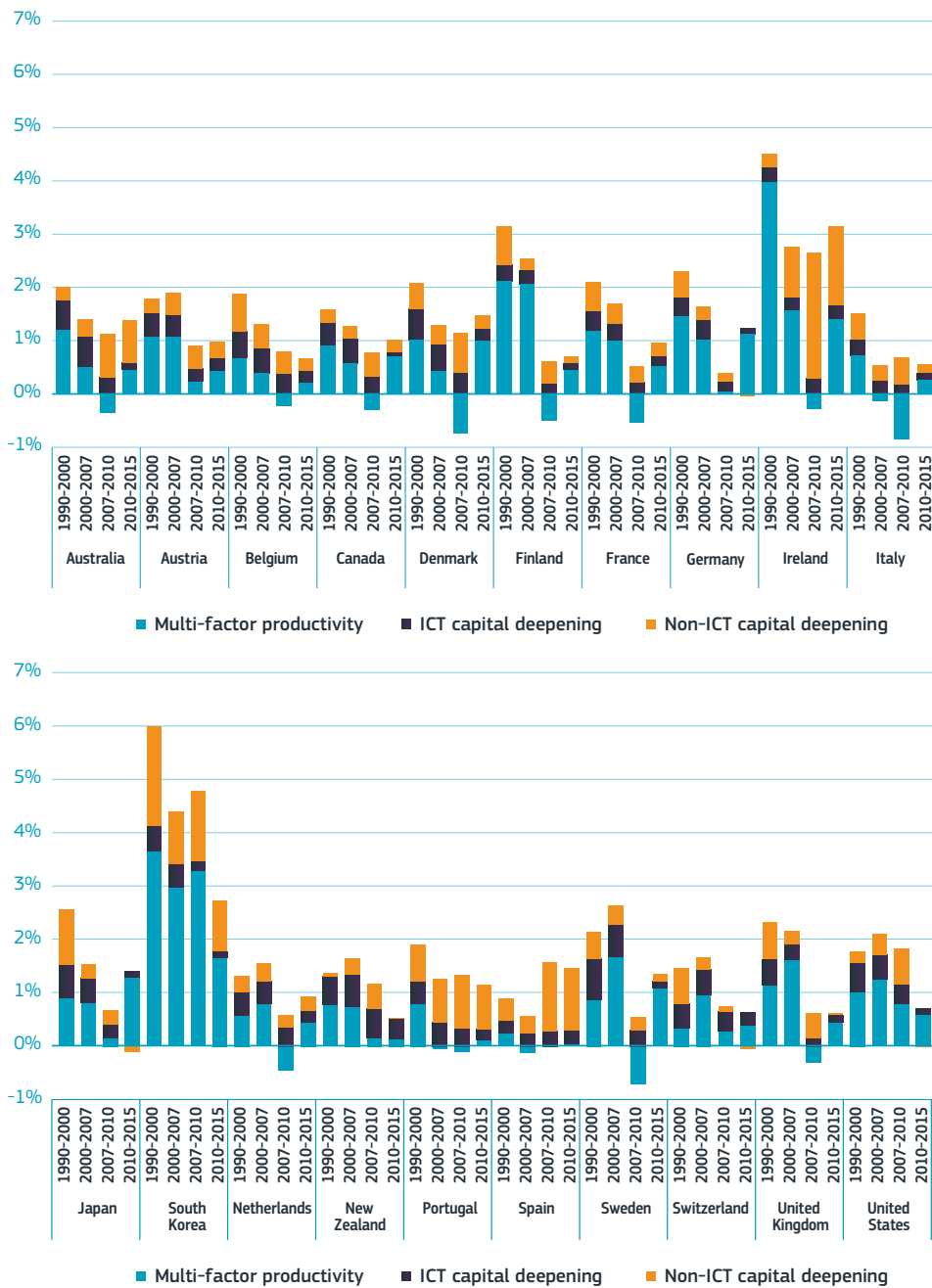
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies.

Data: OECD, Productivity database

Note: <sup>1</sup>GDP per hour worked in PPP\$ at 2010 prices and exchange rates.

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**Figure II.1.2** Decomposition of labour productivity growth - percentage point contribution to labour productivity growth (annual), 1990-2000, 2000-2007, 2007-2010, 2010-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies.

Data: OECD, Productivity database

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_2.xlsx)

Given the importance of productivity and innovation for long-term well-being, the slowdown has sparked a lively debate in the academic arena among those who see it as a permanent feature of a new economic era – the so-called techno-pessimists – and those who see it as a temporary phenomenon, the so-called techno-optimists. Yet other researchers have investigated the role of mismeasurement to explain these patterns.

The techno-pessimists, such as Robert Gordon, argue that the recent slowdown is a permanent phenomenon. Innovations such as electrification, internal combustion and plumbing, which took place during the Second Industrial Revolution, between the second half of the 19th and the first half of the 20th centuries, and their spin-off inventions – aeroplanes, air-conditioning and interstate highways – were the main drivers of rapid productivity growth at the frontier, i.e. in the United States of America, until the 1970s. In contrast, innovations from the Third Industrial Revolution, especially in ICT, have only led to a short-lived spurt of productivity (Gordon, 2012). In addition, current and future innovations and their potential impact on United States economic growth will be dwarfed, according to techno-pessimists, by ‘headwinds’ related to demography, education, inequality, globalisation, environment and the debt overhang.

At the opposing end of the debate, techno-optimists justify the current slowdown as the cost of the transition from an economy based on the production of goods to one based on the production of ideas. This temporary slowdown masks the underlying dramatic speed of technological progress led by the IT and digital revolutions, which will continue to transform the global economy (Brynjolfsson and McAfee, 2011). In their view, science and technology’s main function in history is “to make taller and taller ladders to get to the higher-hanging fruits and to plant new and possibly improved trees” (Mokyr, 2014) and to achieve new frontiers that remain unimaginable today.

Finally, some have argued that the slowdown is not real but is an artefact due to the mismeasurement of productivity growth. Economists such as Hal Varian dispute the use of GDP as the relevant measure of output in today’s digitalised economies (Varian, 2016)<sup>1</sup>. More recently, evidence suggests that we might have been missing growth because of mismeasurement of growth from “creative destruction” and subsequently of inflation rates (Aghion et al., 2017). However, others have suggested that mismeasurement, although an issue, can only explain too small a fraction of the productivity slowdown, given its magnitude and timing (see for example Groshen et al., 2017; Syverson, 2016<sup>2</sup>; Byrne, Fernald and Reinsdorf, 2016) to be considered the main explanation of this phenomenon.

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- 1 The main argument considers the measurement problem related to the fact that a lot of what originates from the digital revolution (e.g. apps; improved search engines) is (nearly) free. For example, Google’s search engine contribution to GDP is measured by the advertising Google manages to sell on it while no value is ascribed to what a user can do on the engine: <https://www.brookings.edu/wp-content/uploads/2016/08/varian.pdf>
  - 2 For example, Syverson (2016) provides various pieces of evidence against the mismeasurement hypothesis. Amongst those, he shows that across different countries the size of the productivity slowdown is unrelated to measures of the countries’ consumption or production intensities of ICTs, often cited as sources of mismeasurement. Second, existing estimates of the surplus created by internet-linked digital technologies are well below the volume of “missing output” due to productivity slowdown.

Both the techno-optimists versus techno-pessimist debate and the measurement hypothesis focus on aggregate and sectoral productivity growth. However, a country's productivity growth performance is driven by the performance of firms in the economy. In addition, there is overwhelming evidence that firms are heterogeneous even within narrowly defined sectors (e.g. Syverson, 2004 and references therein). Thus, aggregate productivity growth will depend both on each firm's growth performance as well as on the extent to which resources are allocated to the most efficient firms. In the long term, the capacity of economies to ensure a productivity enhancing reallocation of resources and a Schumpeterian creative destruction process are also key. The following two sections explore these issues.

## 2.2 Rising inequality

The second key feature of recent decades has been an increase within countries in inequality in income between the rich and the poor (OECD, 2015; Piketty, 2014) and in earnings among different types of workers, for instance between high- and low-skilled workers (Autor et al., 2003) and between those employed in large versus small businesses (Song et al., 2015). Evidence suggests that most of this growing inequality is driven by an increase in wage inequality among workers.

A significant part of the growing inequality in income can be attributed to increasing inequality in earnings driven by a rise in the wage differentials between firms, as found in Brazil (Helpman et al., 2017), Denmark (Bagger et al., 2013), Germany (Baumgarten, 2013; Card et al., 2013; Goldschmidt and Schmieder, 2015), Italy (Card et al., 2014), Portugal (Card et al., 2016), Sweden (e.g. Häkanson et al., 2015), the UK (Faggio et al., 2010), and in the United States (Dunne et al., 2004; Barth et al., 2014; Song et al., 2015).

Productivity has been identified as an important element of the "between-firm" component (Davis and Haltiwanger, 1992; Mortensen, 2003; Dunne et al., 2004; Faggio et al., 2010; Christensen and Bagger, 2014). Berlingieri et al. (2017) show that this growing divergence in between-firm wages is strongly correlated with the within-country-sector divergence of productivity documented over the last decade in 16 countries. This link is explored in Section 5.

### 3. Productivity slowdown from a company perspective: the gap between the global frontier and the rest

As mentioned earlier, most of the debate surrounding the global slowdown in productivity growth has focused on aggregate measures and is abstracted from much of the complexity that characterises today's economies. However, aggregate productivity growth figures are the result of two underlying micro processes: 1) the heterogeneous productivity growth performance of firms; and 2) the processes of creative destruction which enable new firms to enter the market and replace old ones, and resources to be reallocated to higher-productivity businesses.

New OECD research (Andrews et al., 2016) contributes to the ongoing debate on the productivity slowdown precisely by looking into each of these trends, taking into account the significant heterogeneity in productivity performance that exists across firms within sectors at the global level. Distinguishing between companies at the productivity frontier and laggards, the analysis suggests that the latter have experienced a significant slowdown in the rate of catch-up with the frontier (i.e. a slowing down of their productivity growth performance, worsening of process 1), and that business dynamism and the reallocation of resources have deteriorated significantly over time (worsening of process 2).

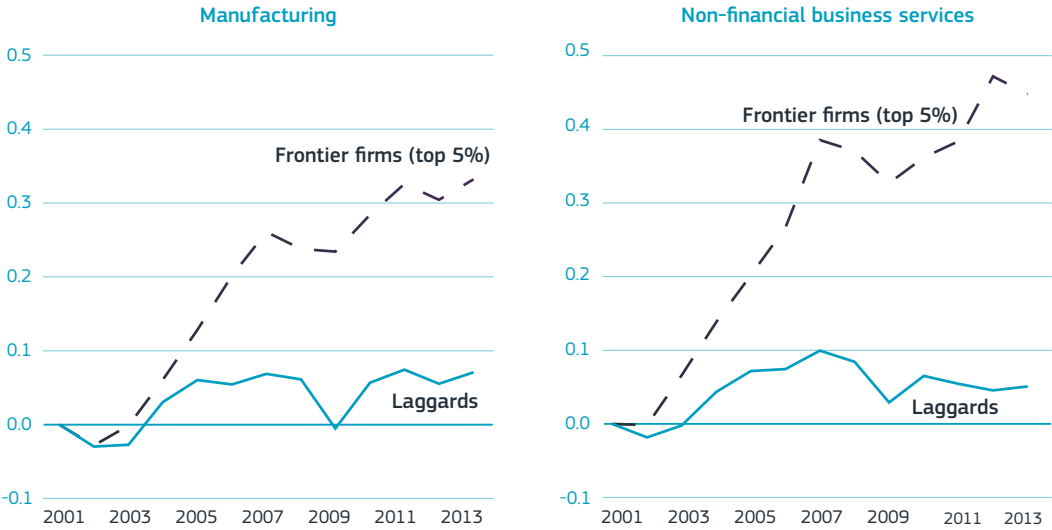
#### 3.1 Breakdown in the diffusion machine

Using a harmonised cross-country firm-level database covering businesses with more than 20 employees across 24 countries, Andrews et al. start by distinguishing firms according to their relative performance. They define global frontier firms as the top 5% in terms of labour productivity levels within each 2-digit sector, in each year, across all countries since the early 2000s.

Isolating this group of firms clearly shows that, contrary to techno-pessimists' narrative (Gordon, 2012), over the first decade of the 21st century productivity slowdown is not a reflection of a slowdown in productivity growth at the global frontier. Rather, it is a reflection of an increasing productivity gap between the global frontier, which experiences robust growth over the period, and the rest of the companies, with a labour-productivity wedge growing at an average annual rate of 2.2% in manufacturing and 5% in non-financial business services (Figure II.1.3).

Repeating this exercise using multi-factor productivity (MFP) estimates suggests that this productivity divergence remains even after controlling for differences in capital deepening and mark-ups. This suggests that the rising MFP gap between global frontier and laggard firms may reflect divergence in innovation between the two groups of firms.

**Figure II.1.3** The widening labour productivity gap between global frontier firms and other firms<sup>1</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Andrews, Criscuolo and Gal, 2016

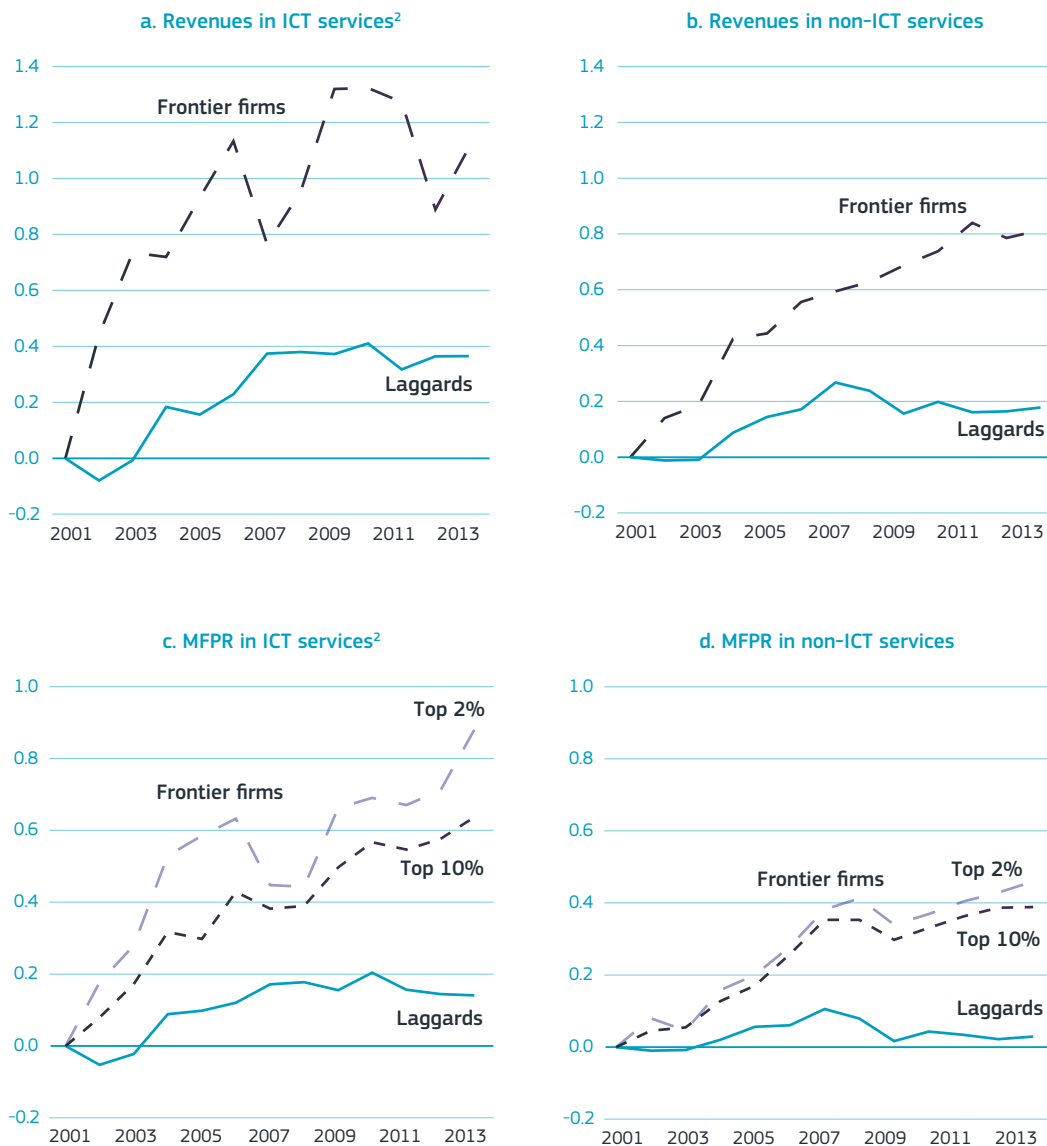
Note: <sup>1</sup>The global frontier is measured by the average of log labour productivity for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalised to 0 in the starting year. The vertical axes represent log differences from the starting year: for instance, the frontier in manufacturing has a value of about 0.3 in the final year, which corresponds to approximately 30% higher in productivity in 2013 compared to 2001. Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_3.xlsx)

The next question is what is driving this increasing wedge between frontier and non-frontier firms. The analysis explores this in two directions. First, it looks at the performance of firms at the frontier and those lagging behind. Secondly, it looks at the dynamics of creative destruction and reallocation over the period.

Looking at the performance of frontier firms, the study explores the potential role of digital technologies to create global winner-takes-most dynamics (Brynjolfsson and McAfee, 2011), focusing on the relative performance of frontier firms in ICT services (computer programming,

software engineering, data storage and so on) vis-à-vis other sectors. The analysis confirms that global frontier firms increased their market share and had a significantly larger MFP gap, not only vis-à-vis non-frontier firms but even within the group of global frontier firms, between the very top firms (top 2%) and other frontier firms (Figure II.1.4).

Looking at the relative performance of non-frontier firms, econometric analysis based on a neo-Shumpeterian model of convergence shows that these firms' catch-up rate has slowed significantly since early 2000 (Figure II.1.5).

Figure II.1.4 Winner takes most dynamics<sup>1</sup>

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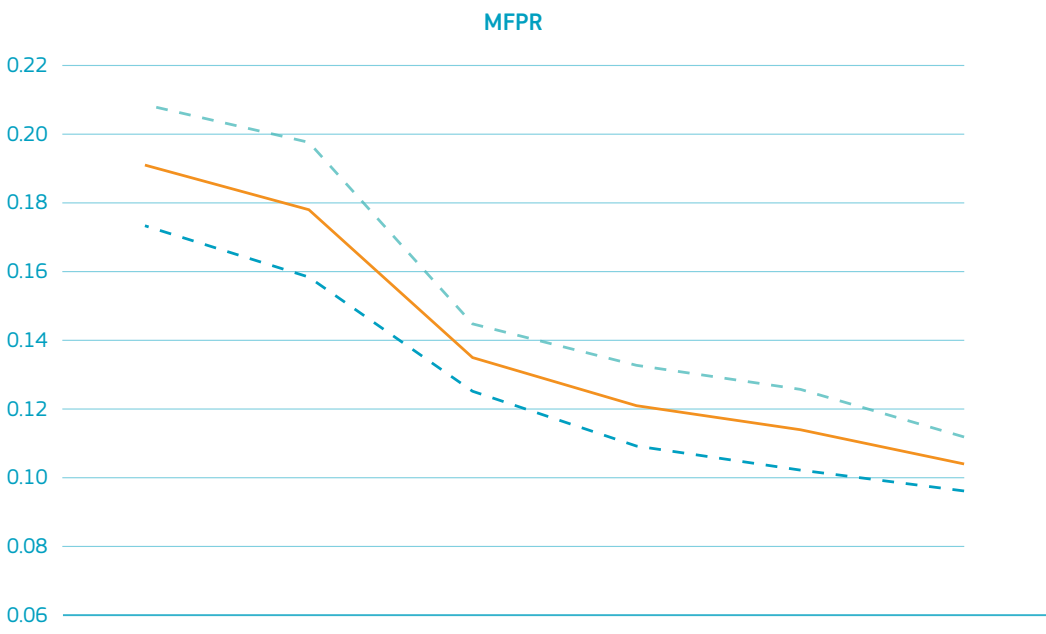
Source: DG Research and Innovation – Unit for the Analysis and Monitoring of National Research and innovation Policies

Data: Andrews, Criscuolo and Gal, 2016

Notes: <sup>1</sup>The global frontier is measured by the average of log labour productivity for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing and services, normalised to 0 in the starting year. The vertical axes represent log differences from the starting year: for instance, the frontier in manufacturing has a value of about 0.3 in the final year, which corresponds to approximately 30% higher in productivity in 2013 compared to 2001. <sup>2</sup>ICT services includes information and communication sector (NACE Rev. 2.0 section J) and postal and courier activities (NACE Rev. 2.0 sector 53).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_4.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_4.xlsx)

**Figure II.1.5** Convergence towards the frontier has slowed down  
 Estimated convergence parameters by time period<sup>1</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Andrews, Criscuolo and Gal, 2016

Note: <sup>1</sup>The solid line shows the period specific coefficients in the convergence equation:

$$\Delta MFPR_{it} = \delta_1 GAP_{i,t-1} + \sum_j \delta_2^j GAP_{i,t-1} * D_t^j + \delta_3 \Delta MFPR_{i,t-1} + \sum_n \delta_4^n X_{it}^n + \mu_{ci} + \eta_j + \varepsilon_{it}$$

where the periods j are, as reported in the Figure, 1997-2000; 2000-2002; 2002-2005; 2005-2007; 2007-2010 and 2010-2014. The dashed lines show the estimated 95% confidence interval.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_5.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_5.xlsx)

Further symptoms of the stalling technological diffusion and slowing dynamism among laggards are found in the declining rate of laggard firms outside the top quintile of productivity distribution that subsequently make it to the global productivity frontier. These patterns are particularly evident among private business services where intangibles and tacit knowledge are important. This suggests that these patterns may reflect the increasing costs incurred by laggard firms of moving from an economy based on production to one based on ideas, as discussed by techno-optimists such as Brynjolfsson. On average

over 2001-2003, 50% of firms at the global frontier in terms of MFPR in the services sector were either classified two years earlier as frontier firms (i.e. 33% of firms were in the top 5%), or resided outside the frontier grouping but were in the top decile (10% of firms) or top quintile (7% of firms). By 2011-2013, however, this Figure had risen to 63%, driven by a significant increase in the proportion of incumbent firms retaining their position in the frontier (43%) with a more modest increase in entry to the frontier by firms residing just outside the frontier but in the top decile (13%) some two years earlier.



### 3.2 Declining business dynamism and “creative destruction”

This rising entrenchment at the frontier is consistent with the broader decline in business dynamism observed across OECD countries using different measures of business dynamism (Figure II.1.16). This, in turn, implies declining incentives among laggard incumbent firms to adopt the latest technologies and business practices (Bartelsman et al, 2013).

This declining entry rate translates into a declining share of young firms and a higher share of non-viable old firms. In addition, it seems to have become relatively easier for weak firms that do not adopt best practices to survive while, at the same time, the average productivity of young

firms has increased, suggesting that entry barriers might have risen, making it more difficult for low-productivity firms to enter the market.

These patterns seem to point to the role of market contestability as a potential policy area to be explored to understand these patterns. Econometric analysis at the industry level confirms the link between stronger productivity divergence between the best firms and the rest and slow pro-competition market reforms. Sectors that saw a very slow pace of product market reforms, such as retail trade and professional services, could have seen their productivity divergence up to 50% lower had they undergone reforms at the same pace as the telecommunications sector, where they were most extensive.

**Figure II.1.6 Declining business dynamism<sup>1</sup> across countries - increased earning inequality and increased between-firms wage dispersion, 2001-2011**



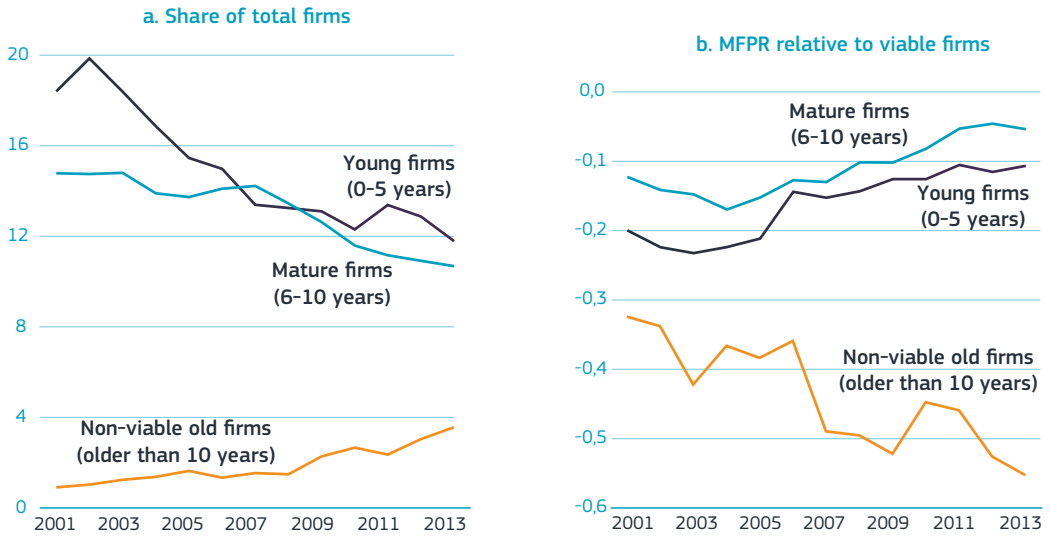
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: OECD

Note: <sup>1</sup>Entry rate is defined using number of units with positive employment (number of entering units with positive employment over total number of units with positive employment). Churning rate is defined as the sum of gross job creation rate and gross job destruction rate. Excess job reallocation rate is defined as churning rate less the absolute value of net employment growth for the period. Excess job reallocation thus reflects the job reallocation that occurs over and above the minimum necessary to accommodate the net employment changes. Figure II.1.6 reports regression coefficients of within-sector country regressions of the relevant variable on year dummies with 2001 being the reference year. Years before 2001 and after 2011 are excluded due to the limited data coverage. Estimates are based on 20 countries (AT, BE, BR, CR, DK, ES, FI, FR, HU, IT, JP, LU, NL, NO, NZ, PT, SE, TR, UK, US).

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**Figure II.1.7 Indicators of declining market dynamism amongst laggard firms<sup>1</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Andrews, Criscuolo and Gal, 2016

Note: <sup>1</sup>Figure II.1.7 shows the frequency and relative productivity of three groups of firms: firms aged 5 years or less (young firms), firms aged 6 to 10 years (mature firms) and firms older than 10 years that record negative profits over at least two consecutive years (non-viable old firms). The omitted group are firms older than 10 years that do not record negative profits over at least two consecutive years (viable old firms). The age of the firm is inferred from the incorporation date. The estimates are unweighted averages across industries in the non-farm non-financial business sector.

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## 4. Zooming in on productivity divergence within countries and sectors

In the previous section, we have shown that over the last decade there has been a steady increase in productivity dispersion between firms at the global frontier and the rest of companies in the same sectors. We will now consider whether the observed global pattern is paralleled by a divergence in productivity within country-sectors during the same period.

### 4.1 The data challenge

One limitation of the sample data used in the study by Andrews et al. (2016) is that it is restricted to covering businesses with at least 20 employees. Whilst this sample restriction does not impact on the conclusion of their study – extending the analysis to businesses with less than 20 employees would likely make their conclusions even stronger – it does mean that they cannot bring their analysis from the global to the country level because the sample size becomes too small for many country-sectors pairs. As shown by previous OECD work, in most OECD and EU countries, firms with fewer than 20 employees represent a large majority of businesses (Figure 8), with companies with fewer than 10 employees accounting for 80% of firms on average.

This means that if we want to analyse productivity dispersion and productivity divergence within countries and sectors, we need to use a different data source which either covers the whole distribution of businesses, such as business registers, administrative records and tax data, or a sample that is designed to be representative of the business population, e.g. stratified random samples often used by statistical offices to run their production surveys.

Unfortunately, while considerable progress has been made in recent years in providing researchers with secure access to official microdata on firms at the country level, significant obstacles remain, especially in terms of transnational access. The challenges of transnational access are many, beginning with locating and documenting information on available sources and their content (i.e. coverage, variables, classifications, etc.) and on accreditation procedures (i.e. eligibility, rules, costs, timing). Finally, data-access systems differ across countries, implying that while remote access or execution could be possible in some countries, in other countries only access on-site is allowed, while non-nationals are not granted access to national data in others. As a result, multi-country studies requiring the exploitation of micro-data are very difficult to conduct.

In the last few years, the OECD Directorate for Science, Technology and Innovation has produced new evidence on employment dynamics and productivity across countries exploiting official and confidential firm-level data within two projects: DynEmp and MultiProd. The projects have relied on countries' confidential microdata to conduct comparable cross-country analysis on employment dynamics and productivity, respectively<sup>3</sup>, via the formation and coordination of networks of national researchers, with each team having access to their respective national microdata. The two OECD projects collect and analyse harmonised cross-country micro-aggregated data from administrative data or official representative surveys, such as business registers, social security and corporate tax records or national statistical offices' surveys of production, ensuring comparability of the country-level results via the use of a commonly specified protocol for data collection

3 See also [www.oecd.org/sti/DynEmp.htm](http://www.oecd.org/sti/DynEmp.htm) and [www.oecd.org/sti/ind/MultiProd.htm](http://www.oecd.org/sti/ind/MultiProd.htm)

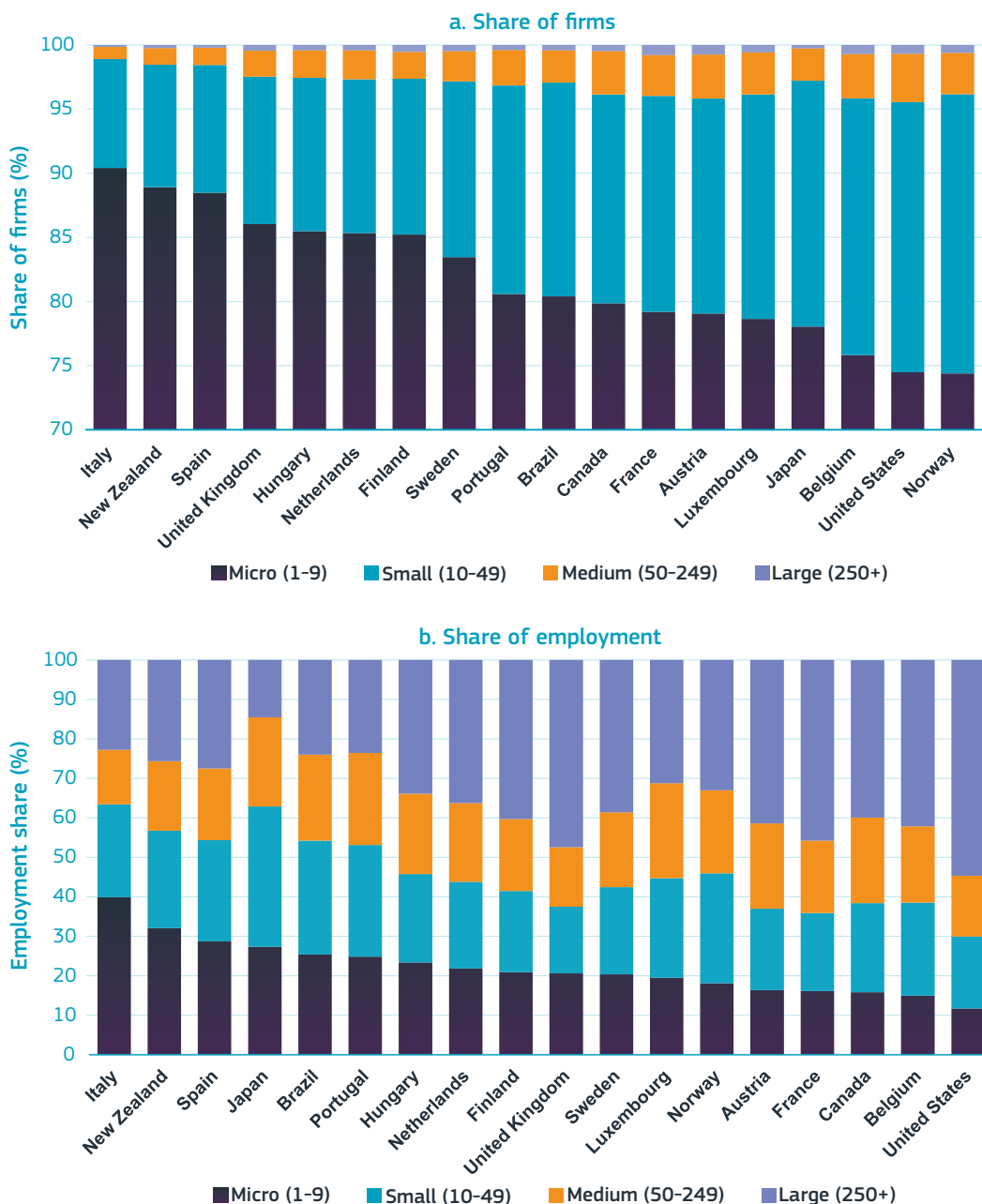
and aggregation and a commonly specified model for the econometric analysis. The methodology followed in the DynEmp and MultiProd projects – a distributed microdata analysis – involves the OECD writing a computer code then running this code in a decentralised manner by representatives in national statistical agencies or experts in public institutions who have access to the national micro-level data. The micro-aggregated data generated are then sent back to the OECD for comparative cross-country analysis. These data reduce confidentiality concerns as they aggregate information at a sufficiently high level and achieve a high degree of harmonisation<sup>4</sup>.

When analysing productivity, being able to use official survey data covering the whole business population, or a random sample of firms that can be made representative by re-weighting using business registers, allows for a reliable and comparable analysis of productivity distributions, the description of trends in productivity dispersion over time, estimation of entry and exit contribution to growth, and many other types of analysis.

Thus, although difficult, the use of these confidential data provides a unique source of information for analysing productivity dispersion within countries and sectors and its trend over time.

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4 Apart from a few previous instances when a similar approach was used – in academic circles and within the OECD, the World Bank and more recently the European Central Bank – this procedure is still not widely applied when collecting statistical information. This may have to do with the time required to set up and manage the network as well as developing a well-functioning, ‘error-free’ program code which is able to both accommodate potential differences across national micro-level databases and minimise the burden on those who have access to the data and run the code.

Figure II.1.8 Firms and employment - % share by size of firm<sup>1</sup>

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Andrews, Criscuolo and Gal, 2016

Note: <sup>1</sup>The period covered is 2001-2011 for BE, CA, FI, HU, NL, UK and US; 2001-2010 for AT, BR, ES, IT, LU, NO and SE; 2001-2009 for JP and NZ; 2001-2007 for FR; and 2006-2011 for PT. Sectors covered: manufacturing, construction, and non-financial business services. Owing to methodological differences, figures may deviate from officially published national statistics. For JP data are at the establishment level, for other countries at the firm level. Average across all available years. Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_8.xlsx)

## 4.2 Cross-country evidence on productivity divergence

The large dispersion in productivity even within narrowly defined industries is an established fact in the literature (e.g. Syverson, 2004). This fact is evident for several countries, as shown in Figure II.1.9 which provides a descriptive account of the dispersion in productivity, measured as the difference between the 90th and 10th percentiles of the log productivity distri-

bution. The table shows a significant dispersion in both manufacturing and services between the top and the bottom performing firms in terms of labour productivity (LP) and multi-factor productivity (MFP): on average across countries, firms in the top decile of the distribution can produce almost five times as much value added per worker as firms in the bottom decile in the same country's manufacturing sector, and more than seven times as much in services; similar ratio hold for MFP.

**Figure II.1.9** 90-10 log productivity differences<sup>1</sup> in 2001

	Log-LP 90-10 diff.		Log-MFP 90-10 diff.	
	Manuf.	Services	Manuf.	Services
Denmark	1.31	1.90	1.19	1.73
Finland	1.19	1.34	1.14	1.22
France	1.30	1.64	1.33	1.62
Hungary	2.45	3.09	2.38	2.83
Italy	1.71	1.93	1.65	1.77
Japan	1.13	1.25	1.02	1.21
Netherlands	1.86	2.69	2.34	2.89
New Zealand	1.93	2.15	1.94	2.00
Norway	1.52	1.96	1.67	1.94

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Berlingieri, Blanchenay and Criscuolo, 2017.

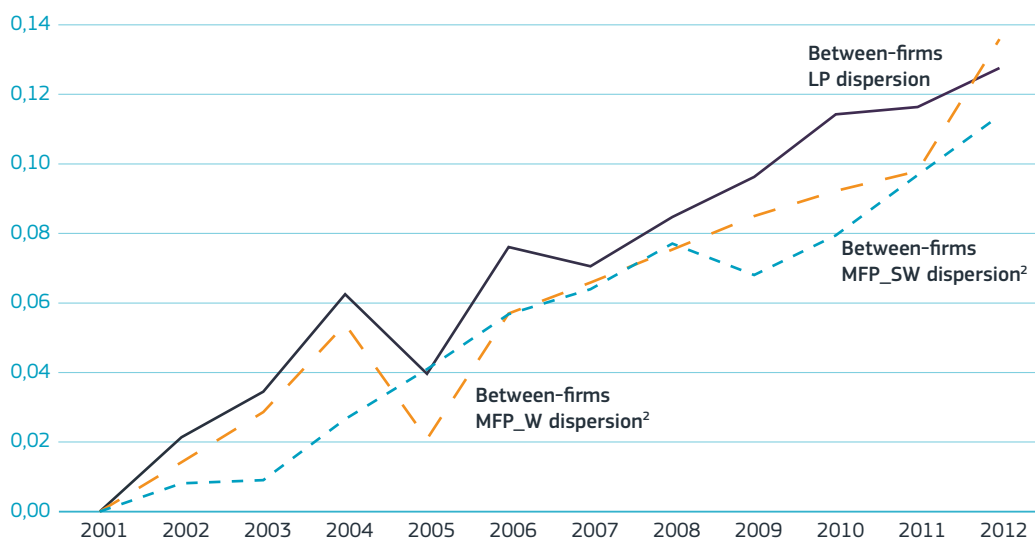
Note: <sup>1</sup>90-10 percentiles log productivity differences, averaged across two-digit sectors using employment and log value-added as weights for labour productivity and MFP respectively.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_9.xlsx)

When looking at how the dispersion has evolved over time, the data confirms that even within countries and sectors, productivity dispersion has actually increased substantially. Indeed, the gap between firms in the top 10% by productivity and those in the bottom 10% increased by approximately 14% between 2001 and 2012. Figure II.1.10 shows that within-sector dispersion has increased for both labour and multi-factor productivity, with a remarkably similar pattern across all productivity measures.

Figures included in the appendix illustrate the trend in log-productivity dispersion, which is increasing both in manufacturing and in services within the countries in the sample. For the majority of countries, dispersion in 2012 is higher than in 2001: in services, this is the case for all countries except New Zealand in terms of labour productivity; and in manufacturing, for all but Italy and New Zealand – both in terms of labour and multi-factor productivity.

**Figure II.1.10** The 'great divergence' in productivity<sup>1</sup>, 2001–2012  
90–10 difference in log productivity



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: Berlingieri, Blanchenay and Criscuolo, 2017.

Note: <sup>1</sup>Figure II.1.10 plots the year dummy estimates  $\beta_t$  of a regression of log-productivity dispersion (measured as the difference between the 90th and 10th percentiles of log-productivity) within country-sector pairs:  $(\log P_{90} - \log P_{10})_{cjt} = \alpha + \sum \beta_t \gamma_t + z_{cj} + \epsilon_{jt}$ , with reference year  $\gamma$  equals to 2001, for a given productivity measure  $P$ , and where  $c$  denotes countries,  $j$  sectors and  $t$  years, using data from the following countries: AU, AT, BE, CH, DK, FI, FR, HU, IT, JP, NL, NO, NZ, SE.

<sup>2</sup>Two measures of MFP are provided: an index-based measure (MFP\_SW: Solow residuals using cross-country industry-specific labour shares) and the semi-parametric measure à la Wooldridge (2009) (MFP\_W).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_10.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_10.xlsx)

### 4.3 Divergence at the top and bottom

An interesting question is whether productivity divergence is driven by an acceleration of frontier firms or by a slowing down of productivity at the bottom relative to the median firm<sup>5</sup>. To answer this question, Berlingieri et al. (2017) estimate the yearly average productivity dispersion within countries and sectors, separately for the top 90-50 and bottom 50-10, differences in the log-productivity distribution.

The estimates suggest that the divergence has happened both at the top and at the bottom of the distribution. The trend highlights that at the beginning of the 2000s, this divide was mainly driven by the bottom performers not keeping up with the median firms. Since the mid-2000s – and especially in the services sector – it has also increasingly been the case that the top performers have left the median firms behind.

In services, the dispersion at the top starts growing after 2005, flattens out slightly during the crisis years before increasing again from 2010. The gap between the median firm and firms in the bottom decile of the distribution has been growing steadily since 2000 and, especially when focusing on trends in MFP dispersion, the crisis has widened the gap even further. In the manufacturing sector, the dispersion at the top declines until 2005, and this pattern contributes significantly to the flat dispersion found in the aggregate economy. After 2005, the dispersion peaks but to a lesser extent compared to services. The dispersion at the bottom still displays higher growth over the period, but is more volatile, especially for MFP.

What drives the divergence at the bottom? Two forces could be at work: an increasing gap between the median and the worst-performing firms might reflect faster growth at the median relative to the bottom firms. However, it could also reflect a worsening of the selection effect at the bottom of the distribution, with unproductive firms managing to remain in the market despite their low productivity. This would mean that the process of productivity enhancing resource reallocation has deteriorated since the early 2000s.

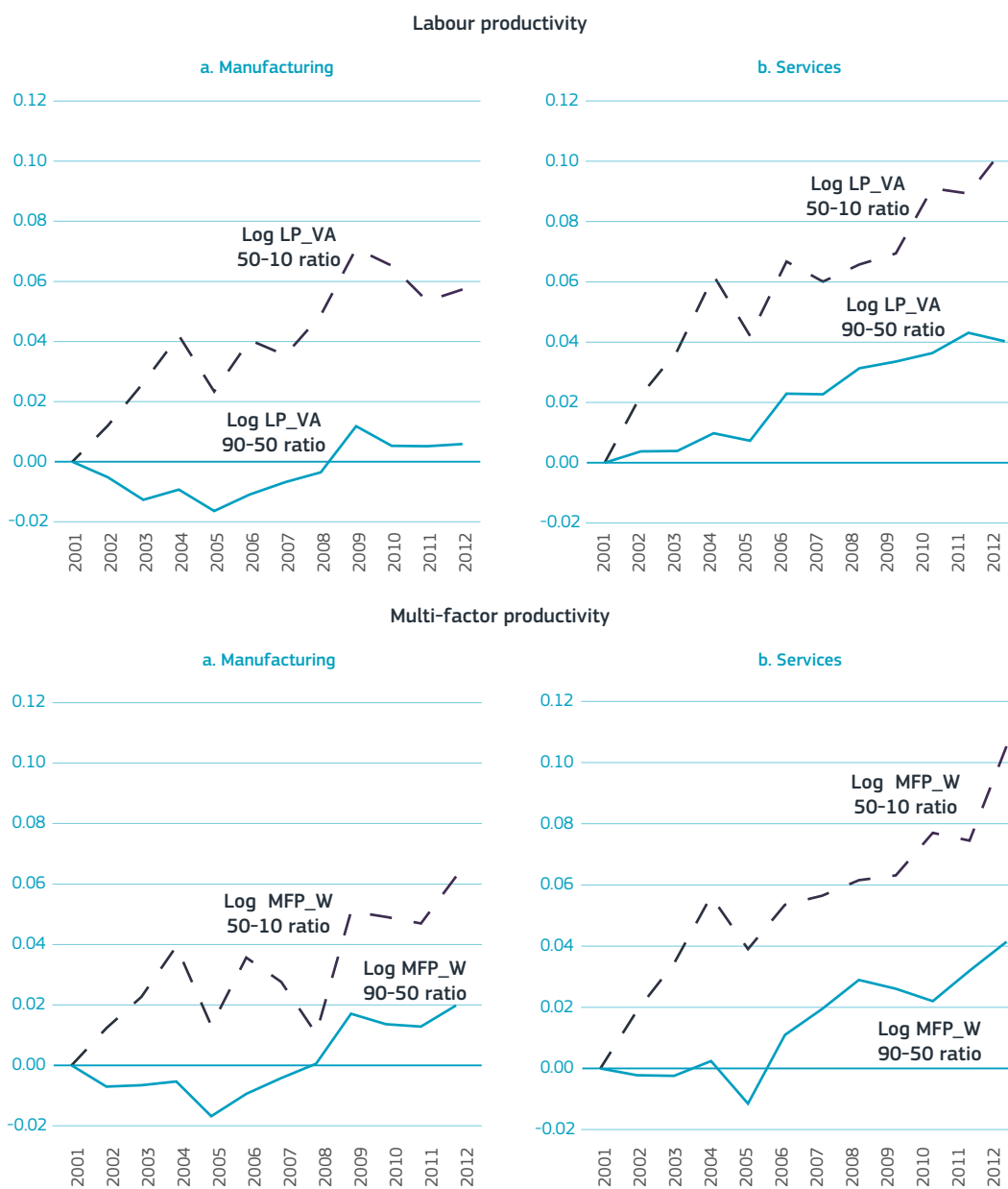
Figures II.1.11 and II.1.12 plot the productivity of the 10th, 50th and 90th percentile of the productivity distribution, normalising the year 2001 to 0. In each figure, the left panel represents productivity dispersion in manufacturing and the right panel represents productivity dispersion in (non-financial) market services. The patterns differ markedly between manufacturing and services. In manufacturing, with the exception of the Great Recession, productivity has increased for all quantiles of the productivity distribution, although the increase is smaller for the least productive firms. This is in line with the hypothesis of accelerating growth for the median firms. In contrast, in services, productivity has largely remained flat for the median firms but has actually declined substantially for the least productive firms, suggesting a break down in the process of ‘creative destruction’.

Figures a and B in the appendix show the same results for individual countries. They suggest that both forces – the improved performance by median firms and the deteriorated selection at the bottom – might have been at work but to a different extent in different countries.

5 Given the limitation of the data used in Andrews et al., 2016, discussed above, and heterogeneous changes in data coverage across countries, especially among small businesses, this analysis was not possible there.



**Figure II.1.11 Labour productivity dispersion - top versus bottom of the labour and MFP productivity distribution, for manufacturing and services<sup>1</sup>, 2001-2012**



Science, Research and Innovation performance of the EU 2018

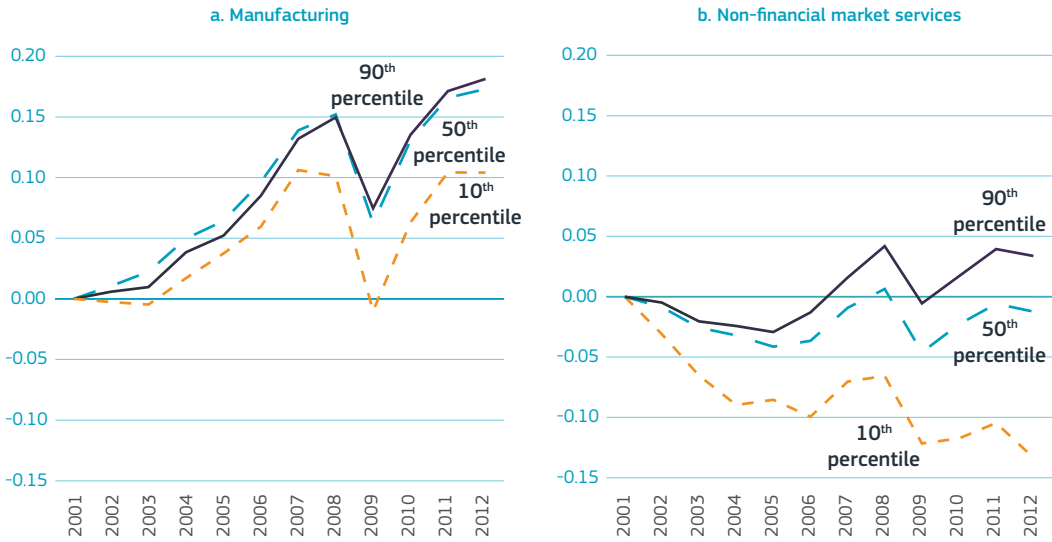
Source: DG Research and Innovation – Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Berlingieri, Blanchenay and Criscuolo, 2017.

Note: <sup>1</sup>Figure II.1.11 plots the year dummy estimates of a regression of log-productivity dispersion at the top (90th and 50th percentiles difference, solid line) and at the bottom (50th and 10th percentiles difference, dashed line) within country-sector pairs, separately for manufacturing and services. Countries: AU, AT, BE, CL, DK, FI, FR, HU, IT, JP, NL, NO, NZ, SE.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_11.xlsx)

**Figure II.1.12 Trends for top, median and bottom decile of the (log) LP distribution<sup>1</sup>, 2001-2012**



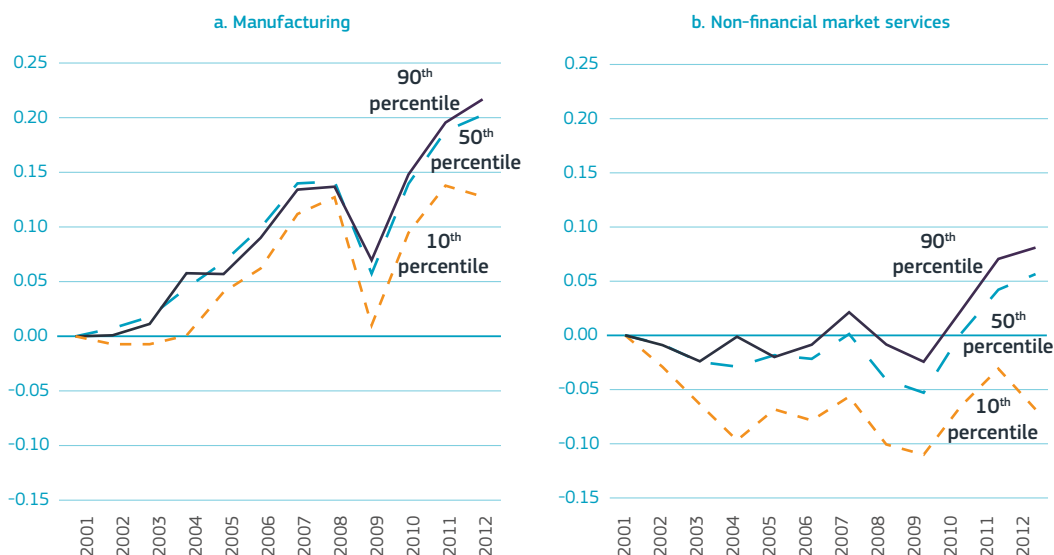
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Berlingieri, G., et al. (2017), "The Multiprod project: a comprehensive overview", OECD Science, Technology and Industry Working Papers, No.2017/04, OECD Publishing, Paris. <http://dx.doi.org/10.1787/2069b6a3-en>

Note: <sup>1</sup>Log labour productivity in the 10th, 50th and 90th percentile of the productivity distribution, for manufacturing (left panel) and non-financial market services (right panel) since 2001. The countries included are: AU, AT, BE, CH, DK, FI, FR, HU, IT, JP, NL, NO, NZ, SE. The graphs can be interpreted as the cumulated growth rates of LP within each country and sector over the period. For instance, in 2012 in manufacturing the 90th quantile of productivity is roughly 19% higher than in 2001. The estimates reported in the graph are those of year dummies in a cross-country regression of log-productivity in the 90th, 50th and 10th percentile of the distribution. Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_12.xlsx)

**Figure II.1.13 Trends for top, median and bottom decile of the (log) MFP distribution<sup>1</sup>, 2001-2012**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Berlingieri, G., et al. (2017), "The Multiprod project: a comprehensive overview", OECD Science, Technology and Industry Working Papers, No. 2017/04, OECD Publishing, Paris. <http://dx.doi.org/10.1787/2069b6a3-en>

Note: <sup>1</sup>Log-MFP (Woodridge) in the 10th, 50th and 90th percentile of the productivity distribution, for manufacturing (left panel) and non-financial market services (right panel) since 2000. The countries included are: AU, AT, BE, CH, DK, FI, FR, HU, IT, JP, NL, NO, NZ.

The graphs can be interpreted as the cumulated growth rates of MFP within each country and sector over the period. For instance, in 2012 in manufacturing the 90th quantile of productivity is roughly 24% higher than in 2001. The estimates reported in the graph are those of year dummies in a cross-country regression of log-productivity in the 90th, 50th and 10th percentile of the distribution.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_1/figure\\_ii\\_1\\_13.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_1/figure_ii_1_13.xlsx)

## 5. The link between productivity divergence and greater wage inequality

As discussed in Section 2.2, a large part of the overall increase in wage inequality is due to greater differences in average wages across firms. This section explores between-firm wage inequality, its link with productivity dispersion, and the effect of policies on both types of dispersion and the link between them over time.

### 5.1 Between-firm wage inequality and its link to productivity divergence

Figure II.1.13 describes the 90-10 log-wage ratio (solid line) which compares wages in firms in the top 10% of the wage distribution with wages in those at the bottom 10%. It shows an upward trend indicating an increase in wage differentials between firms within the same sectors: by 2012, the 90-10 wage ratio is 12.3% higher than in 2001. The increase in between-firm wage dispersion is in the same ballpark as the increase in overall earnings inequality (the broken line in Figure II.1.13). Hence, by analysing wage inequality between firms, we can go a long way in understanding what drives overall wage inequality.

Thus, the divergence in firms' productivity within country-sector pairs is matched by a divergence in wages across both firms and workers in the overall economy. Interestingly, the trends for wages are also similar to those for productivity divergence when analysing separately the upper tail wage inequality – the wage at the 90th percentile (the wage paid by a firm in the top 10% of wage distribution) relative to the 50th percentile (the firm right in the middle) and lower tail wage inequality. Berlingieri et al. (2017) show that the gap in the average wage between the bottom decile and the median grew faster between 2001 and 2012 than the gap between the median and the top decile – i.e. lower-tail

inequality grew faster than upper-tail inequality. In the latter, there is even evidence of a small degree of convergence in the early 2000s, which then disappears in the second half of the decade when there is also divergence at the top.

These parallel trends in dispersion both at the bottom and the top (Figure II.1.14) suggest that the distribution of wages and productivity are linked. Econometric estimates of the correlation between the divergence in wages and divergence in productivity do indeed show a significant positive correlation, even after accounting for a sector's workforce or firm-age composition. An increase of one standard deviation in the dispersion of logged labour productivity (MFP respectively) correlates with an increase of 25.5% in logged wage dispersion (19.5% respectively).

A different way of looking at the link between wages and productivity along their distribution is to analyse the wage distribution conditional on the productivity distribution: i.e. looking at the evolution of wage productivity deciles. Figure II.1.15 indicates the average wages in the top, bottom and the 4th to 6th decile of the labour productivity distribution. The evidence suggests that wage inequality between firms with different productivity performance has increased, in a very similar way to how productivity dispersion has increased. There are, nonetheless, some important cross-sectoral differences in the magnitude of the gap between wages in the most productive firms and those in the worst performing firms. Among the most productive firms, wages have increased more in the service sector than in manufacturing. Again, there are significant differences across countries (see Figures E and F in the appendix) suggesting that structural differences across countries, institutions and policies may play an important role.

**Figure II.1.14 Increased earning inequality and increased between-firms wage dispersion<sup>1</sup>, 2001-2012**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Berlingieri, Blanchenay and Criscuolo, 2017.

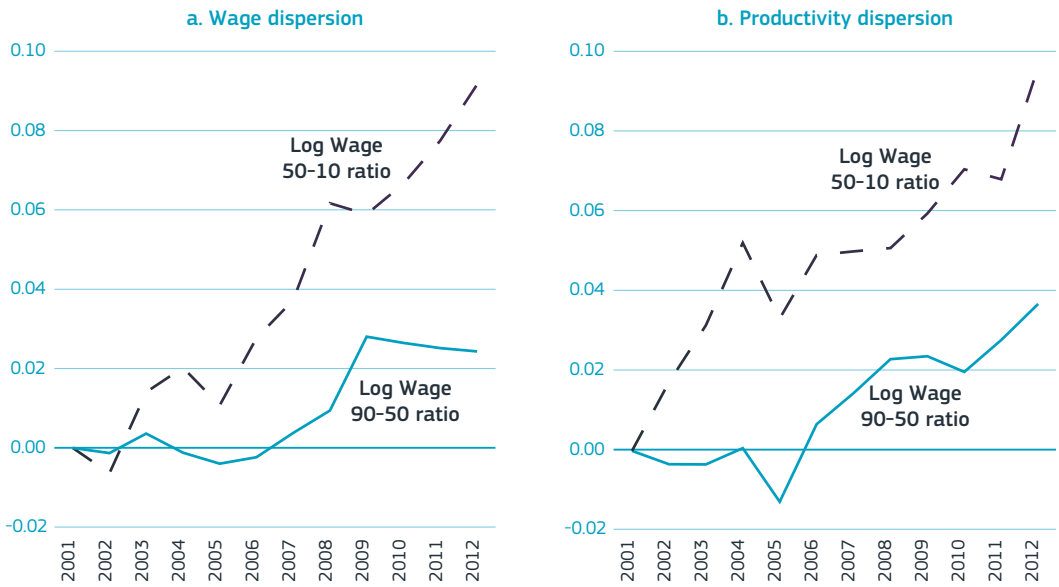
Note: <sup>1</sup>Figure II.1.14 plots the estimated year dummies of a regression of log-wage dispersion (90th and 10th percentiles

ratio) within country-sector pairs, using data from the following countries: AU, AT, BE, CL, DK, FI, FR, HU, IT, JP, NL, NO, NZ, SE.

The line referring to overall earnings inequality plots the estimated year dummies of a similar regression using the dispersion in earnings from the OECD Earnings Distribution database within each country. The data on overall earnings inequality are only available at the country level and for a more limited set of countries: FI, FR, HU, JP, NO, NZ for the whole period; AU, IT, SE from 2002; and NL between 2002 and 2010.

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Figure II.1.15 Upper-tail and lower-tail wage and productivity divergence<sup>1</sup>



Science, Research and Innovation performance of the EU 2018

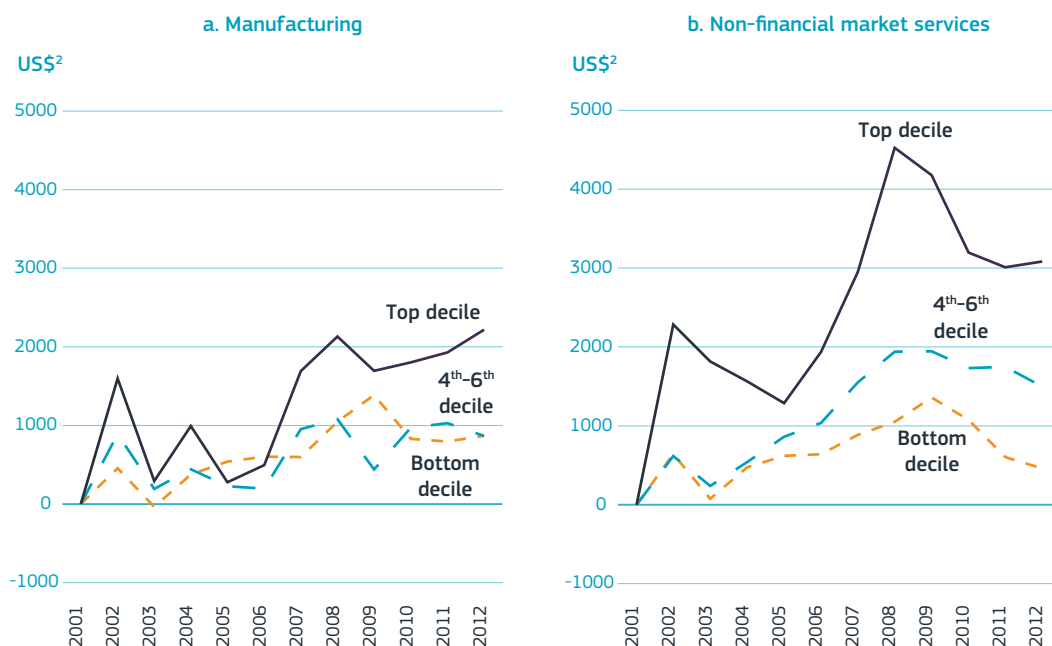
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Berlingieri, Blanchenay and Criscuolo, 2017.

Note: <sup>1</sup>The figure in panel a [resp. b] plots the estimated year dummies of a regression of log-wage [resp. log-MFP] dispersion at the top (90th to 50th percentiles ratio, solid line) and at the bottom (50th to 10th percentiles ratio, dashed line) within country-sector pairs, using data from the following countries: AU, AT, BE, CL, DK, FI, FR, HU, IT, JP, NL, NO, NZ, SE.

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**Figure II.1.16** Change in real wages in different parts of the productivity distribution of firms<sup>1</sup>, 2001-2012



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Berlingieri, Blanchenay and Criscuolo, 2017.

Notes: <sup>1</sup>The countries included are: AT, BE, CH, DK, FI, HU, IT, JP, NL, NO. The graphs can be interpreted as the cumulated increase of average wages within each country and sector over the period. For instance, in 2012 in manufacturing the average wage paid by the 10% most productive firms is on average roughly 2,000 US dollars higher than in 2001. The estimates reported in the graph are those of year dummies in a cross-country regression of the average wage in the bottom, top and 4th to 6th decile of the productivity distribution. <sup>2</sup>PPPS at constant 2005 prices and exchange rates.

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## 5.2 Effect of policies

While it is expected that in well-functioning markets wages reflect labour productivity, so that dispersion in wages could be linked to dispersion in productivity, the literature has suggested that this could be further strengthened by the fact that the most productive workers increasingly work for the most productive firms. For example, there is evidence of a clustering of highly skilled workers in high-paying firms (Bagger et al., 2013), as well as more use of the outsourcing of non-core, low-value-added, low-pay activities (Goldschmidt and Schmieder, 2015). Rent

sharing – i.e. workers in high-profit/high-productivity firms enjoying a share of the firms' rents – also plays a role in explaining this trend (Card et al., 2014; Card et al., 2013). Therefore, it is important to understand whether structural changes, such as globalisation, and digitalisation, and policies, in particular labour market institutions and policies affect the link between productivity and wages.

Berlingieri et al. (2017) find that globalisation and digitalisation are not only associated with a rise in between-firm wage inequality, but they also reinforce the link between wages and productivity dispersion. In sectors where firms increase the

use of information and communications technologies (ICT) over time, wage dispersion grows faster, which suggests that ICT affects firms heterogeneously. In sectors that become more open to trade through either imports or exports, not only has wage dispersion risen but its link with productivity dispersion has also been strengthened (see also Helpman et al., 2017).

Country-specific policies and institutions also play a role in shaping the evolution of wage and productivity dispersions and the link between them. A significant amount of evidence has been gathered on the role of policy and institutions for explaining the observed increase in wage dispersion, in particular the decline in real minimum wage and, for the UK and the US, the decline in unionisation. For continental European economies, the focus has been on the degree of centralisation of wage bargaining, and where greater decentralisation is typically associated with higher wage dispersion. Berlingieri et al. focus on the role of wage-setting institutions and labour market features: minimum wages (in terms of both the hourly real minimum wage and the minimum relative to average wages of full-

time workers); employment protection legislation (strictness of employment protection for both individual and collective dismissals); trade union density; and the coordination of wage setting.

The results of their analysis suggest that all these policies have the intended consequence of reducing wage dispersion and hence overall inequality. At the same time, they affect the link between wage and productivity dispersion. For example, more centralised bargaining is associated with a weaker link between productivity and wage dispersion, while this is not the case for changes in employment protection legislation and union density, the effects of which are significant only in the cross-section but not over time. Although more centralised bargaining can thus help to limit wage dispersion, at the same time it weakens the link between wages and productivity dispersion, which might be detrimental for long-term growth. Conversely, minimum wage policies, while also reducing wage dispersion, are associated with a stronger link between wage and productivity dispersion over time, which could benefit long-term growth.

## 6 Conclusions

Productivity growth plays a central role in shaping the welfare of societies and the competitiveness of countries. Productivity differences, for instance, explain a large share of the differences in income per capita across countries. But as firm-level productivity can vary widely, even within narrowly defined industries, analysing aggregate or even industry-average productivity data cannot provide the evidence needed to understand the complex dynamics that characterise our economies.

Aggregate productivity performance is the result of the productivity performance of heterogeneous firms as well as the process of resource reallocation among those firms, and of creative destruction enabling new companies to enter the market and inefficient firms to exit it.

Ongoing OECD research is using firm-level data to explore three main features of OECD and European economies over recent decades: global productivity slowdown, greater



divergence in productivity performance across firms, and an increase in earnings inequality.

Recent research has shown that the within-firm productivity growth of laggards has worsened during the last decade leading to a slowdown in the convergence towards the best performing firms, the frontier, and also that the process of reallocation has worsened. The two may be closely linked as a weakening in the reallocation process might translate into fewer incentives for incumbents to innovate and improve their productivity. The rise in productivity dispersion, which is evident not only globally within sectors but also within countries, is significantly related to the observed increase in earnings inequality. This is yet another reason to search for policies that include productivity divergence as they may carry a double dividend for inclusiveness to the extent that the observed rise in wage inequality is closely related to the rising dispersion in average wages paid across firms (Card et al., 2013; Song et al., 2016). This is particularly evident in sectors that are more open to trade and are more ICT-intensive. As expected, wage-setting institutions affect the distribution of wages, although recent OECD research shows that they also have an indirect effect by impacting the link between productivity and wage dispersion.

To promote productivity growth, it is important to provide incentives for advancing the productivity frontier, helping laggards to catch up, and facilitating the reallocation of resources to their most productive use.

Effective innovation policies are crucial for extending the global frontier. They must provide the right incentives for researchers to continue investing in basic research and breakthrough innovations. In addition, given the increasingly key role of transnational corporations, they

should coordinate investment efforts across the globe, both in basic and applied research, via policies such as R&D tax incentives, corporate taxation and IPR regimes.

The ability of laggards to catch up with more innovative firms depends on greater domestic and international competition and the international mobility of skilled workers who will facilitate the diffusion of existing technologies to the lagging firms. Once again, this is an area where policy has a significant role to play.

Finally, an effective reallocation process requires well-functioning product, labour and risk capital markets as well as the implementation of policies that do not result in resources being ‘trapped’ in inefficient firms. This includes efficient judicial systems and bankruptcy laws that do not excessively penalise failure. The latter are particularly important as recent evidence suggests that they affect disproportionately more start-ups in high-risk sectors (Calvino et al., 2016). Framework policies that reduce barriers to firm entry and exit have also been found to improve reallocation and productivity performance.

Finally, given the important role of different policies, coordination across different policy areas within countries as well as greater collaboration in the analysis of productivity and the effective sharing of good practices across countries are needed for productivity to become the driver of strong and inclusive growth.

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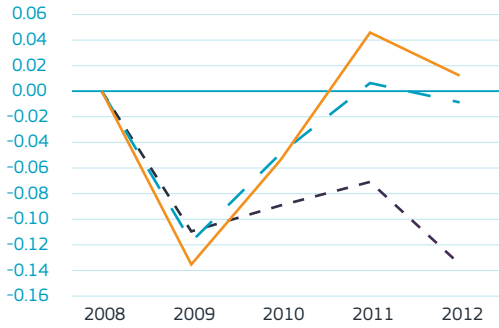
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# Appendix

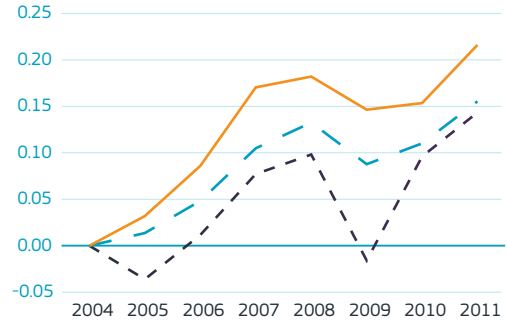
Figure a Divergence in labour productivity performance<sup>1</sup> in the manufacturing sector

--- Bottom decile    - - - 4<sup>th</sup>-6<sup>th</sup> decile    — Top decile

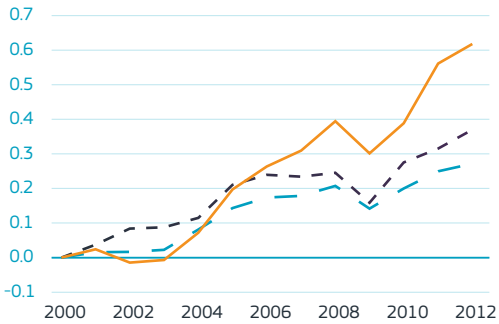
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## Belgium



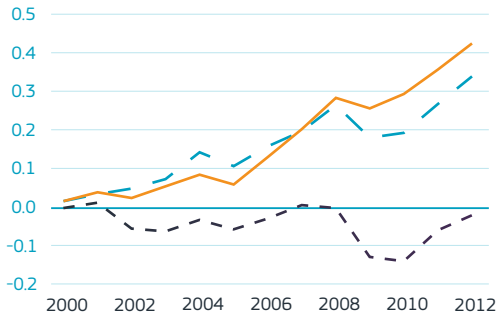
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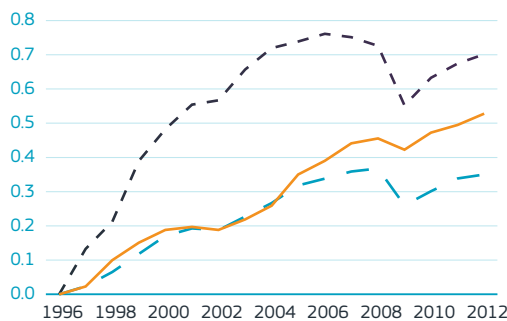
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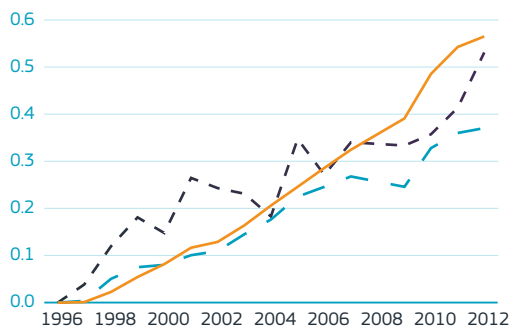
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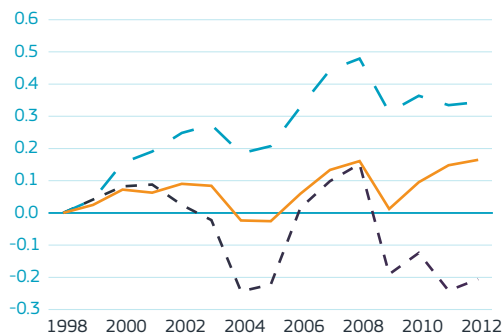
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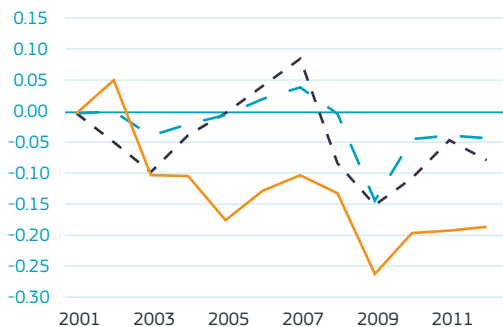
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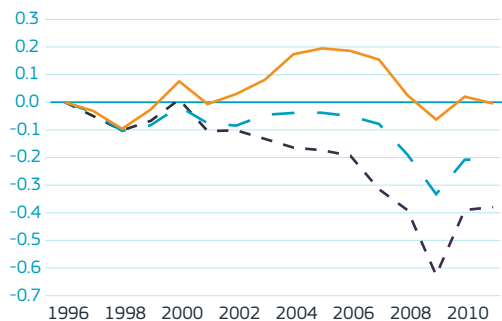
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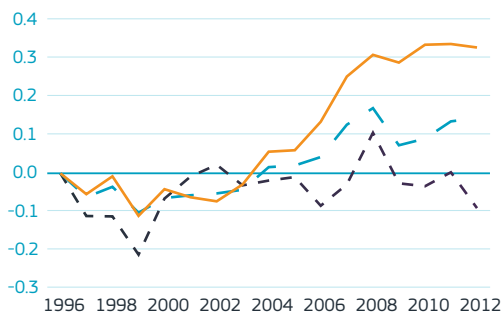
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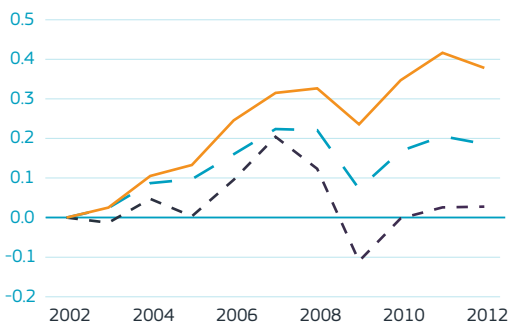
## Japan



## Norway



## Sweden



Science, Research and Innovation performance of the EU 2018

Source: Data from the OECD Multiprod project, preliminary results, April 2016.

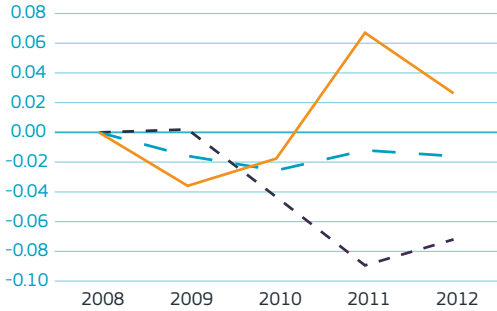
Note: <sup>1</sup>Figure a reports the unweighted average of real labour productivity (defined as real value added per employee) expressed in 2005 US dollars for firms in the bottom decile, between the 4th and 6th deciles, and in the top decile of the labour productivity distribution in any given year. The values are normalised at their initial values in 1996 for Finland, France, Japan and Norway, 1998 for Hungary, 2000 for Canada and Denmark, 2001 for Italy, 2002 for Sweden, 2004 for Belgium, 2005 for Chile and 2008 for Austria. Data for Japan only includes firms above 50 employees.

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Figure B Divergence in labour productivity performance<sup>1</sup> in the services sector

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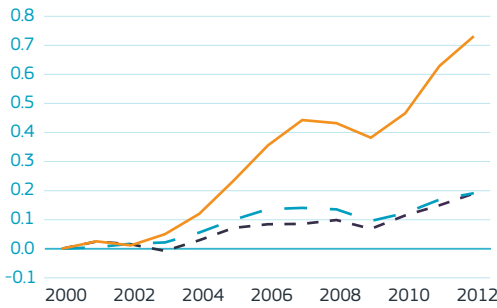
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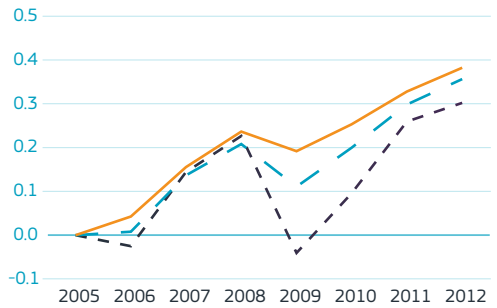
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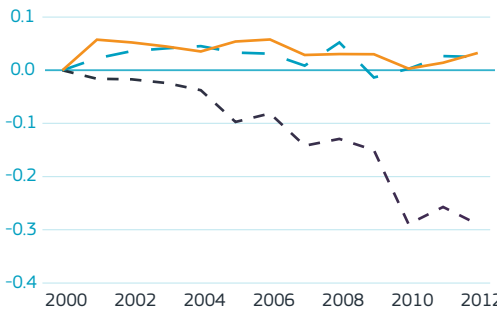
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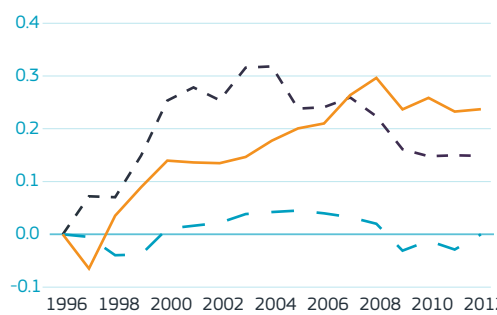
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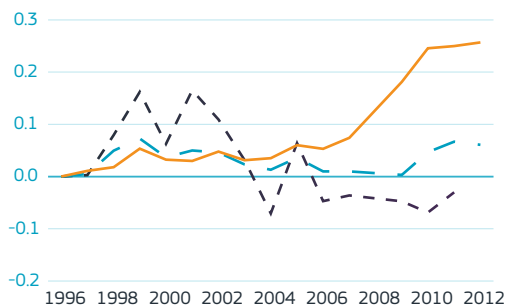
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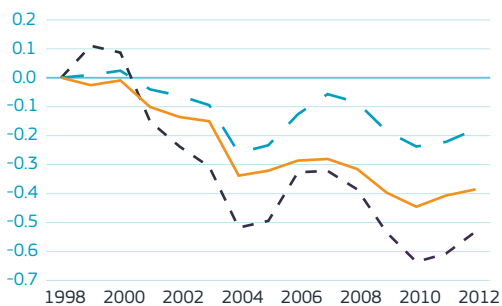
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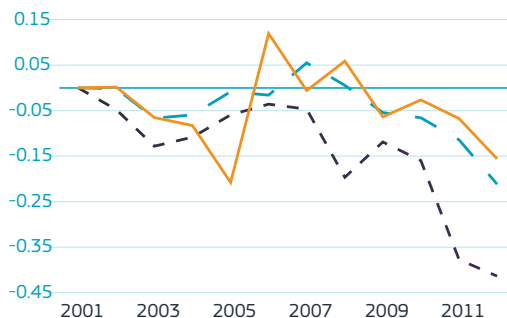
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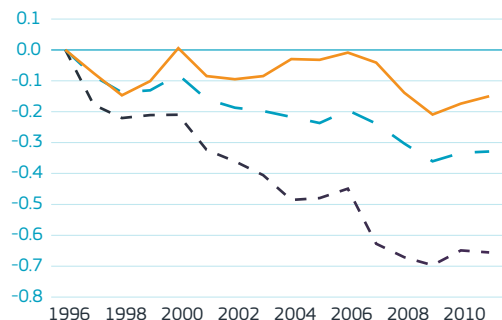
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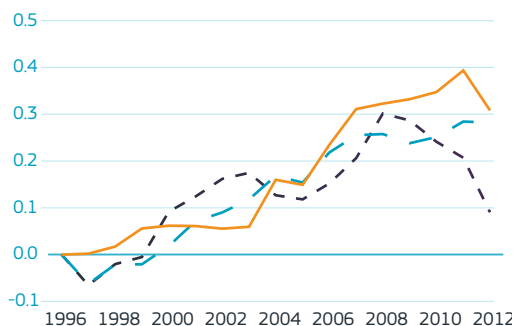
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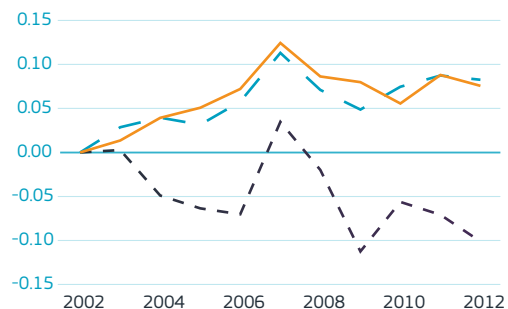
## Japan



## Norway



## Sweden



Science, Research and Innovation performance of the EU 2018

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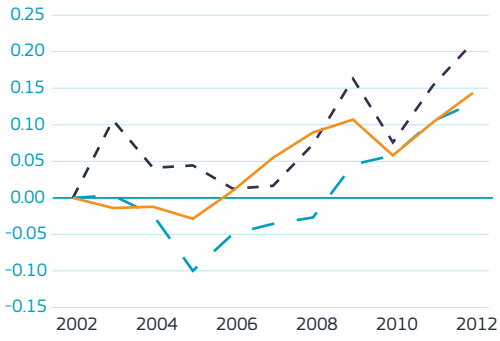
Note: <sup>1</sup>Figure B reports the unweighted average of real labour productivity (defined as real value added per employee) expressed in 2005 US dollars for firms in the bottom decile, between the 4th and 6th deciles, and in the top decile of the labour productivity distribution in any given year. The values are normalised at their initial values in 1996 for Finland, France, Japan and Norway, 1998 for Hungary, 2000 for Canada and Denmark, 2001 for Italy, 2002 for Sweden, 2004 for Belgium, 2005 for Chile and 2008 for Austria. Data for Japan only includes firms above 50 employees.

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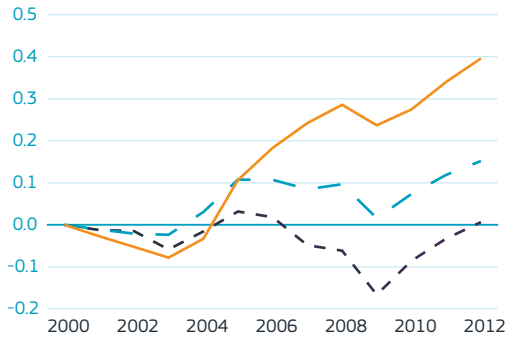
Figure C Polarisation of MFP-Wooldridge in the manufacturing sector

--- Bottom decile    - - - 4<sup>th</sup>-6<sup>th</sup> decile    — Top decile

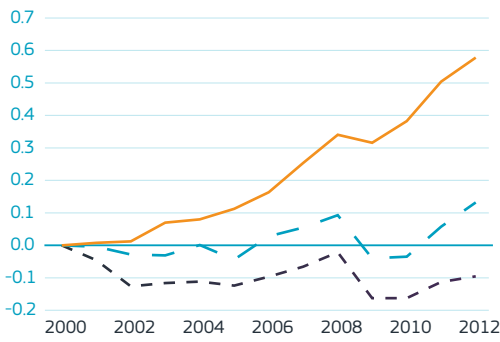
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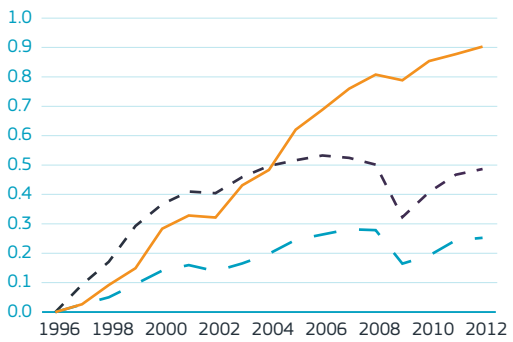
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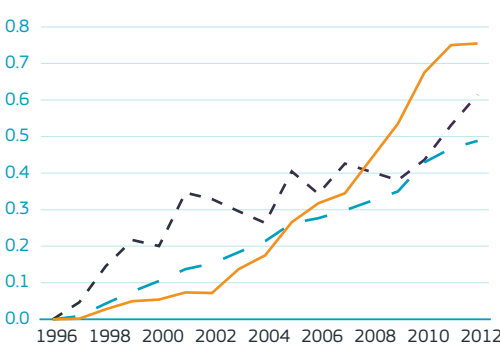
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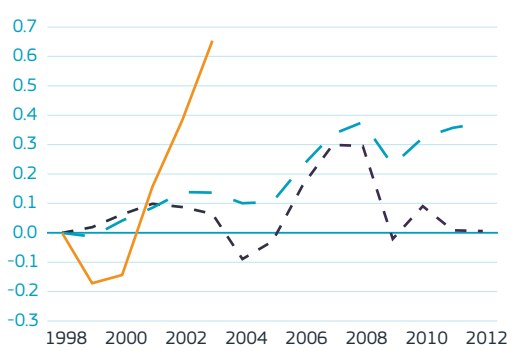
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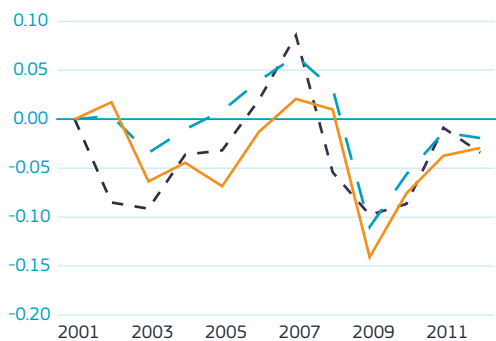
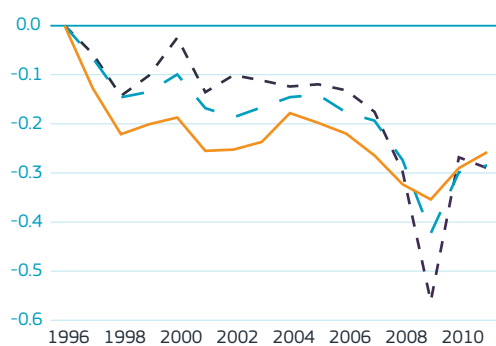


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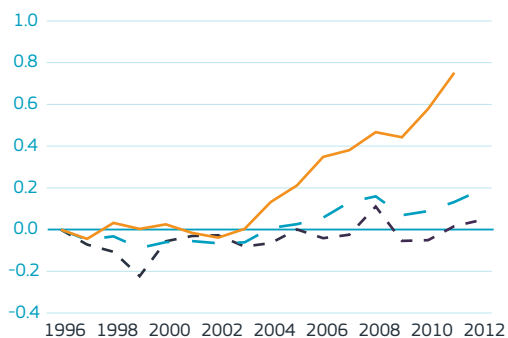




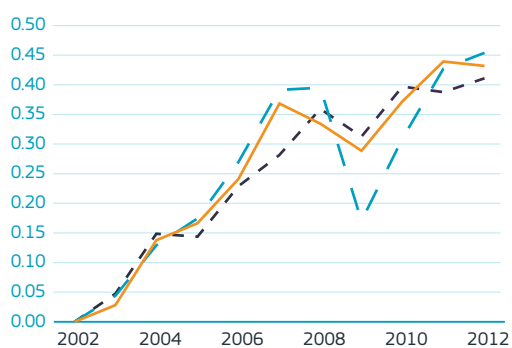
## Italy

Japan<sup>1</sup>

## Norway



## Sweden



Science, Research and Innovation performance of the EU 2018

Source: Data from the OECD Multiprod project, preliminary results, February 2016.

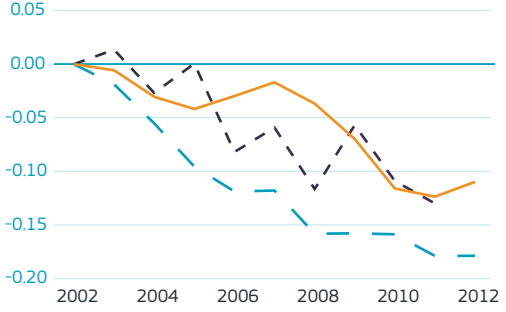
Note: <sup>1</sup>Data for Japan only includes firms above 50 employees.

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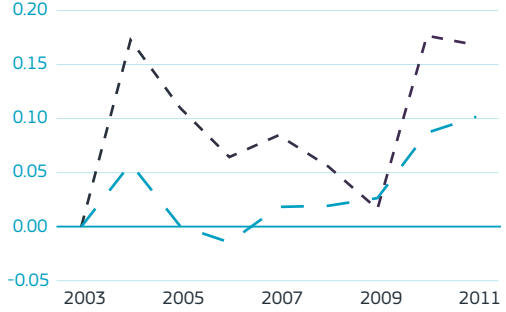
Figure D Polarisation of MFP-Woolldridge in the services sector

--- Bottom decile    - - - 4<sup>th</sup>-6<sup>th</sup> decile    — Top decile

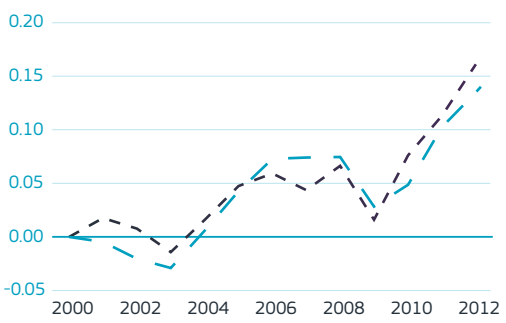
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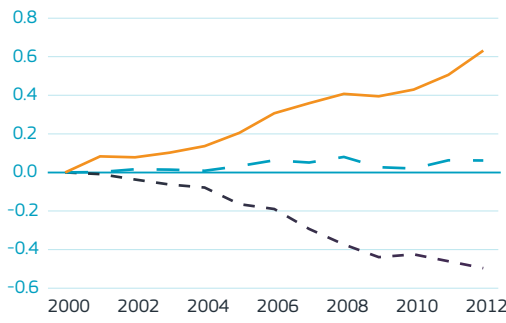
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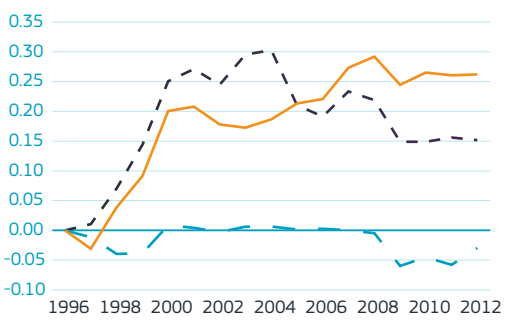
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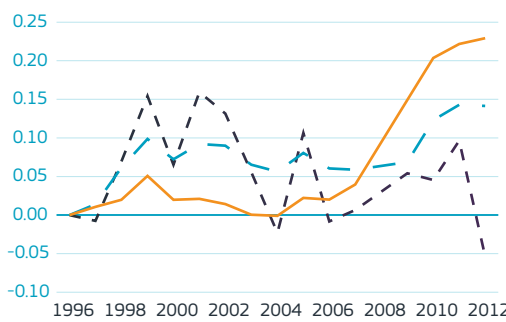
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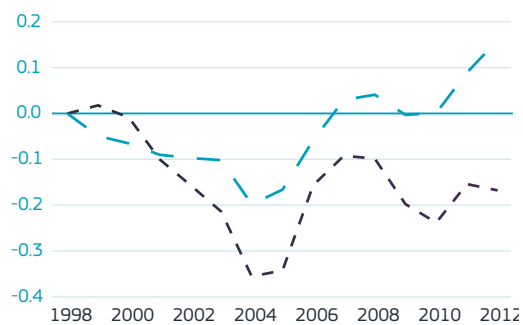
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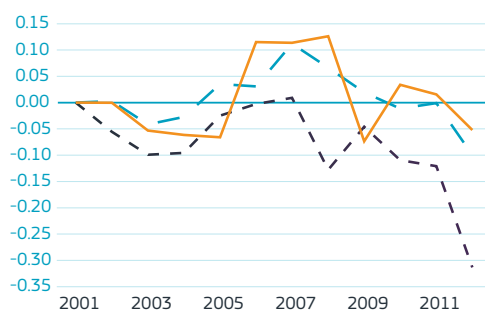
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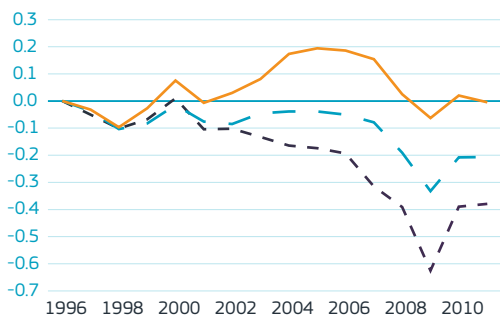
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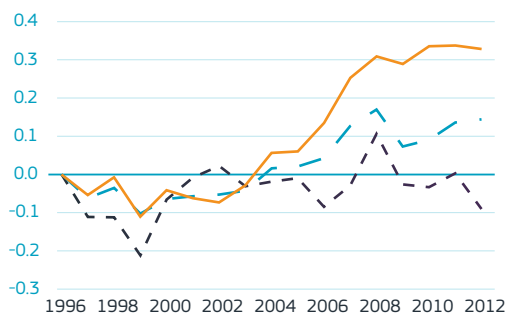
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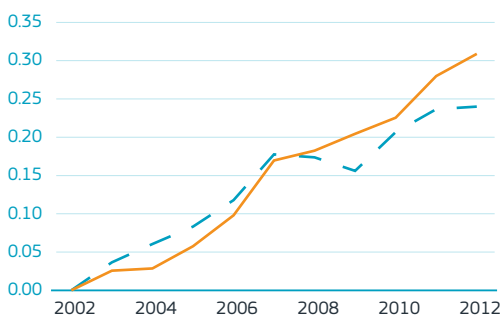
### Japan<sup>1</sup>



### Norway



### Sweden



Science, Research and Innovation performance of the EU 2018

Source: Data from the OECD Multiprod project, preliminary results, February 2016.

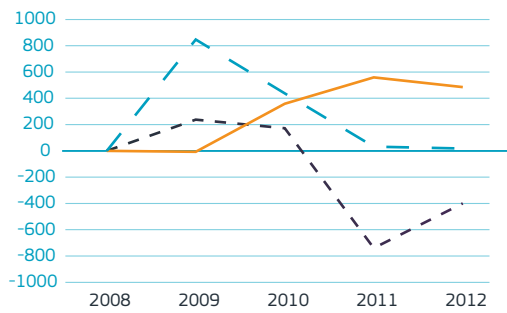
Note: <sup>1</sup>Data for Japan only includes firms above 50 employees.

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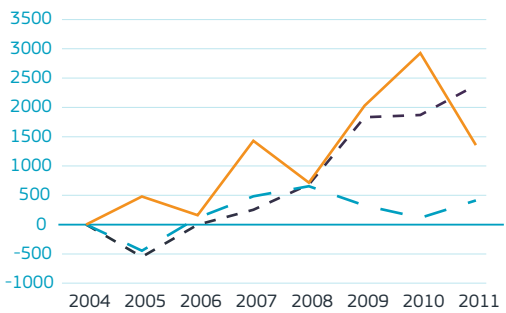
**Figure E** Change in real wages in different parts of the productivity distribution of firms<sup>1</sup> in the manufacturing sector

--- Bottom decile    - - - 4<sup>th</sup>-6<sup>th</sup> decile    — Top decile

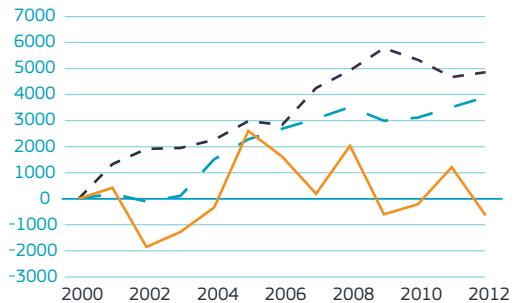
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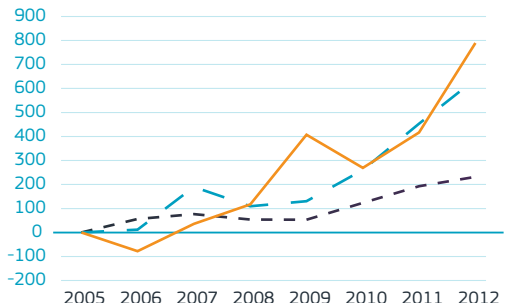
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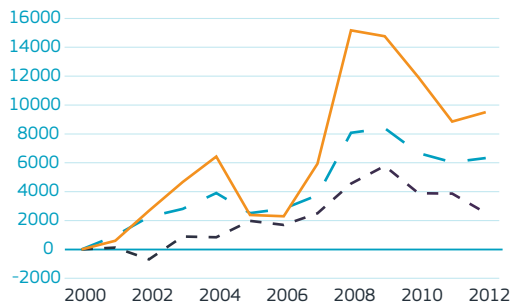
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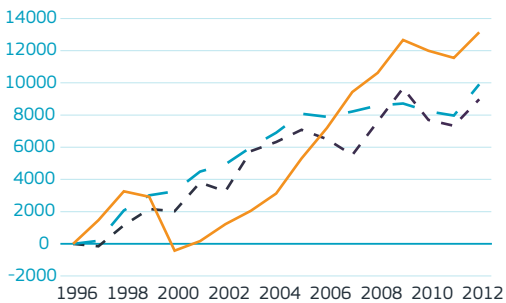
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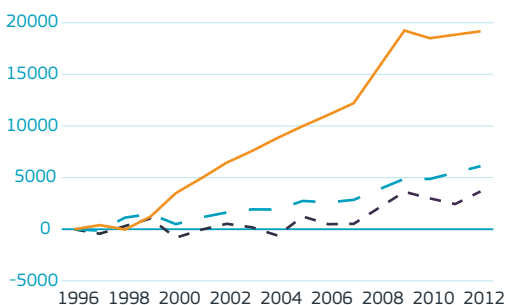
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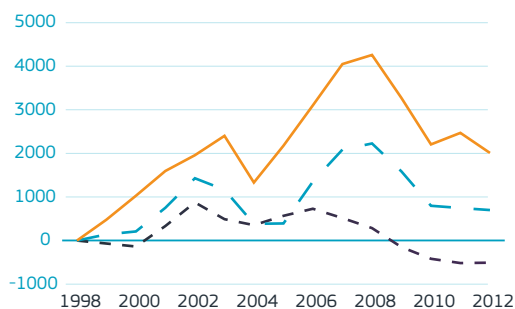
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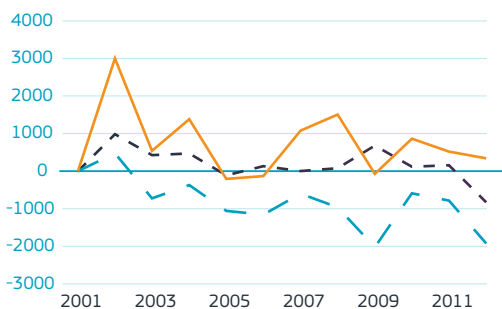
### France



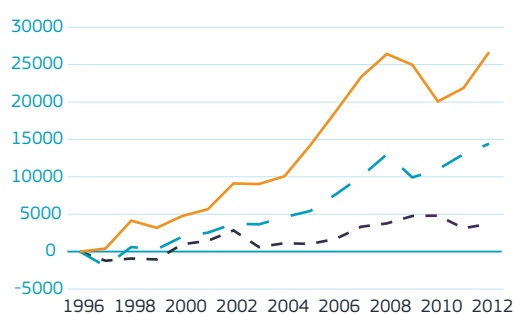
### Hungary



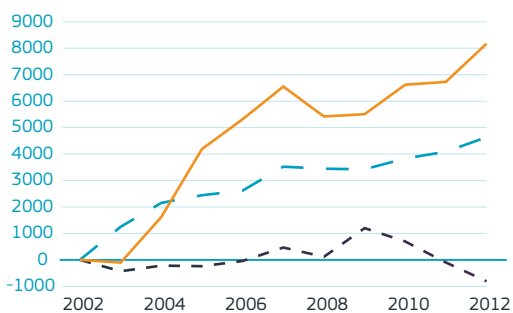
### Italy



### Norway



### Sweden



Science, Research and Innovation performance of the EU 2018

Source: Data from the OECD Multiprod project, preliminary results, April 2016.

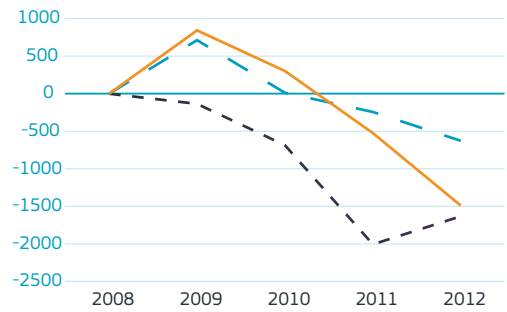
Note: <sup>1</sup>Each line represents the unweighted average of real wages across firms in a given part (bottom decile, 4th to 6th deciles, and top decile) of the productivity distribution in each year. Thus, "Top decile" represents the evolution of the average wage among the 10% most productive firms of a given year. Within each part of the distribution, wage levels are normalised at 0 in the first available year: in 1996 for Finland, France and Norway, 1998 for Hungary, 2000 for Canada and Denmark, 2001 for Italy, 2002 for Sweden, 2004 for Belgium, 2005 for Chile and 2008 for Austria. Wages are expressed in 2005 US dollars.

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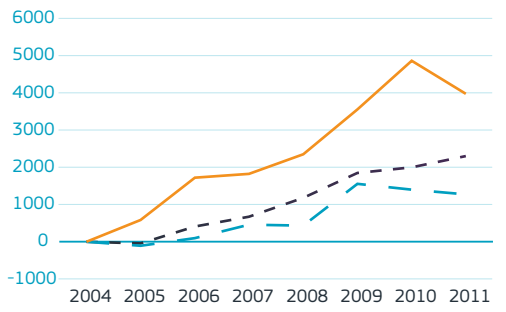
**Figure F** Change in real wages in different parts of the productivity distribution of firms<sup>1</sup> in the services sector

--- Bottom decile    - - - 4<sup>th</sup>-6<sup>th</sup> decile    — Top decile

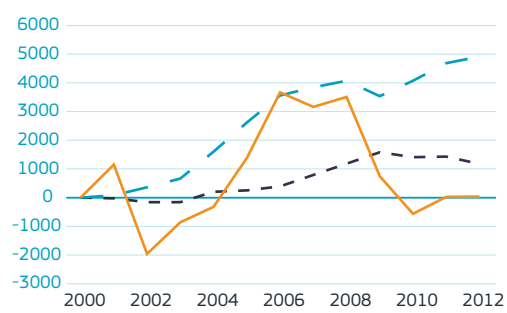
**Austria**



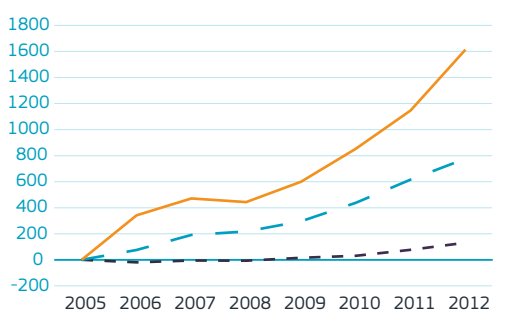
**Belgium**



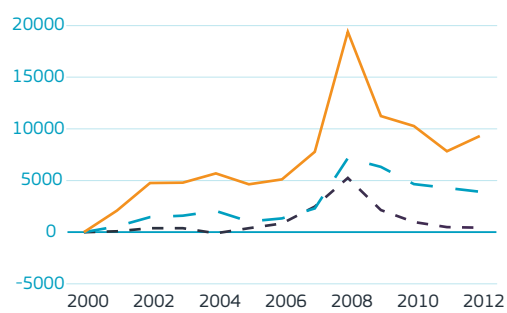
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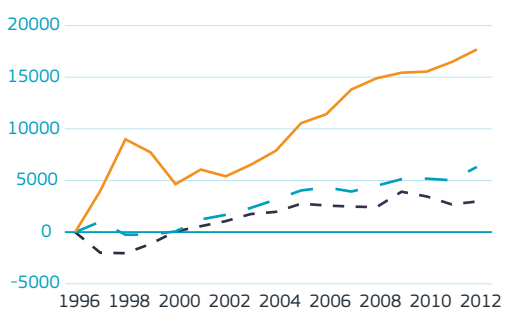
**Chile**



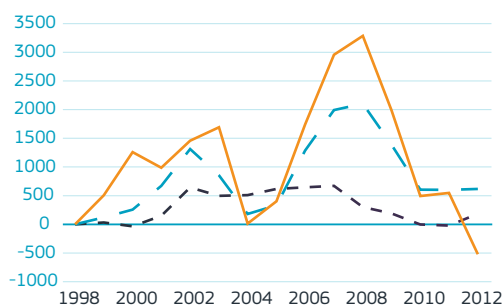
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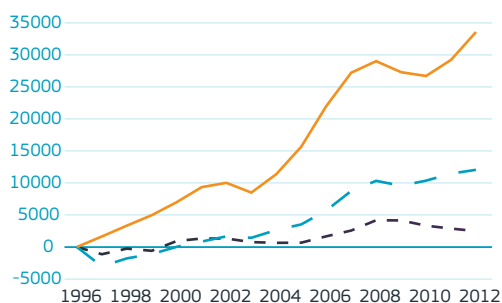
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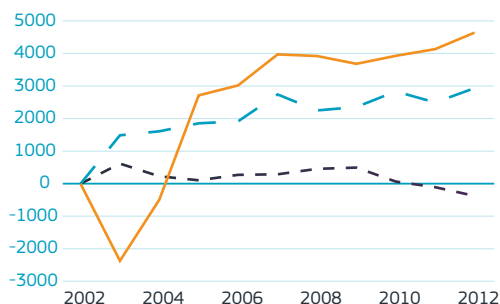
## Hungary



## Norway



## Sweden



Science, Research and Innovation performance of the EU 2018

Source: Data from the OECD Multiprod project, preliminary results, April 2016.

Note: <sup>1</sup>Each line represents the unweighted average of real wages across firms in a given part (bottom decile, 4th to 6th deciles, and top decile) of the productivity distribution in each year. Thus, "Top decile" represents the evolution of the average wage among the 10% most productive firms of a given year. Within each part of the distribution, wage levels are normalised at 0 in the first available year: in 1996 for Finland and Norway, 1998 for Hungary, 2000 for Canada and Denmark, 2002 for Sweden, 2004 for Belgium, 2005 for Chile and 2008 for Austria. Wages are expressed in 2005 US dollars.

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# CHAPTER 11.2



# HAS THE EUROPEAN CORPORATE R&D LANDSCAPE BECOME INCREASINGLY MORE CONCENTRATED IN a FEW HAPPY 'SUPERSTARS'?

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**Reinhilde Veugelers<sup>6</sup>**

*Full Professor at KU Leuven and Senior Fellow at Bruegel*

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<sup>6</sup> Research support from Robert Kalcik is gratefully acknowledged.

## 1. Introduction

Social exclusion and rising inequality are phenomena that could potentially be the most important challenges facing the EU and the world at large, threatening its political and societal stability and future prosperity. Most of the attention in the inequality debate focuses on the rising income inequality among individual citizens, and polarisation in the labour market (for example, McAfee and Brynjolfsson, 2016).

Disruptive innovations and technological progress, such as the rise of robots, are often seen as the culprits for the increasing income inequality and loss of jobs – with young tech geeks becoming billionaires overnight by selling their apps, or start-ups, while older low-skilled factory workers find their jobs are being replaced by robots. Aghion et al. (2015) argue that although innovation partly accounts for the surge in income inequality, it also fosters social mobility, at least when the innovations come from new inventors.

While most of this discussion on inequality is at the level of individual citizens, another strand of recent literature has looked into how unequal the corporate landscape has become. Both technological change, especially the Digital Revolution, and globalisation are predicted to lead to ‘winner takes most’ industries, dominated by a few superstar firms. As the importance of large fixed investments driving scale and scope advantages grows, and network effects become more prominent, sectors will become increasingly concentrated in a small number of firms, leaving an increasingly unequal corporate landscape. This is particularly true for digital sectors.

This superstar firm model has been checked recently in the United States by Autor et al. (2016) who looked at the concentration of sales and employment. They found a remarkably consistent upward trend in concentration

in each sector over the period studied (1982–2012). In manufacturing, the sales-concentration ratio<sup>7</sup> increased from 38% to 43%; in finance from 24% to 35%; in services from 11% to 15%; and in the retail trade from 15% to 30%. They also found that employment concentration grew, although notably more slowly than sales concentration. The pattern suggests that firms may attain large market shares with a relatively small workforce, as illustrated by companies such as Facebook and Google.

Autor et al. (2016) found that the industries which became more concentrated over time were also those in which productivity – measured either by output per worker, value-added per worker, total factor productivity (TFP), or patents per worker – increased the most. These findings suggest that a positive productivity-concentration relationship will most likely feature in any plausible explanation of rising industry concentration.

Other evidence supporting the positive link between concentration and productivity comes from the OECD. Using a harmonised cross-country, firm-level database for 24 countries, Andrews, Criscuolo and Gal (2017) show an increasing productivity gap between the global frontier and laggard firms. They define global frontier firms as the top 5% of firms in terms of labour productivity levels, within each two-digit sector, in each year, across all countries since the early 2000s. All other firms are defined as laggards. Between 2000 and 2013, global frontier firms displayed larger labour productivity growth rates than laggards in the manufacturing sector. Repeating this exercise using multi-factor productivity (MFP) estimates suggests that this productivity divergence remains after checking the ability of frontier firms to charge higher mark-ups, supporting the idea that divergence in productivity is technology driven.

7 i.e. the share of the four largest firms in total sector sales (CR4).

Since the growing concentration of superstars in the corporate landscape seems to be at least partly driven by divergences in productivity and the adoption of new technology, it is important to look at the corporate R&D landscape: **would we see similar growing trends in concentration in corporate R&D and how would changes in R&D concentration feed into rising sales and employment concentration?**

The speed, depth and breadth of technology change, large investments sunk into building R&D capacity, and the need to access networks and alliance partners for innovation are all characteristics that would predict R&D races increasingly characterised as ‘winner takes most’, where incumbent firms are the most likely winners in the innovation race (Schumpeter Mark II). However, the speed at which the latest technological innovations are either being diffused or spill over voluntarily or involuntarily will lead to the catching up and dissipating of previous leadership positions. If the diffusion process happens fast enough, the difference between leaders and laggards should shrink.

At the same time, the fluidity of the R&D environment needs to be recognised where the competences, network positions and technology leaderships of incumbents can be quickly overturned by radically new technology avenues. This will disrupt the incumbent leaders, creating room for new winners (Schumpeter Mark I). Even if the R&D landscape remains concentrated, new tenants will inhabit the top level.

An important issue for the policy discussion is to examine whether the ‘superstar R&D firms’ are either incumbent market leaders exploiting their market power, or incumbent R&D superstars exploiting their superior innovative capacities and experience, or new superstar firms introducing radically new innovations. Just how the concentration of R&D in fewer firms will impact the overall innovative performance of nations will depend on who these R&D superstars are, how they can ob-

tain, maintain and expand their superstardom and how contestable these superstar positions are.

Evidence on the concentration of the R&D landscape and trends therein is very thin. Recently, Rammer & Hünermund (2017) have examined this for Germany. They provide several interesting findings suggesting an increasing concentration in the German R&D landscape. They have found that the share of German firms that are innovation active has dropped over time. In particular, many small and medium-sized firms have stopped investing in innovation. As a consequence, the inequality among innovation activities has grown over time in Germany: since the mid-1990s, the Gini coefficient for the distribution of business-sector innovation expenditure has been exhibiting a rising trend. At the same time, they have identified high stability among the group of firms with the largest R&D budgets in Germany. In the 12 years between 2003 and 2015, nine out of 10 companies remained in the top 10 of the largest R&D spenders, and even changes in rankings were only marginal in the top 10.

In this contribution, we will look at the concentration of the R&D landscape and trends therein in Europe. We have used various editions of the European Commission’s Joint Research Centre Scoreboard of the largest R&D spenders worldwide which provides R&D profiles across all sectors and regions. We will examine the inequality in R&D expenditure by European Scoreboard firms, its concentration in a few leading firms and the trends therein. We will compare the (trends in) inequality and the concentration of R&D expenditure with the sales and the employment figures in Scoreboard firms. We will compare Europe with other world regions, and look at specific trends in high- and medium-tech sectors, focusing on several selected important sectors, most notably biopharma, vehicles and parts and ICT. Finally, we will look at incumbency among the top R&D spenders, concluding with a summary of the main findings and some tentative policy implications.

## 2. Methodology and information sources

The study uses the EC-JRC-IPTS R&D Scoreboard<sup>8</sup> of the largest R&D spenders in the world, for various years from 2005 to 2015. The various year editions were made compatible and top firms linked across them.

The R&D Scoreboard has the advantage that for individual firms it covers their R&D expenditure, sales and employment, for several years and for companies from all sectors and all countries<sup>9</sup>. Among the 2500 firms featured in the 2016 Scoreboard, 1075 are European (representing a total of EUR 223 billion of R&D expenditure or an estimated 95% of total corporate R&D spending in Europe<sup>10</sup>).

The R&D Scoreboard only covers the largest R&D spenders, which means that we will only characterise R&D distribution in the top part of the R&D size distribution, omitting the part with the lowest spenders. Focusing only on the Scoreboard firms in the total distribution of R&D-active firms is likely to generate less inequality than the total set of R&D-active firms and will give an upward bias in levels of concentration.

We will calculate various concentration and inequality indicators, similar to concentration and inequality measured in economic analysis.

**For concentration**, we will look at the share of the top 10% (decile) of the distribution. As regards **inequality**, we will calculate both the Gini coefficient and the **Theil** coefficient. The Theil coefficient for inequality can be broken down into subgroups, which enables a check to be made as to whether the overall inequality is due to high inequality within certain groups and/or because of differences between groups. We will do a Theil decomposition analysis to create two groups: the P10% and P90%. A Theil decomposition into deciles of the R&D expenditure distribution will allow us to investigate in more detail to what extent the overall inequality is due to the difference between the upper decile and the rest, and hence the concentration among top spenders.

8 European Commission, DG Joint Research Centre, 'The EU Industrial R&D Investment Scoreboard', 2017. See <http://iri.jrc.ec.europa.eu/Scoreboard.html>.

9 The Scoreboard consolidates R&D expenditure, sales and employment information at the firm's headquarter country. It also classifies the firms according to the sector where they carry out the majority of their activities.

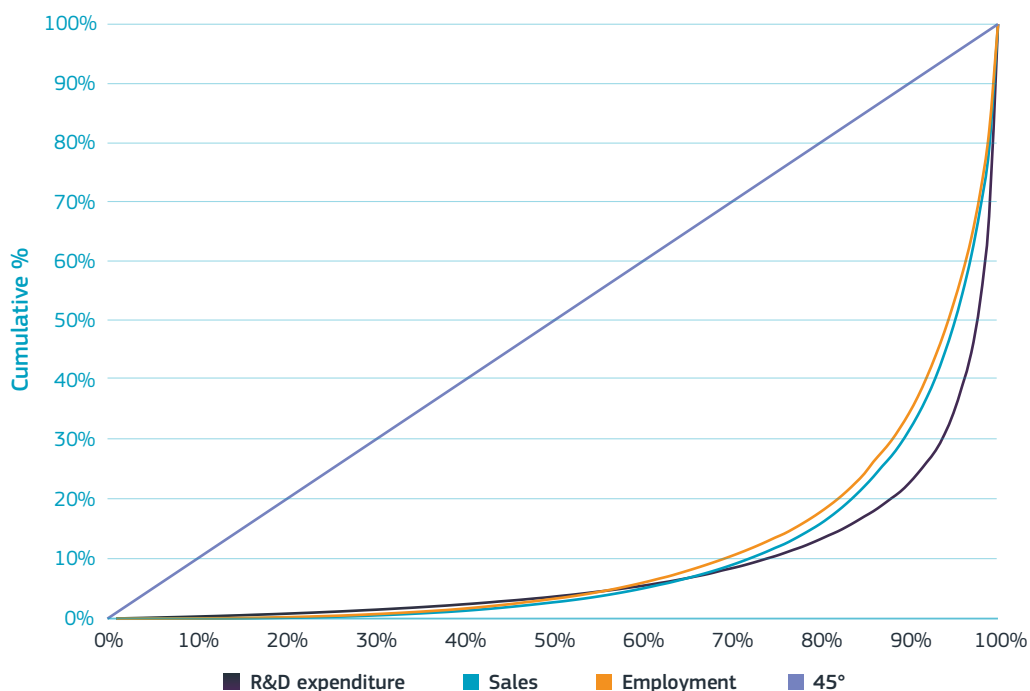
10 The European perimeter used in this study is the EU plus Switzerland and Norway, all members of the European Research Area. Switzerland has 58 companies in the 2015 Scoreboard and Norway has 12. The EU-28 has 1000 companies, with the UK and Germany the most represented with 276 and 217 companies, respectively. France has 117 and Sweden 83. All other countries have less than 100 companies in the 2015 Scoreboard.

### 3. How unequal and concentrated is the European corporate R&D landscape among a few star firms? Substantially, more so than sales and employment

The distribution of R&D expenditure among European Scoreboard firms is highly uneven (Figure II.2.1). The distribution of European Scoreboard firms' sales and employment is also highly unequal, although less so than

their R&D expenditure. This is confirmed in Figure II.2.2 by the Gini and Theil coefficients (columns 3 and 4), which are highest for R&D and lowest for employment.

**Figure II.2.1** Characterising the distribution of 1075 European R&D Scoreboard firms, 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard.

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The inequality of R&D is mostly driven by the concentration at the top. The Theil decomposition between the top 10% and bottom 90% groups for European R&D Scoreboard expenditure shows that most of the inequality in R&D expenditure is due to inequality between the top 10% and the bottom 90% (71%) rather than inequality within each groups (see column 5 in Figure II.2.2). This confirms that most of the inequality in the corporate R&D landscape is due to concentration in the top decile. This is much less the case for European Scoreboard firms' sales and employment, where only 37% and 33%, respectively, of the inequality is due to between group inequality and there is much higher inequality within the bottom 90% than there is for R&D (column 7).

The high between component of overall inequality of R&D expenditure correlates to a high concentration of R&D expenditure in the top decile of the distribution. This is confirmed in column 2 of Table 1, which shows the share of the top10% of the firms in total Scoreboard R&D, sales and employment.

The top 10% of European Scoreboard firms (i.e. the largest 107 firms) represent 77% of all European Scoreboard R&D expenditure. For sales and employment, the share of the top 10% is also substantial but nevertheless smaller than for R&D.

The Theil decomposition shows that even within the top 10% (column 6 in Figure II.2.2) there is substantial inequality in R&D expenditure and sales, although somewhat less so for employment. This would suggest that even within the top 10% there is a still considerable concentration in only a few firms. The top 1% of R&D spenders in the European Scoreboard (i.e. the 11 largest firms) (column 1 in Figure II.2.2) represents 32% of all European R&D Scoreboard expenditure or 42% of the top 10%. This concentration of R&D expenditure in a few firms in the top group is much less so for sales and employment among Scoreboard firms: for sales, the top 1% represents 21% of total Scoreboard sales; for employment, 18%.

The leading group of R&D spenders are much less dominant in employment and sales than in R&D. While the top 10% of European R&D spenders represent 77% of total European Scoreboard R&D, they only represent 51% of total European Scoreboard sales and 46% of total European Scoreboard employment (Figure II.2.3). This shows that the companies which spend the largest amounts on R&D are relatively leaner on employment and sales.

**Figure II.2.2** Inequality in the distribution of European R&D Scoreboard firms, 2015

		1	2	3	4	5	6	7
	N	Share Top 1%	Share Top 10%	Gini <sup>1</sup>	Theil <sup>2</sup>	% BTW <sup>3</sup>	Theil Top 10%	Theil Bottom 90%
R&D expenditure	1074	32%	77%	0.83	1.78	71%	0.52	0.51
Sales	893	21%	68%	0.80	1.39	37%	0.56	1.25
Employment	893	18%	65%	0.78	1.28	33%	0.40	1.28

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard

Notes: <sup>1</sup>The Gini coefficient measures the area between the 45° line and the distribution of the variable (R&D expenditure, sales, employment) as a share of the total area below the 45° line (see Figure II.2.1). It ranges between 0 (for perfect equality) to 1 (perfect inequality). <sup>2</sup>The Theil index is measured as follows:  $T = 1/N * (\sum (x_i / x_M) * \ln (x_i / x_M))$  where  $x_M$  is the mean value. The Theil index can be decomposed as follows:  $T = \sum_j s_j T_j + \sum_j s_j * \ln (x_M j / x_M)$  with  $j$  groups (i.e. 2 groups: the top 10% the bottom 90%, respectively); the first part represents the weighted sum of the within-group Theils and the second part, each group's weighted contribution to the between-group inequality. <sup>3</sup>The % of inequality explained by the inequality between the top 10% and the bottom 90%.

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**Figure II.2.3** Top European R&D Scoreboard firms and their shares in sales and employment<sup>1</sup>, 2015

	R&D expenditure	Sales	Employment
Top 1% R&D spenders	32%	11%	10%
Top 10% R&D spenders	77%	51%	46%

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard

Note: <sup>1</sup>Percentages are calculated based on top R&D spending firms with non-missing values in employment and sales (N=893) respectively. There are no non-missing values in the top decile.

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## 4. Comparing Europe-North America-Asia: higher R&D inequality and concentration in Europe than in North America and Asia

A comparison with the North American Scoreboard firms indicates whether or not the concentration of R&D expenditure in just a few firms is a bigger phenomenon in North America or Asia than in the EU. Figure II.2.4 compares some key statistics on the distribution of R&D Scoreboard firms in Europe with North America and Asia. For the comparison across regions, we have used a constant number of Scoreboard firms in each region (i.e. 750, which is the number of Asian firms in the sample).

The Theil R&D coefficient shows a smaller inequality in the R&D landscape in North Amer-

ica and Asia than in Europe. In addition, the concentration of R&D expenditure in a few firms is less pronounced in North America and Asia than in Europe. The top 10% of firms (i.e. the 75 largest firms) represent a smaller share of total Scoreboard R&D in North America and Asia than in Europe. For the top 1%, this difference is only marginal.

In contrast to Europe, North America's sales and employment distribution among Scoreboard firms is more unequal than in Europe, especially sales distribution, as shown by the higher Theil coefficients.

**Figure II.2.4** Comparing inequality and concentration of R&D Scoreboard firms by region

	Europe	North America	Asia
N	750	750	750
Theil R&D expenditure	1.51	1.45	1.15
Theil sales	1.20	1.54	1.15
Theil employment	1.05	1.28	0.89
% between Theil R&D expenditure	74%	71%	71%
% between Theil sales	31%	41%	47%
Share of Top 1% in R&D expenditure	27%	26%	25%
Share of Top 10% in R&D expenditure	73%	70%	65%
Share of Top 10% in sales	63%	72%	61%
Share of Top 10% in employment	58%	66%	55%

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard

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## 5. Sectoral comparisons of inequality and concentration in the corporate R&D landscape in Europe: a higher concentration in high-tech

In this section, we look at the difference in inequality and concentration between the high-tech, medium-tech and low-tech sectors. Most of Europe's Scoreboard R&D expenditure is found in medium-tech sectors (52%). Only 38% is located in high-tech sectors, and 10% is located in low-tech sectors.

The Theil coefficients (Figure 11.2.5) show a higher inequality in high tech compared to medium tech and especially compared to low

tech. This higher inequality holds true not only for R&D, but also for sales and employment.

Furthermore, the concentration of R&D expenditure in top firms is much lower in low-tech sectors compared to high- and medium-tech sectors. This is true for the share of the top 10%, but is even more pronounced for the top 1%. In high and medium tech, a much higher concentration of R&D is noted in the top 1% than in low tech.

**Figure 11.2.5** Comparing inequality and concentration in European R&D Scoreboard firms for high-, medium- and low-tech sectors

	High-tech	Medium-tech	Low-tech
N	438	553	174
Theil R&D expenditure	2.00	1.73	1.06
Theil sales	1.68	1.25	0.95
Theil employment	1.57	1.22	0.81
Share of Top 1% in R&D expenditure	33%	34%	15%
Share of Top 10% in R&D expenditure	84%	75%	61%
Share of Top 10% in sales	78%	65%	54%
Share of Top 10% in employment	77%	65%	50%

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard

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## 6. Trends in inequality and concentration: has the corporate R&D landscape become more concentrated over time? No

The Scoreboard data enables a comparison to be made over time from 2005 until 2015. As the number of firms included in the Scoreboard exercise has changed over time, we will use the same number for each year in the trends analysis. The time-comparable sample contains a somewhat smaller set of 1046 Scoreboard firms every year<sup>11</sup>.

For this set, inequality in R&D expenditure, as measured by the Theil coefficient, was lower in 2015 than in 2005. Thus, the Scoreboard data do not signal rising inequality in R&D; on the contrary, inequality in R&D seems to have fallen. Nevertheless, it remains at high levels and, in addition, the downward trend seems to have stopped since 2011. Inequality in sales and employment among these Scoreboard firms also declined from 2005 to 2015, although with a period of increasing inequality, particularly for sales between 2009 and 2014.

The concentration of R&D expenditure remained fairly stable at high levels, with only a small drop in the share of the top 10% (from 81% to 77%) and of the top 1% (from 35% to 32%). While the share of the top 10% continued to trend downwards until 2012, since then it has remained stable. Since

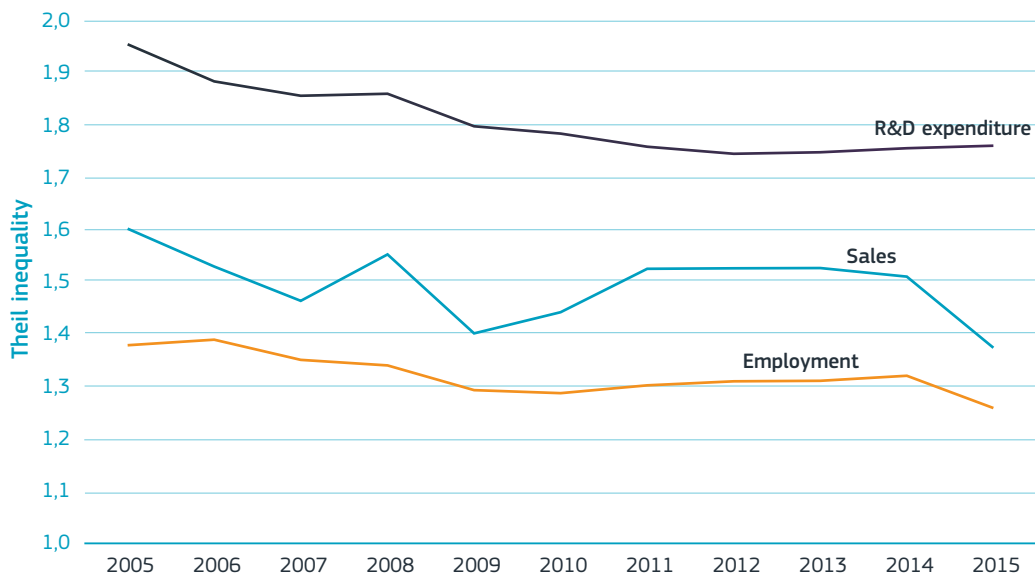
2012, the share of the top 1% has started to move slightly upwards. This corresponds with the end of the downward trend in Figure II.2.6 since 2011. All this suggests that since 2012, the super-top R&D spenders have forged ahead, leaving an even more concentrated R&D landscape in Europe than before.

For North America, the time-comparable sample includes 503 Scoreboard firms every year. This set shows a slight upward trend in inequality in R&D expenditure (Theil-R&D coefficient ranging from 1.18 in 2005 to 1.22 in 2015). In addition, the concentration is fairly stable over time for North America: the share of top 10% firms in R&D remained at 65% across the time period under consideration.

Inequality (as measured by the Theil coefficient) of R&D expenditure has declined over time, both in the high-tech and medium-tech sectors, while remaining consistently low in low tech. The concentration of R&D expenditure (as measured by the share of the top 10%) has gone down in the medium-tech sectors while remaining persistently high in high tech. Although lower in low tech, there is a slight increase in concentration over time in these sectors.

11 The time-comparable 1046 firms each year are not a panel of 1046 firms traced over time. The 1046 firms included for each year in the analysis of the distribution for that year may differ each year.

**Figure II.2.6** Trends in inequality among European R&D Scoreboard firms, 2005-2015



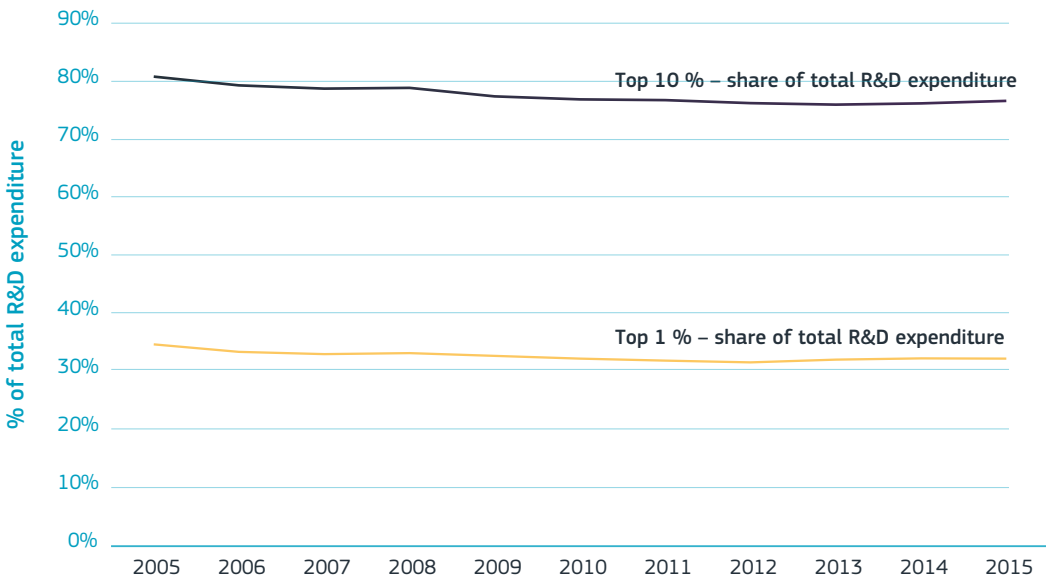
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU R&D Industrial R&D Investment Scoreboard

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**Figure II.2.7 Trends in concentration of R&D spending among European R&D Scoreboard firms, 2005-2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU R&D Industrial R&D Investment Scoreboard  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_2/figure\\_ii\\_2\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_2/figure_ii_2_7.xlsx)

**Figure II.2.8 Trends in inequality and concentration in European R&D Scoreboard firms for high-, medium- and low-tech sectors**

	R&D expenditure				N
	Theil		Top 10%		
High-tech	2.07	1.85	84%	83%	292
Medium-tech	1.89	1.69	81%	74%	528
Low-tech	1.00	1.03	57%	60%	168

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_2/figure\\_ii\\_2\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_2/figure_ii_2_8.xlsx)

## 7. Trends in inequality and concentration of R&D, incumbent vs. new leaders: a strong incumbency profile among R&D leaders

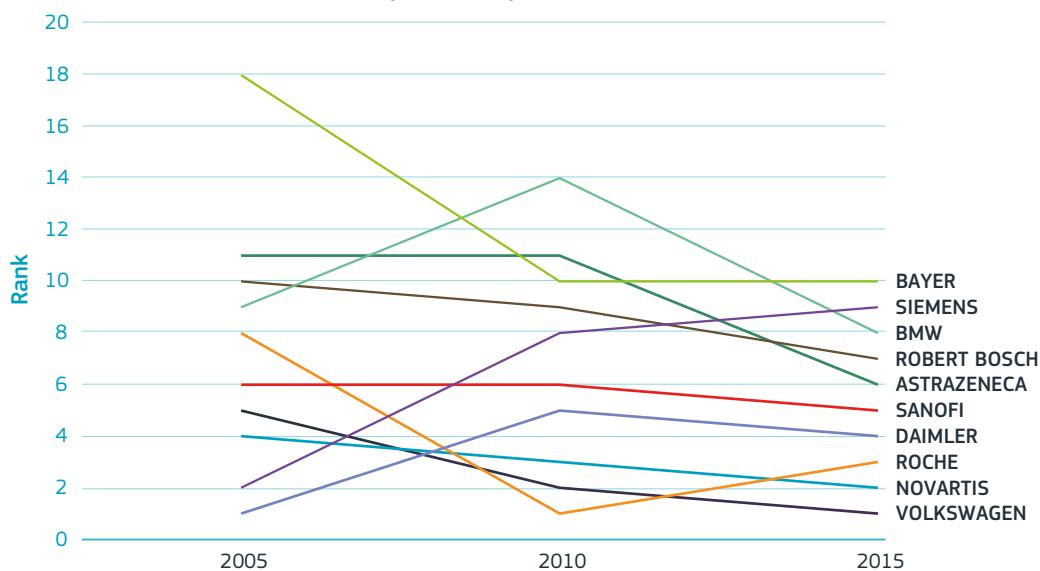
An important issue is to examine whether the ‘superstar R&D firms’ are incumbent R&D leaders or new leading R&D firms. In this section, we consider which of the leading R&D firms in Europe in 2015 were already leading, in this case, before 2010 and 2005. Identifying the incumbency status of top firms in the Scoreboard is a cumbersome exercise, requiring the firms’ history and their entry in the Scoreboard to be tracked over time. We do this exercise for those European Scoreboard firms that belong to the top 10/20.

When looking at the top 10 largest R&D spenders in Europe in 2015, it can be noted that their ranking among the largest R&D spenders has

remained very stable over time. Only two were not the top 10 in 2010 (AstraZeneca and BMW) and only AstraZeneca and Bayer did not join the top 10 in 2005. In 2015, all of the top 10 had already been in the top 20 in 2005 and 2010.

There was also significant stability in the top 20 in 2015: 17 firms already belonged to the top 20 at that time (representing 92% of R&D expenditure among the top 20). When looking back further, to 2005, there were six ‘new’ top 20 firms which had yet to join the top 20 in 2005. However, these six firms represented only 17% of the R&D expenditure of the top 20 in 2015 (20% of employment). Only two of the six did not belong to the top 50 in 2005.

**Figure II.2.9 Comparing the past rankings of the European R&D Scoreboard top 10 companies in 2015**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU R&D Industrial R&D Investment Scoreboard

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## 8. Trends in inequality and concentration of R&D, incumbent vs. new leaders in selected sectors

When considering the trends and stability in R&D leadership, it is more relevant to look at the ranking of firms within sectors. Figures II.2.10 and II.2.11 provide some key statistics on trends for three major sectors in the European R&D landscape: biopharma, cars and parts and ICT.

For **biopharma**, the time-comparable sample includes 150 European Scoreboard firms. In this group, the top 10% firms represented 84% of total Scoreboard R&D spending in this sector in 2015. Thus, the European R&D landscape in pharma and biotech is very skewed, which is not surprising, in view of the high economies of scale and scope in R&D in this sector (for example, Henderson and Cockburn, 1996). Although the inequality in R&D spending has fallen, particularly more recently, it remains considerable. The inequality of sales and employment among Scoreboard firms has also declined over time. The concentration of R&D, as measured by P10% (as well as P1%, not shown) has gone down but only very slightly and remains at a high level. This suggests that the decline in inequality in R&D is only marginally due to the drop in difference between the top 10% and the rest.

The digital sectors are often portrayed as being 'winner takes all'. Indeed, the distribution of R&D spending among European **ICT** Scoreboard firms is indeed significantly unequal, although less than in pharma and biotech. The top 10% represents 74% of total sector R&D spending. In ICT, although expected, there is no trend of increasing inequality and concentration is evident in either R&D, sales or employment among European Scoreboard firms. The trend is one of declining inequality and concentration – a downward trend that is far more

pronounced than in pharma/bio. Nevertheless, the levels of concentration and inequality in R&D remain high.

In **cars and parts**, the inequality and concentration of R&D is less pronounced compared to pharma, although in this sector, both inequality and concentration of R&D has risen over time. Inequality in sales has also increased, although not in employment.

To understand the impact of concentration on top firms, it is important to look at the type of top firms – i.e. whether they are incumbent or new firms. We have done this exercise for those European Scoreboard firms that belong to the top 10 in three sectors: pharma, cars and ICT (see Figure II.2.10).

In **Bio/Pharma**, the high concentration of R&D expenditure is characterised by a very strong incumbency effect. Of the 10, only one firm (in 8th position) did not belong to the top 10 in either 2010 or 2005. Although the sector did see substantial new entries in its Scoreboard, typically in biotech, none of these made it into the top 10.

We can see a similar story with **Cars**. In this sector, too, the dominance of the 10 largest R&D spending firms is high (than Pharma and ICT). Also in this sector, there is a high incumbency effect.

The dominance of the 10 largest R&D spending firms is least pronounced in the **ICT** sector. In addition, the incumbency effect is smaller. Nevertheless, in view of the rapid changes in technology in this sector, a smaller incumbency effect may have been expected.

**Figure II.2.10** Trends in inequality and concentration of European R&D Scoreboard firms for pharma, cars and ICT

	Pharma / Bio / Med (N = 150)		Cars and Parts (N = 43)		ICT (N = 260)	
	2005	2015	2005	2015	2005	2015
Theil R&D expenditure	1.95	1.84	1.13	1.26	1.92	1.55
Theil sales	1.74	1.52	1.14	1.26	1.80	1.55
Theil employment	1.58	1.45	0.91	0.84	1.67	1.46
Share of Top 10% in R&D expenditure	85%	84%	65%	69%	80%	74%

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard

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**Figure II.2.11 Incumbent European R&D leaders in pharma, cars and ICT**

	European R&D Scoreboard, 2015		
	Bio / Pharma	Cars and Parts	ICT
Share of Top 10 in 2015	79% <sup>12</sup>	88% <sup>13</sup>	55% <sup>14</sup>
2010 Top 10 - share in 2015 Top 10	95%	94%	82%
2005 Top 10 - share in 2015 Top 10	95%	94%	78%
New share in 2015 Top 10	0%	0%	0%

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Bruegel calculations on the basis of EC-JRC-IPTS, EU Industrial R&D Investment Scoreboard

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_2/figure\\_ii\\_2\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_2/figure_ii_2_11.xlsx)

- 12 The top 10 includes Allergan in 8th position, a United States firm in 2015 classified as European because its HQ is in Ireland. In 2010 and 2005, it was still categorised as United States. Allergan is the only top 10 firm which did not belong to the top 10 in 2010 and 2005. If Allergan was excluded from the European rankings (i.e. treated as non-European throughout the time period), UCB would enter the top 10. In this scenario, the top 10 would include 80% of total 2015 European bio/pharma R&D. As UCB was also in the top 10 in 2010 and 2005, the share of top 10 in 2015 from the top 10 in 2005 or 2010 would be 100%.
- 13 In 2015, the top 10 includes Delphi, in 10th position, which was a United States-based firm in 2005 and 2010, but in 2015 became a UK-based firm. Dropping Delphi (i.e. treating it as non-European throughout), introduces Valeo (France) into the top 10 for 2015. Delphi and Valeo are very similar with respect to their R&D expenditure in 2015, 2010 and 2005 – both just dropped out of the top 10 in 2010 but would have been in 10th position in 2005. Replacing Valeo with Delphi would therefore leave identical numbers in the table.
- 14 The top 10 in 2015 includes Seagate, in 8th position, a United States company classified as European because it moved its HQ to Ireland in 2010. In 2005, it was still classified as American. Seagate was not in the top 10 in 2010 or 2005 (even if it had been classified as European). Dropping Seagate (i.e. treating it as non-European throughout) introduces Schneider (FR), thus leaving very similar numbers (55%, 83% and 79%, respectively).



## 9. Concluding remarks on trends in inequality and concentration in corporate R&D in Europe

As recent research has shown a trend in the growing concentration of corporate sales and employment among a few ‘superstars’ – a trend which seems to be at least partly (digital) technology driven – it is important to look at the corporate R&D landscape and its concentration in superstars. Furthermore, R&D ‘races’ are increasingly expected to become “winner takes most”, in view of high economies of scale, scope and network economies, especially in digital technologies. At the same time, incumbents’ technology leaderships can be quickly overturned by radically new technology avenues. This will disrupt the incumbent leaders, creating room for new winners. Even if the R&D landscape may still be concentrated, new tenants will inhabit the top.

In this contribution, we have looked at the concentration of the R&D landscape and trends therein in Europe. We have used the 2005 to 2015 editions of the EC-JRC Scoreboard of the largest R&D spenders worldwide, which allows for analysis of each year’s R&D expenditure, sales and employment of 1047 European Scoreboard firms.

Our main findings can be summarised as follows:

- ▶ R&D expenditure by European Scoreboard firms is very unevenly distributed. This is confirmed by the Gini and Theil coefficients for R&D.
- ▶ The distribution of sales and employment in European Scoreboard firms is also very unequal, although less so than their R&D expenditure.
- ▶ Most of the inequality in R&D expenditure is due to the difference between the top 10% and the bottom 90% of spenders. This is much less so for sales and employment in European Scoreboard firms.
- ▶ R&D expenditure by European Scoreboard firms is concentrated in a few firms: the top 10% of European Scoreboard firms represent 77% of all European Scoreboard R&D expenditure. The top 1% of R&D spenders account for almost one-third of all European R&D Scoreboard expenditure.
- ▶ For sales and employment, the concentration in the top 10 and top 1% is also substantial, although less pronounced than for R&D.
- ▶ While the top 10% of European R&D spenders represent 77% of total European Scoreboard R&D, they only represent 51% of total European Scoreboard sales and 45% of total European Scoreboard employment. This indicates that the top R&D companies are relatively leaner on employment and sales compared to non-top firms.
- ▶ Inequality in the R&D landscape is somewhat higher in Europe than in North America and Asia. In contrast to Europe, the North American sales and employment distribution among Scoreboard firms is more unequal than the European, especially for sales distribution.
- ▶ When looking at the trend in inequality and concentration over time, from 2005 to 2015, the Scoreboard data do not signal

increasing inequality in R&D: on the contrary, the trend is downward. Nevertheless, this declining trend still leaves high levels of inequality and, furthermore, seems to have stopped since 2011. Since 2012, the top 1% of R&D spenders has forged ahead, leaving a more concentrated R&D landscape than before.

- ▶ When looking at the top 10 largest R&D spenders in Europe in 2015, this group of top leading R&D firms shows an extremely strong incumbency profile: almost all of the R&D expenditure by the top 10 (top 20) leading firms in 2015 can be accounted for by incumbent leaders which already belong to the group of top 10 (top 20) leading firms in 2005.
- ▶ In addition, the inequality in Scoreboard firms' sales and employment fell from 2005 to 2015, although indicating a period of increasing inequality, particularly for sales, between 2009 and 2014.
- ▶ The distribution of R&D expenditure across European Scoreboard firms in pharma and biotech is most unequal. Although the inequality in R&D spending has shrunk, particularly more recently, it remains at a high level, and the concentration in a few firms is high in this sector. This high concentration is characterised by a very strong incumbency effect. Although the sector saw substantial new entries in its Scoreboard in biotech, none of these made it into the top 10.
- ▶ The digital sectors are often portrayed as being "winner takes all". Indeed, the distribution of R&D spending among European

ICT Scoreboard firms is very unequal, but less so than in pharma and biotech. In addition, the concentration of R&D spending in the top 10% firms is high, but not as high compared to pharma, and the incumbency effect is also smaller than in pharma. In ICT, although expected, no trend can be seen of increasing inequality and concentration, either in R&D, sales or employment.

At this stage, the main message from the analysis seems to be that the European R&D landscape is highly unequal and concentrated in a few superstars in the European corporate R&D landscape, and is much higher than for sales and employment. Furthermore, there is a strong incumbency effect for these R&D superstars. Whether this concentration in a few incumbent firms is a reflection of differences in R&D advantages for large incumbent firms or it reflects barriers for new leading firms to grow into superstar status remains to be further explored. Evidence of declining inequality and concentration is a positive sign, but its high incumbency characteristic, its slow downward pace and particularly its loss of momentum more recently, requires further monitoring and analysis to understand its implications for the overall performance of the corporate R&D system.

Clearly, further analysis of this important dimension is needed. We hope that the analysis presented here instigates more work on more data. Further analysis using datasets that cover the full distribution of R&D active firms, beyond the Scoreboard firms, is actively encouraged.

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# CHAPTER

## 11.3

# R&D, ICT AND PRODUCTIVITY

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15 The views expressed in this paper are those of the authors and do not necessarily reflect the views of Statistics Netherlands.

## 1. Introduction

It is now largely confirmed that progress in information and communication technologies (ICT) has increased labour productivity (Jorgenson, Ho and Stiroh (2008), Syverson (2011)), in particular the revolutionary digital technology, which is recognised as a general purpose technology with a widespread application in many industries. ICT can affect productivity through various channels. First, productivity may increase as firms invest more into ICT capital goods, following a price reduction in these goods, possibly accompanied by changes in quality. Second, by increasing transparency and the information available to economic agents, it may render markets more efficient and thereby improve the allocation of resources. Third, it may bring people closer together and create network effects, for instance through social media. And finally, by increasing knowledge diffusion it may create accelerate the R&D spillover effects, making knowledge produced in one sector available more quickly in another sector, which could use it to produce new knowledge.

But there is another indirect way by which ICT may increase TFP growth, namely by boosting the productivity of research and development. There are good reasons to believe that this is so. First, ICT has reduced communication costs and concomitantly increased the speed of communication and thereby the linkages between researchers, enabling collaboration between researchers located far apart. In this way, they may bring their expertise together more easily and work in larger teams with a more specialised division of tasks. Secondly, ICT al-

lows for the storage and easy retrieval of huge amounts of data, improved search capabilities, the constitution of large databanks and access to a much larger scale of information. Third, electronic technologies have made it possible to apply data-mining techniques, to perform complex calculations and to reach a degree of precision that would have been impossible a century ago. Although there are good reasons to believe that investment in ICT could increase the return to R&D, evidence supporting the complementarity between R&D and ICT is mixed. Exploring this complementarity is the prime objective of this paper.

While innovation and its main R&D input are considered as the main drivers of long-term economic growth, Europe is lagging behind the United States in terms of R&D intensity. In order to create a stimulating environment for innovation, the European Union conceived the Europe 2020 flagship initiative known as the Innovation Union. To facilitate innovation you need basic skills, in particular e-skills, easy access to finance, protection of intellectual property rights, mobility of researchers, inter-regional and international collaboration, procurement and standards. The Innovation Union includes 34 commitments which it wants to be developed to improve the EU's innovation performance. ICT plays a particular role not only by providing the latest hardware, software and internet infrastructure, but also by changing the way researchers operate, replacing the closed mode of doing research by a more open innovation system, which relies on external as much as internal sources of knowledge.

## Literature

By and large, there is agreement on three empirical regularities: that R&D earns a positive rate of return and contributes to TFP growth (Hall, Mairesse and Mohnen, 2013); that computers and the adoption of ICT show up in productivity statistics (Jorgenson, Ho and Stiroh, 2008; Bigagi, 2013); and that investments in ICT affect productivity growth if they are accompanied by changes in work organisation (Brynjolfsson and Hitt, 2000; Bloom, Sadun and Van Reenen, 2012). Evidence of complementarity between R&D and ICT is more mixed. In fact, very few studies have directly examined this issue.

The study by Hall, Lotti and Mairesse (2012), based on Italian firm data, finds no conclusive evidence in favour of either a complementarity or a substitution between R&D and ICT on Italian firm data. R&D and ICT increase total factor productivity (TFP) individually but their joint investment does not give an additional boost to productivity. Cerquera and Klein (2008) point to a complementarity in the adoption of R&D and ICT but do not examine the complementarity at the outcome stage. They find on German firm data that ICT explains an increase in heterogeneity in productivity and that this process of creative destruction gives firms incentives to invest in R&D.

Some work has examined a possible complementarity not between ICT and R&D but between ICT and innovation output. Spiezia (2011) concludes from the OECD-lead international comparison study, based on company data, that ICT enables the adoption of innovation but does not increase the probability of coming up with a new innovation developed in-house. In contrast, Kleis, Chwelos, Ramirez and Cockburn (2012) find that investments in information technology increase innovation output when measured by patents. Van Leeuwen and Farooqui (2008), in

the Eurostat report on ICT impacts, show that e-sales and broadband use affect productivity significantly via their effect on innovation output. Forman and van Zeebroeck (2012) found that internet connections increased collaborative research, but not the productivity of lone researchers or of researchers located close to each other. By facilitating access to outside R&D and allowing it to be conducted on an international basis, ICT makes it possible to follow the open innovation model proposed by Chesbrough (2003), evidence of which has been provided by Laursen and Salter (2006).

Some studies have been conducted at the industry level. Using data from 26 industries and 10 European countries, Corrado, Haskel and Jona-Lasinio (2017) find that the returns on intangibles in a particular industry increase with the average ICT intensity across countries in that industry. Their intangibles contain innovative property (including R&D), and economic competencies (including organisational structure). They have not investigated the complementarity of ICT with individual components of intangible capital, in particular R&D. Chen, Niebel and Saam (2014) measure the intangible capital stock at a one-digit level in 10 European countries and examine whether the intensity of ICT (computing equipment, communications equipment and software) increases the return on intangibles. They find that the output elasticity of intangible capital increases with ICT intensity whatever measure is used for the latter. When intangibles are broken down into different components, complementarity with ICT shows up only for organisational capital and R&D. However, in a similar exercise on data for 33 Dutch industries, Polder (2015) fails to replicate these results for the Netherlands, suggesting that there might be cross-country differences.

## Two kinds of data and two types of approach

We will conduct the analysis at two levels of aggregation: at the micro-level, using firm panel data from the Netherlands, and at the meso-level, using sector panel data from nine EU countries. Micro-data are characterised by a lot of heterogeneity, which will allow us to examine non-linearities. At the firm level, we can also distinguish between firms investing in R&D or ICT and those that do not. At a more aggregate level, some of the individual heterogeneity gets washed away, but in exchange there is the institutional heterogeneity across countries. Aggregate data may pick up the presence of spillovers without having to make specific assumptions about the way they occur when constructing externality variables. Given that we want a sufficient degree of freedom, we have decided to work at the meso- rather than the macro-level.

First, we take a descriptive look at the link between investments in ICT/R&D and the growth rate of TFP, primarily for both kinds of investment separately and then for their interaction. We will conduct the analysis at the extensive margin – that is to say, we will compare firms that invest and those that do not invest in R&D/ICT, and at the intensive margin – that is to say looking at the link between the distribution of R&D/ICT and TFP growth. This first approach delivers an in-depth insight into the correlation between firm performance and investment in ICT and R&D and a possible complementarity between both investments. Finally, we will conduct an econometric analysis where we re-

gress TFP growth on investments in R&D and ICT, controlling for industry-specific effects, and formally test for the presence of complementarity between both investments.

It is difficult to establish a causal link between investment and performance. Besides the obvious simultaneity problem, various issues complicate the analysis. First, it should be acknowledged that the distribution of investment is not smooth. Because investment is subject to adjustment costs, it is not a continuous process, and thus firms do not necessarily invest in each period. Secondly, there may be non-linearities in the sense that effects on performance are only visible for specific ranges of intensity. In addition, the effect on performance could depend on other characteristics, which means that there could be substantial heterogeneity across firms or industries. The complementarity between R&D and ICT of interest can once again show up at two stages: at the extensive or intensive margin. There is complementarity at the extensive margin when firms or industries tend to invest either in both R&D and ICT at the same time or in neither of them, more formally when investing in both yields a higher return than the sum of the returns from each investment in isolation. There is complementarity at the intensive margin when the marginal return of investing in R&D increases with the amount invested in ICT or vice versa. The return can be measured in different ways. We will concentrate on TFP growth.



## A micro-level perspective

The firm-level data used is sourced from Statistics Netherlands. Three surveys have been combined for our purposes: the Production Statistics (PS), the Investment survey (INV), and the Community Innovation Survey (CIS). All results presented here pertain to the sample whereby firms are covered in each survey. The years 2000–2012 are used, where odd years have been removed because of the biannual nature of the CIS. This yields 257 763 observations covering a total of 144 949 individual firms. Productivity is calculated using the PS data from a regression of labour productivity on capital intensity, controlling for industry effects, and assuming constant returns to scale. Output is measured as value added and capital is proxied by the depreciation costs. Firms are classified in industries (economic activities) according to the publication level of the National Accounts based on NACE Rev. 1. In total, 36 industries are differentiated, covering various economic activities<sup>16</sup>.

Firms in the research and development sector (NACE code 73) have been dropped from the sample. Appropriate deflators at this level of aggregation have been used to convert nominal into real figures. The residual of this regression is our measure of TFP. By taking into account industry averages, TFP figures are comparable across firms from different industries. The bottom and top percentiles of TFP levels have been discarded to avoid sensitivity to outliers in TFP distribution. Productivity growth is then computed as the differences in log-trans-

formed productivity TFP levels. Investment in ICT is taken from the Investment Survey. R&D and innovation variables are sourced from the biannual Community Innovation Survey. ICT investment is restricted to hardware, as software data have only been included in the Investment Survey since 2012.

The intensities of ICT and R&D investment are calculated by taking ratios of investment to labour input (in full-time equivalents), and are divided by the pertinent industry average. This makes it convenient to compare above- and below-average firms, and across industries. For the analysis, the distributions of the relevant variables are broken down into quintiles or deciles. For each sub-sample, these breakdowns are calculated separately. Moreover, these groups are defined by industry-year combinations separately, so that each industry and year is represented in each bin according to its share in the total number of observations, mitigating any issues of selectivity which are typical when looking at such a granular level of detail.

We start by examining whether firms' productivity performance varies with investments in ICT and R&D. Therefore, a comparison is carried out between firms that invest and those that do not (i.e. the extensive margin), as well as between firms in different parts of the investment distributions (i.e. the intensive margin)<sup>17</sup>. Panel (I) of Figure II.3.1 considers TFP growth rates of firms that invest in ICT and/or R&D, and those that do not invest in either.

16 The economic activities covered include (subsectors of) agriculture; mining and quarrying; manufacturing; electricity, water and gas; construction; wholesale and retail trade; accommodation and food services; transportation, storage and communication; business services; health care; and other services.

17 It is important to note that the results of this analysis do not imply or make claims about causality. The analysis is intended to illustrate the performance of firms that invest in ICT and R&D. A better performance of investing firms could mean that investment in ICT and R&D raises productivity, but also that firms invest in ICT and R&D because they are productive and, for instance, subject to fewer financial constraints. Moreover, since our analysis does not control for any additional factors, there could be other variables affecting both investment and performance.

Average TFP growth for the whole sample<sup>18</sup> is 1.1%. Firms that do not invest in either ICT or R&D are substantially below that figure at 0.4%, which is the lowest of all categories considered. Firms that invest in ICT perform only slight better, with 0.6% TFP growth on average. The group that comprises firms that invest in R&D only has a TFP growth of more than twice the average (2.3%); firms that invest in both ICT and R&D are slightly below that with 2.2%. Therefore, there is no sign that ICT ‘helps’ R&D in realising productivity growth, or vice versa. However, it should be noted that this analysis concerns the extensive margin only, i.e. whether or not firms make an investment. Complementarities could be present in the intensive margin, which will be discussed next.

Turning to panels (II) and (III), we relate the average TFP growth to positive investments in either ICT or R&D in order to assess whether TFP performance varies as the intensity of investment increases. Looking at ICT investment, in contrast to the earlier finding related to the extensive margin, firms investing *more* in ICT do seem to show higher TFP growth. Another interesting result is that firms in the lowest quintile of the ICT distribution have higher TFP growth than those in the second and third quintile of the distribution. It is those latter two groups of firms in particular that bring down the overall average.

Considering R&D investment, in panel III, TFP growth is on average also higher for firms investing more in R&D. In this case, it seems that there is clear delineation between firms with lower levels of investments (first and second quintiles) and those with higher levels of investment (third to fifth quintiles). Once firms

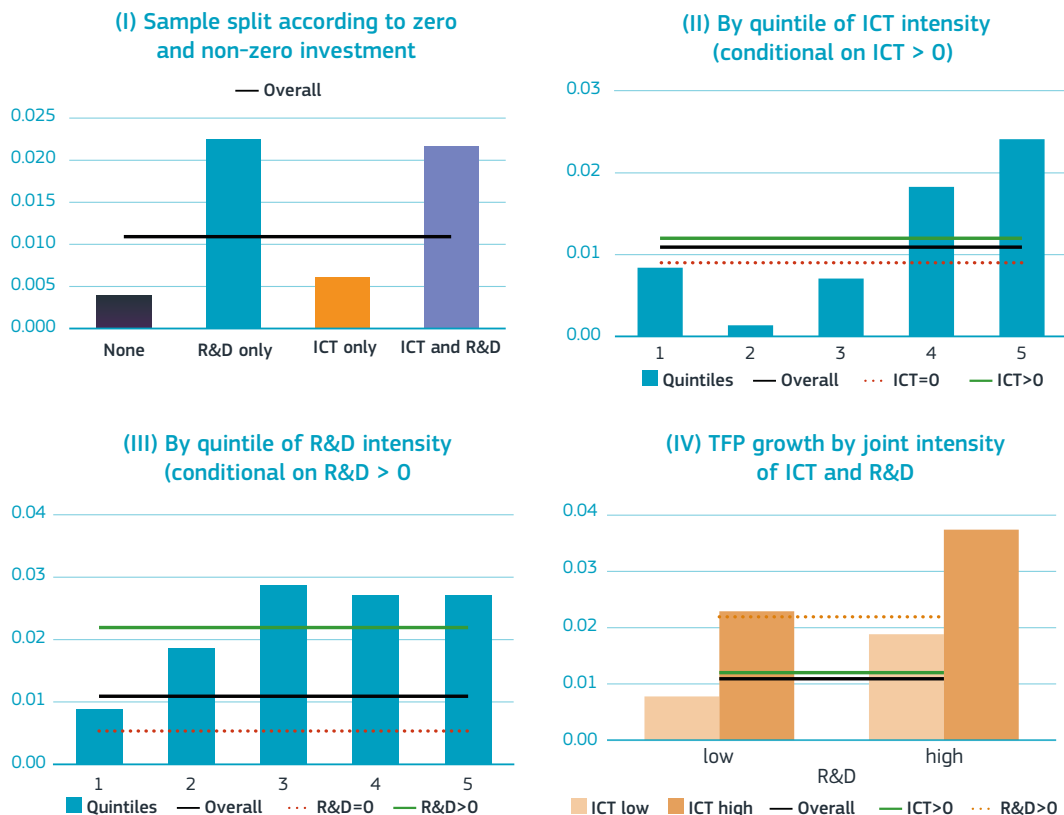
reach a level of R&D investment that corresponds to the average of the third quintile of the distribution, additional investments do not produce any proportional increase in terms of TFP growth beyond that achieved by firms in the third quintile of the distribution.

To summarise, panels I to III suggest that performance in terms of productivity seems to vary along the distribution of ICT and R&D intensity. While switching to ICT investment does not seem to be associated with higher TFP growth, higher levels of ICT intensity correlate positively with TFP growth. The positive correlation of R&D investment with TFP growth should also be attributed to firms with a higher R&D investment intensity.

Panel IV looks at the cross relation between low (below the median) and high (above the median) ICT and R&D vis-à-vis the growth of TFP. a central question in this paper is whether ICT can help R&D to increase productivity, and vice versa. If such complementarities are present, average TFP growth should increase in the intensity of one type of investment as the other type of investment increases as well. The results in panel IV offer *prima facie* evidence of complementarity between ICT and R&D. Indeed, the difference in TFP growth between high and low R&D-intensive firms is higher for high (the two right-hand columns) than for low R&D-intensive firms (the two left-hand columns). Vice versa, high R&D performers show a greater increase in TFP performance as ICT intensity shifts from low to high than low R&D performers. The highest TFP growth is achieved in the high R&D/high ICT column; the lowest TFP growth is in the low R&D/low ICT group.

18 The sample comprises firms present in all three surveys combined.

**Figure II.3.1 TFP growth by ICT and R&D intensity, 2000-2012 (even years)**



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Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Statistics Netherlands: Production Statistics, Investment Survey, Community Innovation Survey (authors' own calculations)  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii-3\\_1\\_i.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii-3_1_i.xlsx), [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii-3\\_1\\_ii.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii-3_1_ii.xlsx), [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii-3\\_1\\_iii.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii-3_1_iii.xlsx), [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii-3\\_1\\_iv.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii-3_1_iv.xlsx)

Next, we consider the investment behaviour of firms along the distribution of productivity. With the availability of firm-level panel data, the heterogeneity in firms' performance has become well documented (Bartelsman and Doms, 2000). Recently, Andrews, Criscuolo and Gal (2016) have attributed the dismal macroeconomic productivity performance since the beginning of the new century to a growing gap between 'leaders' and 'laggards'. That is, although a clear slowdown in productivity growth can be seen in the aggregate numbers,

nonetheless, frontier firms seem to have experienced significant productivity growth while a larger proportion of firms is falling behind with marginal growth numbers. An important question for policy is to identify the characteristics of firms in different parts of the productivity distribution. Who are the top performers, and who are the firms lagging behind? Andrews et al. (2016) show that frontier firms are typically larger, more profitable, younger and more likely to patent and be part of a multinational group than other firms.

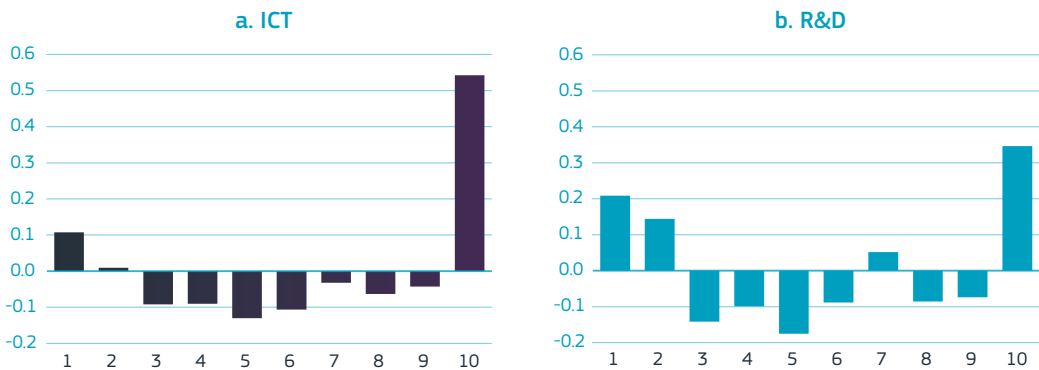
Figure II.3.2 shows ICT and R&D expenditures by growth of TFP. We consider the entire distribution of TFP growth, not only the leaders versus laggards. Frontier firms can be thought of as those in the top decile. ICT and R&D expenditures are expressed relative to the number of workers (in full-time equivalent (fte)), and the ratios are divided by the relevant industry averages. Figure II.3.2 shows deviations from the industry averages (e.g. 0 means on par with the firm's industry)<sup>19</sup>.

Panel I of Figure II.3.2 shows that ICT investments seem to be strongly concentrated among those firms that are in the top 10% of the TFP growth distribution. On average, firms in the highest TFP growth decile have ICT investments of 54% above the industry average. By contrast, they are below average in the rest of the TFP growth distribution, except in the two bottom deciles. In the bottom decile, ICT investments appear to be 10% above average. The pattern for R&D is rough-

ly similar (panel II). However, the TFP growth distribution suggests that R&D expenditure is relatively more concentrated not only in the top decile, but also in the bottom deciles. Firms with the strongest TFP growth spend 35% more on R&D compared to the industry average, while expenditure on R&D is relatively high in the bottom two deciles as well, with 21% and 14% above average, respectively.

In conclusion, it can be noted that there is a U-shaped distribution of R&D and ICT per fte as productivity growth increases. The high intensities at the two extremes of the TFP growth distributions could be explained as follows. At the top end, the explanation is quite straightforward. Firms that are close to the frontier, in terms of technology adoption or best practice, invest relatively more in R&D and ICT to stay at or push out the frontier, and they also probably have the means to finance those investments. Those at the bottom of the distribution could be small firms, maybe

**Figure II.3.2** ICT and R&D intensity relative to the industry average, by deciles of the distribution of TFP growth, 2000-2012 (even years)



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Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: Statistics Netherlands: Production Statistics, Investment Survey, Community Innovation Survey (authors' own calculations)  
 Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii\\_3\\_2.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii_3_2.xlsx)

19 ICT and R&D distributions have been cleaned to exclude the most extreme observations. The TFP distribution was not cleaned for this analysis. Commonly, outliers are dealt with by setting them at a value in line with the bottom or top deciles. Therefore, assigning any potential outliers to the bottom or top decile does not make a difference to any of our results.

start-ups, that have to invest in ICT and R&D because they are newcomers, investing in the latest technology, or in order to grow. However, these firms may not have the capacity yet to be very productive because of adjustment costs, lack of experience, and their size does not allow them to benefit from returns to scale. As they grow, if they survive, they become more productive, moving up the learning curve, and they need to invest relatively less compared to the number of workers they have in ICT equipment and R&D.

This leads us to adopt the following specification for TFP growth:

$$\begin{aligned} tfpg = & \beta_1 ICT + \beta_2 R\&D + \beta_3 I [ICT \text{ high}] + \beta_4 I [R\&D \text{ high}] \\ & + \beta_5 I [ICT \text{ high}] \times ICT + \beta_6 I [R\&D \text{ high}] \times R\&D \\ & + \beta_7 ICT \times R\&D + \beta_8 I [ICT \text{ high}] \times I [R\&D \text{ high}] \\ & + \beta_9 (ICT \times R\&D) \times I [ICT \text{ high}] \times I [R\&D \text{ high}] \end{aligned}$$

where *tfpg* denotes TFP growth, ICT and R&D are investment intensities (i.e. investment per *fte*), in deviation from the industry averages, and *I [ ]* is an indicator of whether ICT or R&D are higher than the corresponding medians. That is *I [ ]* = 1 indicates that the firm is research- or ICT-intensive. All variables are in logs. The interpretation of the coefficients is as follows: first,  $\beta_1$  and  $\beta_2$  measure the linear effect of the investment intensity of ICT and R&D on TFP (growth), whereas  $\beta_3$  and  $\beta_4$  measure whether firms that have a relatively high intensity of investment display a higher-than-average TFP growth. Then,  $\beta_5$  and  $\beta_6$  measure whether the linear effect in the high-intensity groups deviates from the overall linear effect. In a similar vein,  $\beta_7$  assesses whether there is complementarity between ICT and R&D, and  $\beta_8$  and  $\beta_9$  whether such a complementarity is stronger in the high-intensity groups. We prefer to estimate a TFP growth equation rather than a TFP level equation, because our data refer to investments. What matters for TFP are the stocks of R&D (a proxy for the stock of knowledge) and ICT, while the corresponding investments matter more for the explanations

Finally, we present the results of a simple regression analysis relating firms' TFP growth performance to ICT and R&D investment. The descriptive analysis above shows that there may be relevant non-linearities in the relation between productivity and investment in ICT and R&D. In particular, there may be differences in the correlations depending on whether the investment intensity is high or low. In addition, there could be complementarities between ICT and R&D, meaning correlations are stronger for firms that conduct joint investment.

of TFP growth. It should be noted that these coefficients should be seen as estimates of the excess effects of ICT and R&D on value-added growth – i.e. the effect over and above the 'normal returns' which equal the respective cost shares and are already included in the TFP measure. Thus, an insignificant coefficient implies that the contribution of ICT and R&D to the growth of output (or labour productivity) is in line with its cost share.

Figure 11.3.3 reports the results. We have experimented with two measures of TFP: one where factor weights sum up to 1, i.e. constant returns to scale are imposed, and one that allows for non-constant returns to scale. As the results are basically the same for both measures, we report only those obtained with constant returns to scale imposed. The results point to ICT having a significant positive correlation with TFP growth, but only in the high-intensity group. The intensity of R&D investment has a significant positive correlation that is similar for both the low- and high-intensity groups. There is no evidence of complementarity between R&D and ICT.

In a separate estimation, we simplified the above specification and only examined the excess effect by the interaction between R&D and ICT – i.e. we ignored all the terms that involve the intensity dummy  $I[\ ]$  and made  $\beta_3, \beta_4, \beta_5, \beta_6, \beta_8,$  and  $\beta_9$  equal to zero. We used a less-flexible model, but in return the estimation was performed for each 2-digit industry

separately. We only found a significant positive interaction term (i.e. for coefficient  $\beta_7$ ) pointing to complementarity between ICT and R&D for rubber and plastics, basic metal, wholesale, transport services, environmental services and other manufacturing, and a significant negative coefficient pointing to substitutability for transport on land.

**Figure II.3.3** Regression of TFP growth on ICT and R&D, Dutch firm data, 2000–2012

	Coef.	Std. Err.	p-value
ICT	-0.007	0.008	0.370
High ICT (dummy)	0.018	0.014	0.185
ICT*High ICT <sup>1</sup>	0.029	0.012	0.016*
R&D <sup>1</sup>	0.008	0.005	0.087*
High R&D (dummy)	0.000	0.012	0.997
R&D*High R&D	-0.001	0.010	0.933
ICT*R&D	0.001	0.002	0.795
High ICT*High R&D (dummy)	-0.019	0.013	0.136
(ICT*R&D)*(High ICT*High R&D)	0.001	0.001	0.362
Constant	0.005	0.014	0.737

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Source: DG Research and Innovation – Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Statistics Netherlands: Production Statistics, Investment Survey, Community Innovation Survey (authors' own calculations)

Note: <sup>1</sup>p-value: \* = significant at 5%

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## A meso-level perspective

At the meso-level, we used data from the 2016 release of the EU-KLEMS data (Jäger, 2016) to cover nine countries (Austria, Germany, Spain, Finland, France, Italy, the Netherlands, Sweden and the UK), and 32 manufacturing and service industries at the NACE 2 2-digit level, over the period 1995 to 2014. ICT comprises computing and communication equipment, software and databases. For labour, we used hours worked, and the non-ICT capital stock comprises non-residential buildings, transportation equipment and other machinery. Output is measured as value added. Following the European System of National Accounts ESA2010, R&D is considered as a separate investment rather than an intermediate input. Value added has been corrected for this capitalisation of R&D. As in the micro-analysis, TFP growth is determined by first estimating a Cobb-Douglas production function with constant returns to scale, retrieving the residual (all in logarithms) and then taking the differences in the residual measure of TFP growth. Swedish and UK data have been converted into euros. The nominal investment and value-added data have been deflated by appropriate deflators (base year = 2010). The capital stock data by industry and asset type are taken directly from Eurostat and constructed by the national statistical offices using the perpetual inventory method.

At the industry level, it is impossible of course to analyse the extensive margin as in every industry there is at least one firm that carries out ICT and/or R&D. Therefore, we have concentrat-

ed on the intensive margin. In Figure II.3.4, we compare the figures of TFP growth along the quintiles of the distributions of ICT intensity (in panel a) and R&D intensity (in panel b). The distribution quintiles are computed separately for each industry. Because of differences in institutions, policies and industrial specialisations, it makes little sense to assume the same distribution across sectors per country. There is probably more homogeneity in the distribution of R&D and ICT intensity (in millions of euro per hour worked) per industry than per country. For every industry, we have included observations on ICT and R&D that vary across countries and over time. We have plotted the average TFP growth corresponding to each quintile of the distribution of ICT or R&D for the 32 industries.

The highest rate of annual TFP growth occurs around the middle of the distribution of ICT intensity. But higher rates of TFP growth are found at both extremes of the distribution of ICT investment per hour worked than at the second and fourth quintile. At the lower tail of the distribution of ICT intensity, TFP growth declines as more is spent on ICT per hour worked, but at the high end of the distribution, TFP growth is positively related to ICT intensity. In contrast, there seems to be a more or less monotonically increasing link between R&D intensity and TFP growth. Interestingly, however, the returns to R&D seem to jump between the fourth and fifth quintile, indicating an excess return for the most research-intensive countries or in the periods where R&D intensity was highest.

In Figure II.3.5, we compare the intensities of ICT (in panel a) and R&D (in panel b) across the deciles of the distribution of TFP growth where the intensities are compared to the mean intensities in the respective industries over the nine countries and 20 years<sup>20</sup>. There is no clear pattern for ICT, except that industry observations that correspond to above median TFP growth figures show above-average ICT investments per hour worked. On the R&D front, however, we observe once again markedly higher-than-average R&D intensities when TFP growth is high, and a slightly higher R&D intensity in the first decile compared to the next five deciles. This phenomenon could be explained by the presence of adjustment costs or lags between the time the R&D investments are made and when the benefits of those investments are earned. Or it could be, although this hypothesis seems less plausible, that R&D has a low rate of return in a particular country.

In Figure II.3.6, we examine any evidence of complementarity between R&D and ICT at the meso-level. We compare TFP growth when ICT intensity is both below and above the median, conditional on R&D intensity being below or above the median value of its distribution per industry. We have noticed that, when R&D

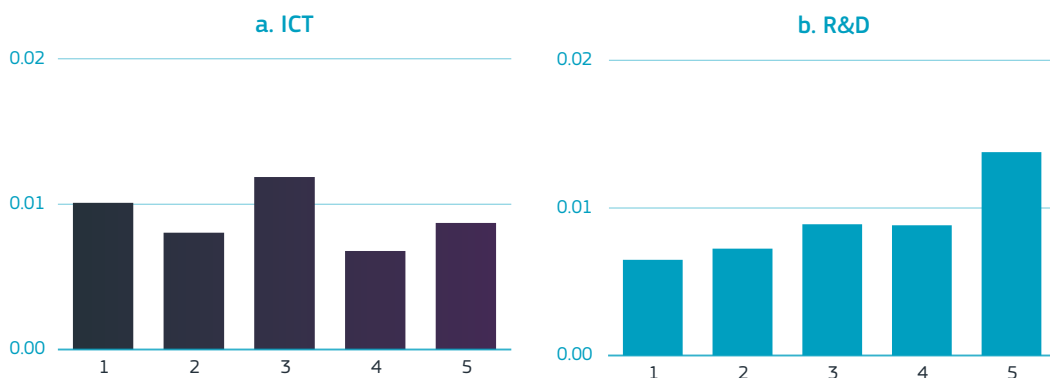
per hour worked is low, TFP growth is higher when more than the median is invested in ICT. However, when R&D is high, TFP growth is lower when more than the median is invested in R&D. Therefore, on the data from the whole sample, it cannot be concluded that R&D and ICT are complements. If that was the case, we would have observed an even higher increase in TFP growth when R&D and ICT are high than when ICT is high and R&D is low. One explanation could be that both contribute to productivity growth but do not complement each other, ICT being devoted more to production, logistics and marketing than to R&D activities. It could also be that the complementarity would show up in more direct measures of research output, such as innovations, patents or publications and only appear much later in the productivity figures.

Nevertheless, there seems to be heterogeneity across industries in this respect. If we do the same computation of double differences for each of the 32 sectors individually, we see apparent signs of complementarity for 17 of them, as shown in Figure II.3.7. Of course, this kind of descriptive analysis does not indicate whether these differences in TFP growth are significantly different from zero.

<sup>20</sup> Observations with missing values for TFP growth or R&D and ICT investment are deleted.



**Figure II.3.4** TFP growth by quintiles of ICT and R&D intensity - EU KLEMS data, 32 industries, 9 countries, 1995-2014



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Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

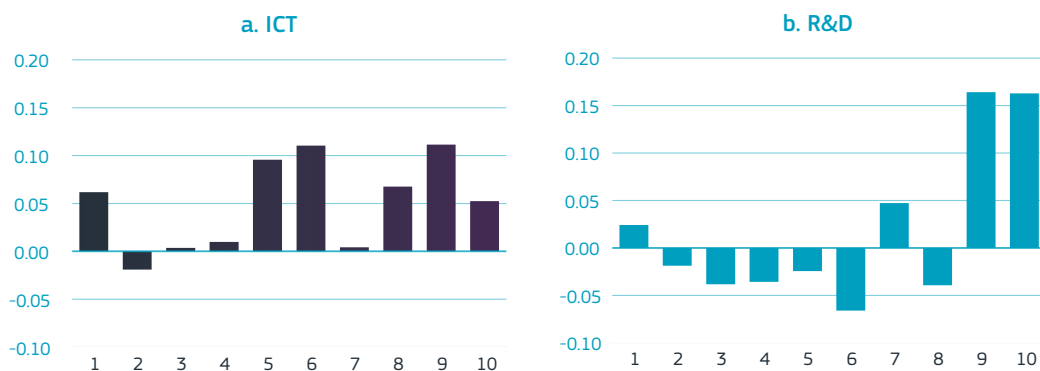
Data: EU KLEMS Growth and Productivity Accounts 2017 Release, see Jäger (2017).

Reference: Jäger, K. (2017), EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module, The Conference Board.

[http://www.euklems.net/TCB/2017/Methodology\\_EU%20KLEMS\\_2017.pdf](http://www.euklems.net/TCB/2017/Methodology_EU%20KLEMS_2017.pdf)

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**Figure II.3.5** ICT and R&D intensity by decile of TFP growth - EU KLEMS data, 32 industries, 9 countries, 1995-2014



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Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

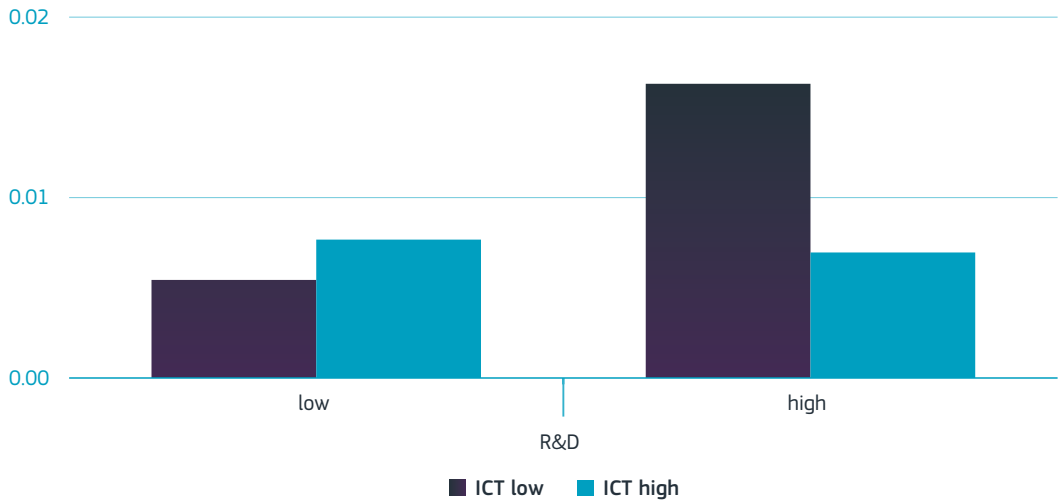
Data: EU KLEMS Growth and Productivity Accounts 2017 Release, see Jäger (2017).

Reference: Jäger, K. (2017), EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module, The Conference Board.

[http://www.euklems.net/TCB/2017/Methodology\\_EU%20KLEMS\\_2017.pdf](http://www.euklems.net/TCB/2017/Methodology_EU%20KLEMS_2017.pdf)

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**Figure II.3.6** Growth of TFP by joint intensity of ICT and R&D - EU KLEMS data, 32 industries, 9 countries, 1995-2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EU KLEMS Growth and Productivity Accounts 2017 Release, see Jäger (2017).

Reference: Jäger, K. (2017), EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module, The Conference Board.

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**Figure II.3.7** Complementarity across industry - EU KLEMS data, 31 industries, 9 countries, 1995-2014<sup>1,2</sup>



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EU KLEMS Growth and Productivity Accounts 2017 Release, see Jäger (2017).

Reference: Jäger, K. (2017), EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module, The Conference Board.

[http://www.euklems.net/TCB/2017/Methodology\\_EU%20KLEMS\\_2017.pdf](http://www.euklems.net/TCB/2017/Methodology_EU%20KLEMS_2017.pdf)

Notes: <sup>1</sup>Each bar represents the double difference in TFP growth, between above and below median ICT intensities, for below and for above median R&D intensities (as in Figure II.3.6). <sup>2</sup>Coke and refined petroleum products was dropped from Figure II.3.7 as the magnitude was not comparable to other industries.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii\\_3\\_7.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii_3_7.xlsx)

**Figure II.3.8** Labour productivity, system GMM, EU KLEMS industry data, 9 countries, 1995-2014<sup>1,2</sup>

Dependent variable: labour productivity	coefficient	t-statistic
N = 4509		
Labour productivity (lagged)	0.911 ***	214.62
Employment	-0.016	-0.73
Capital intensity		
ICT	0.044 ***	7.03
Tangible non-ICT	0.379 ***	13.37
Software and databases	0.091 ***	6.73
R&D	-0.003	-0.46
Interactions of capital intensities		
ICT and tangible non-ICT	-0.007 ***	-3.35
ICT and software/databases	0.008 ***	4.67
ICT and R&D	-0.001	-0.92
Tangible non-ICT and software/databases	0.009 ***	6.44
Tangible non-ICT and R&D	0.000	0.10
Software databases and R&D	0.000	0.05
Trend	-0.001 ***	-4.18

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EU KLEMS Growth and Productivity Accounts 2017 Release, see Jäger (2017).

Reference: Jäger, K. (2017), EU KLEMS Growth and Productivity Accounts 2017 Release, Statistical Module, The Conference Board.

[http://www.euklems.net/TCB/2017/Methodology\\_EU%20KLEMS\\_2017.pdf](http://www.euklems.net/TCB/2017/Methodology_EU%20KLEMS_2017.pdf)

Notes: <sup>1</sup>All variables are in logs. Labour productivity is real value added over hours worked. The capital intensities are in terms of hours worked. The instruments used are two and more lagged inputs in the first difference equation and one lagged growth rate in the level equation. Estimation includes time and country dummies. <sup>2</sup>\*\*\* = significant at 1% level of confidence.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_3/figure\\_ii\\_3\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_3/figure_ii_3_8.xlsx)

Finally, we have estimated a labour productivity equation with productivity persistence, derived from a Cobb-Douglas production function, allowing for returns to scale and letting the various capital stocks interact with each other. The estimation was performed using the generalised method of moments estimator known as the GMM system. This is a fairly unrestricted specification and an estimation method that tackles problems of endogeneity typical in this kind of model. Under pairwise complementarity, the interaction terms should have a positive and significant coefficient. Software and databases have been taken out of the composite ICT capital stock to form a separate capital stock. There is high persistence in labour productivity (shown by the positive and significant coefficient of lagged labour productivity), and constant returns to scale cannot be rejected

(as the coefficient for employment, which captures the deviation of the sum of capital and labour output elasticities from one is not significant). Software and databases, tangible ICT and non-ICT capital are positively correlated to labour productivity, but in this dataset the stock of accumulated R&D does not appear to be significant, contrary to most studies on the topic. This could be due to double-counting if R&D labour and the various capital inputs devoted to R&D are not subtracted from the conventional inputs (Schankerman, 1981). Tangible ICT and non-ICT capital appear to be substitutes, whereas tangible ICT capital and software and databases are complements, as expected. Non-ICT capital as well as software and databases also appear to be complements, although between R&D and hardware or software ICT there is no sign of complementarity.

## Conclusion

The aim of this chapter was to test whether there is any complementarity between investments in R&D and investments in ICT, in the sense that investing in one increases the return on investing in the other. The returns were measured by TFP growth. The analysis was conducted from various angles: using micro data from the Netherlands and industry data from nine European countries, examining the TFP growth performance across the joint distribution of the two types of investment, looking for complementarity at both the extensive and intensive margin, and estimating production functions sufficiently flexibly to capture the returns from joint investments.

There is only weak evidence of complementarity along the different approaches to the problem. It is only by looking at the differ-

ences in productivity growth for high and low intensities of R&D and ICT at the firm level that some weak signs of complementarity are evident. This evidence is not confirmed in a regression analysis either on firm or on industry data. However, there appears to be a lot of heterogeneity across industries with respect to the magnitude of complementarity, with some evidence of it for about half of our industries. Furthermore, the visual evidence should be confirmed by a more extensive multivariate analysis, which would also control for other confounders of productivity growth and would test whether statistically speaking the observed differences in TFP growth across the joint densities of R&D and ICT investments are significantly different from zero. To do this kind of analysis, more data would be needed at both the firm and industry level.

It is also possible that we would observe more complementarity between the two investments if we considered other measures of performance, such as publications, patent counts, co-publications and co-patenting, scientific discoveries and so on – i.e. innovation output measures rather than measures of economic performance. As mentioned in the introduction, various studies have found evidence of complementarity in terms of innovation output. It is hard to believe that all the progress in ICT over the last 50 years (computers, software, internet, cloud computing, skype, teleconference and so on) has had no effect on the productivity of scientific research. It has changed the way research is organised and enlarged the researchers' toolbox. All this may lead to a better research outcome and yet be hardly visible or even invisible in the productivity statistics. There are various reasons for that. First, as it opens up the realm of research opportunities, ICT may also increase the costs of doing research. Firms need to buy the appropriate equipment, continuously update their software, train their workers to use the ICT equipment and reorganise their way of operating in an ICT-dominated environment. Second, even if more knowledge is created thanks to progress in ICT, it may take time for that knowledge to be converted into new products or processes, and even more time and effort to bring the new products successfully to market. Third, the new ways of communicating, gathering and storing information may create their own hurdles in terms of learning, reorganisation of work and too much information. Finally, while the adoption of ICTs, such as PCs and the internet, may have significantly boosted the effectiveness and speed of R&D, as their usage has become ubiquitous across firms and industries, it may become more challenging to identify such a positive effect from cross-sectional information or panel data covering only a short and recent period.

However, there seems to be a positive correlation between R&D, respectively ICT, and productivity growth. Although the relationship is non-linear, firms or industries that invest more in R&D or ICT experience higher productivity growth. Normally, companies are aware of this positive correlation and invest accordingly. It may be that there are market failures which prevent firms from investing as much as they would like to. This is where policymakers can intervene to overcome these market failures and enable those investments to occur which are beneficial to individual firms and society as a whole. Examples of such market failures include lack of access to finance, too little or too much competition, and overzealous employment protection legislation.

In the absence of complementarity between R&D and ICT investments, a stimulating measure in favour of R&D, such as a grant or tax incentive, will not automatically increase the return on an investment in ICT, and vice versa. Since, as our analysis has shown and many previous studies have concluded, both R&D and ICT eventually increase TFP growth, it is still beneficial to invest in them, although from a policy perspective it is not possible, so to say, to kill two birds with one stone. Each has to be stimulated separately without relying on the possibility that they may reinforce one another.

Lacking any evidence on complementarity between ICT and R&D, a policy goal could be to stimulate such mutually reinforcing benefits. There may be various ways to achieve this. One would be to increase the research in ICT to push the limit of what can be achieved with this technology even further. a second one would be to allow this technology to reach its full potential by making science and innovation more open, and sharing the knowledge instead of hiding it in order to exploit a temporary knowledge-based monopoly.

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# CHAPTER

## 11.4

# MISSION-ORIENTED INNOVATION POLICY: CHALLENGES AND OPPORTUNITIES

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*“We need to define [innovation] missions that breakdown silos... We need to set our eyes on a specific target, and drive our scientific efforts towards reaching that target. And we need to be ambitious about it. As Mariana Mazzucato says: ‘Innovation-led growth is not just about fixing a market failure but also about setting direction and creating new markets. If you just tackle the market failure you can head into the wrong direction.’ So we need to set direction for the future, and having a clear mission is a way of doing that.”*

(Speech by Carlos Moedas, EC Commissioner for Research, Science and Innovation, Brussels 15 May 2017<sup>21</sup>)

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21 [https://ec.europa.eu/commission/commissioners/2014-2019/moedas/announcements/presentation-rise-group-publication-future-eu-research-and-innovation-policy-best-possible-future\\_en](https://ec.europa.eu/commission/commissioners/2014-2019/moedas/announcements/presentation-rise-group-publication-future-eu-research-and-innovation-policy-best-possible-future_en)

## 1. Introduction

Countries around the world are seeking to achieve economic growth that is smart (innovation-led), inclusive and sustainable. Such ambitious goals require re-thinking the role of government and public policy in the economy. In particular, it requires a new justification of government intervention that goes beyond the usual one of simply fixing market failures. It also requires a new way to assess intervention so that dynamic system-wide spillovers are better captured.

This ambition to achieve a particular type of economic growth (smart, inclusive, sustainable) is a direct admission that economic growth has not only a **rate but also a direction**. In this context, industrial and innovation strategies can be key pillars to achieving transformational change – in particular, identifying and articulating new *missions* that can galvanise production, distribution and consumption patterns across various sectors. Addressing such challenges – whether travelling to the moon, battling climate change or tackling modern care problems – requires investments by both private and public actors. The role of the public sector here is not just about de-risking, and levelling the playing field, but tilting the playing field in the direction of the desired goals. This includes making strategic decisions on the kind of finance that is needed, the types of innovative firms that will need extra support, the types of collaboration with other actors (in the third and private sector), and the types of regulations and taxes that can reward the desired behaviour. While public funding has always been important in the early, capital-intensive high-risk areas that the private sector tends to shy away from, modern-day missions can provide an even more fervent ground for an ambitious catalytic role for government in

*creating and shaping markets* which provide the basis for private investment. Animal spirits are created not assumed.

### **From sectors to cross-sectoral solutions to concrete problems.**

Mission-oriented thinking requires understanding the difference between: (1) narrow sectors; (2) missions; and (3) broad challenges. a challenge is a broadly defined area which a nation may decide is a priority (whether through political leadership or the outcome of a movement in civil society). These may include areas like inequality, climate change or an ageing population. Missions involve tackling specific problems, such as reducing carbon emissions by x% over a specific period. Missions should be able to activate innovation across different sectors. For example, going to the moon required many different high-tech sectors (e.g. aerospace) and low-tech sectors (e.g. textiles) – and the process involved over 50 homework problems concerning different types of partnerships. Similarly, in Germany today, the *Energiewende* policy is a concrete mission with a specific reduction in carbon emissions over a specific period of time, aimed at tackling a broadly defined challenge (fighting climate change), which has required many different sectors to transform themselves. For example, steel in Germany has lowered its material content through repurpose, reuse and recycle strategies. While the man-on-the-moon mission was decided top down via political leadership, the German *Energiewende* policy was the fruit of bottom-up green movements, which culminated in political understanding and eventually leadership from above. Missions may require consensus building in civil society, and the need to set directions from above, with bottom-up experimentation processes from below.

## 1.1. Innovation at the centre of economic growth

As industrial policy is returning in many countries (e.g. after years of industrial policy being neglected, the UK's Prime Minister, Teresa May, formed a new department around it in 2016), a mission-based approach can help to ensure that industrial policy does not just end up being a static list of sectors to support. Rather, mission-oriented policies focus on creating system-wide transformation across many different sectors. The Apollo mission to the moon required high-tech and low-tech sectors to work together – and while the mission itself was top down, it was the bottom-up experimentation around many different ‘homework problems’ that galvanised the ensuing growth. In the same way, missions around sustainability and green growth will require many different sectors to rethink themselves and to work together in dynamic and interconnected ways. Among other things, this can lead to more ‘additionality’ in business investment, helping companies in different sectors to rethink themselves and make investments that would otherwise have not been made – which is extremely important in countries suffering from low business investment.

A *mission-oriented* approach means developing, implementing and monitoring a strategic innovation policy programme that draws on the strengths of an innovation system to overcome a country's weaknesses and address its challenges, seizing the opportunities offered by current capabilities and resources but especially the transformation of new capabilities and competencies. It requires putting innovation at the heart of economic growth policy – rendering the conversation between departments of finance and departments of innovation (or development) more horizontal and equitable, without the ‘growth plans’ (often driven by an assumed need to cut the deficit) to counteract the long-run innovation plans.

In this sense, it also means challenging economic policies that focus too much on short-term fiscal restraints, potentially damaging long-run growth opportunities. Investments in industrial transformation, R&D, human capital training and innovation take time. They involve high risks as there is no guarantee that the investment will pay off. But they are worth the wait as they are the key source of *productivity-enhancing*, creating well-paid jobs, with a higher multiplier effect than other types of governmental expenditure. Such investments can therefore help rebalance the public budget in the longer term by increasing future revenues. Thus, while the deficit might increase in the short term, the long-term debt/GDP is likely to fall. Such dynamic effects are often neglected in fiscal adjustment programmes.

Crucial to the implementation of a mission-oriented approach to innovation policy is the need to revitalise and reinvigorate capacity-building, competencies and expertise within the state (the ‘*developmental and networked*’ *entrepreneurial state*, as referred to below). In this way, its different organisations can effectively fulfil their roles in coordinating and providing direction to private actors when formulating and implementing policies that address societal challenges through innovation (Mazzucato, 2016).

This scoping document outlines the challenges and opportunities of reviving industrial and innovation policies via a mission-oriented lens. It is meant to spark new thinking around the following specific areas:

- ▶ the possibilities of using **mission-oriented strategies** directed at solving concrete societal and/or technological challenges which catalyse innovation across a variety of sectors;
- ▶ the importance of a **systemic approach** to industrial and innovation strategies, and

the problems that can result when such an approach is lacking;

- ▶ the need to see industrial strategy as an **interaction between multiple actors** in both the public and private sectors;
- ▶ the need for public actors (decentralised networked entrepreneurial state state) to be positioned strategically along the **entire innovation curve** (e.g. not just upstream or

downstream), including bold *demand-side* policies;

- ▶ ways in which industrial strategy can be used to **direct a green-growth agenda**;
- ▶ the role **public investment banks** can play in providing **patient long-term strategic finance** to high-risk and capital-intensive projects, ushering in future business investment.

## 2. Grand challenges and ‘wicked problems’

The 21st century is becoming increasingly defined by the need to respond to major social, environmental and economic challenges. Sometimes referred to as ‘grand challenges’, these include environmental threats like climate change, demographic, health and well-being concerns, and the difficulties of generating sustainable and inclusive growth. The problems are ‘wicked’ in the sense that they are complex, systemic, interconnected and urgent, requiring insights to be addressed from many perspectives – including design thinking. Poverty cannot be solved without attention to the interconnections between nutrition, health, infrastructure and education. Grand challenge thinking is equally being tackled and thought about in developed and developing countries, with some of the most interesting experiments on sustainability being driven by the needs of emerging economies.

### 2.1 Mission-oriented innovation and grand challenges

This type of broad-based innovation policy has been called ‘mission-oriented’ for its aim to achieve specific objectives (Ergas, 1987; Freeman, 1996). It does not merely facilitate inno-

vation through levelling the playing field with horizontal policies that prescribe no direction. On the contrary, by definition, such policies give explicit technological and sectoral directions to achieve the ‘mission’. At the same time, to be successful they must enable bottom-up experimentation and learning (Rodrik, 2004).

Examples of such direction-setting policies abound, including different technology policy initiatives in the United States (Chiang, 1991; Mowery et al., 2010), France (Foray, 2003), the UK (Mowery et al., 2010) and Germany (Cantner and Pyka, 2001). These policies were implemented by mission-oriented agencies and policy programmes: military R&D programmes (Mowery, 2010); the National Institutes of Health (NIH) (Sampat, 2012); grand missions of agricultural innovation (Wright, 2012); and energy (Anadón, 2012). In such cases, it was the organisation that had to make choices on what to fund: tilting the playing field rather than ‘levelling it’ (Mazzucato and Perez, 2015). Thus the ‘picking a winner’ problem, which continues to dominate the industrial policy debate, is a static one that creates a false dichotomy: what is crucial is not whether choices must be made, but how ‘intelligently’ can the picking of ‘directions’ be performed.

While the literature has focused more on mission-oriented policies in developed countries, there are even more opportunities in developing countries due to the greater ‘challenges’ they face. Indeed, mission-oriented policies can be a way for the natural resource ‘curse’ to be approached as natural resources would no longer be seen as belonging to a sector, but rather as being part of a solution to a greater mission. What are the missions that innovation in precious metals can help address? What are the missions that innovation in biotech and agribusiness can address? How can a ‘green growth’ strategy help to address innovations in traditional sectors that must lower their material content?

A second problem (besides ignoring developing countries) is that the literature on mission-oriented policies has not integrated empirical insights to provide a fully-fledged theory that can replace the orthodox view of direction-less policy. Consequently, studies have resulted in *ad-hoc* theoretical understandings and policy advice on how to manage mission-oriented initiatives, without tackling the key justifications for mission-oriented policies that contrast those of simply fixing market failures. In a market failure framework, *ex-ante* analysis aims to estimate benefits and costs (including those associated with government failures) while *ex-post* analysis seeks to verify whether the estimates were correct and the market failure successfully addressed. Instead, a mission-oriented framework requires continuous and dynamic monitoring and evaluation throughout the innovation policy process. In its most general form, the mission-oriented framework differentiates between public policies that target the development of specific technologies in line with state-defined goals (‘missions’) and those aimed at the institutional development of an innovation system (Ergas, 1987; Cantner and Pyka, 2001). The state must therefore be able to learn from past experiences in mission-oriented innovation policy.

Systemic mission-oriented policies must be based on a sound and clear diagnosis and prognosis (foresight). This not only requires the identification of missing links, failures and bottlenecks – the weaknesses or challenges of a national system of innovation – but also recognition of the system’s strengths. Foresight is necessary in order to scrutinise future opportunities and identify how strengths may be used to overcome weaknesses. This diagnosis should be used to devise concrete strategies, new institutions and new linkages in the innovation system (Mazzucato, 2016). It may also be necessary to ‘tilt’ the playing field in the direction of the mission being pursued rather than ‘levelling’ it through such means as technologically neutral policies (Mazzucato and Perez, 2015).

In its most general form, the mission-oriented framework differentiates between public policies that target the development of specific technologies in line with state-defined goals (‘missions’) and those that aim at the institutional development of an innovation system (Ergas, 1987; Cantner and Pyka, 2001). This framework helps us to understand the greater breadth of activities that public spending fosters.

Mission-oriented policies can therefore be defined as systemic public policies that draw on frontier knowledge to attain specific goals or “big science deployed to meet big problems” (Ergas, 1987, p. 53). The archetypical historical mission is NASA’s putting a man on the moon. Contemporary missions aim to address broader challenges that require long-term commitment to the development of many technological solutions (Foray et al. 2012) and “a continuing high rate of technical change and a set of institutional changes” (Freeman, 1996, p. 34). The public sector’s current active role in tackling renewable energy investments can be seen as a new mission in relation to the green economy (Mazzucato and Penna, 2015b; Mazzucato and Semieniuk, 2017). Other new missions include addressing

such ‘grand societal challenges’ as the ageing/ demographic crisis, inequality, and youth unemployment (European Commission, 2011). In fact, these challenges – which can be environmental, demographic, economic or social – have entered innovation policy agendas as key justifications for action, providing strategic direction for funding policies and innovation efforts.

However, Foray et al. (2012) claimed that modern missions are more complex because there are fewer clear technological challenges and

outcomes are less clearly defined. Contemporary missions aim to address broader challenges that require long-term commitment to the development of many technological solutions *and* “a continuing high rate of technical change and a set of institutional changes” (Freeman, 1996, p. 34). One could add that these challenges also require changes at the societal/national systems level. The so-called Maastricht Memorandum (Soete and Arundel, 1993) provides a detailed analysis of the differences between old and new mission-oriented projects (Figure II.4.1):

**Figure II.4.1 Characteristics of old and new mission-oriented projects**

Old: Defence, nuclear, and aerospace	New: Environmental technologies and societal challenges
Diffusion of the results outside of the core of participants is of minor importance or actively discouraged.	Diffusion of the results is a central goal and is actively encouraged.
The mission is defined in terms of the number of technical achievements, with little regard to their economic feasibility.	The mission is defined in terms of economically feasible technical solutions to particular societal problems.
The goals and the direction of technological development are defined in advance by a small group of experts.	The direction of technical change is influenced by a wide range of actors including government, private firms and consumer groups.
Centralised control within a government administration.	Decentralised control with a large number of agents involved.
Participation is limited to a small group of firms due to the emphasis on a small number of radical technologies.	Emphasis on the development of both radical and incremental innovations in order to permit a large number of firms to participate.
Self-contained projects with little need for complementary policies and scant attention paid to coherence.	Complementary policies vital for success and close attention paid to coherence with other goals.

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Slightly modified version of table 5 in Soete and Arundel (1993, p. 51).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_4/part\\_ii\\_4\\_mariana\\_mazzucato\\_figure\\_ii\\_4\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_4/part_ii_4_mariana_mazzucato_figure_ii_4_1.xlsx)



Although the Memorandum specifically focuses on mission-oriented programmes that tackle environmental challenges, its analysis applies to other contemporary challenges (water and food supply, energy efficiency and security, disease, well-being, demographic change, etc.). This is because all challenges present similar characteristics, particularly the fact that new technological solutions to address them will need to replace incumbent technologies and therefore require long-term commitments from both public and private agents – i.e. the diffusion of solutions to a broad base of users is key.

One of the most pressing contemporary challenges is the need for *inclusion* of vast portions of the population (and of entire regions) in the innovation process and the socio-economic system as a whole, to tackle the issue of inequality<sup>22</sup>. Therefore, missions should, where feasible, be designed in a way that contributes to tackling inequality. Some will do this directly, others indirectly. In some cases, complementary investment in infrastructure and skills will be required if innovation policies are to be effective in addressing inequality. A mission-oriented policy agenda would increase the effectiveness of innovation policy while also having the potential to help rebalance public finances. This is not done by cutting expenditures – as in the prevailing austerity agenda (which often affects the most vulnerable parts of the population) – but by increasing strategic investments which, due to the higher multiplier effect, would increase future revenues.

The six characteristics of contemporary missions identified in Figure 11.4.1 – diffusion of technologies, economic feasibility, shared sense of direction, decentralised control by (strategic public) agencies, development of both radical and incremental innovations, and enabling complementary policies –

are of pragmatic importance for the promotion and implementation of mission-oriented policies.

A mission-oriented approach highlights the need to make a precise diagnosis of the technological, sectoral or national system of innovation that innovation policy wishes to transform. The alignment of different types of capabilities is key for the success of any mission-oriented policy programme. These can be described, as in Mazzucato and Penna (2016a), as:

- ▶ **Missions should be well defined and not overly abstract.** More granular definition of the technological challenge facilitates the establishment of intermediate goals and deliverables, and processes of monitoring and accountability. When governance is too broad, it can become faulty, and there is a risk of it being captured by vested interests.
- ▶ **A mission does not comprise a single R&D or innovation project, but a portfolio of such projects.** Because R&D and innovation are highly uncertain, some projects will fail while others will succeed. All concerned should be able to accept failures and to use them as learning experiences. Furthermore, stakeholders should not be punished because of failures derived from efforts made in good faith.
- ▶ **Missions should result in a trickle-down effect,** whereby the priorities are translated into concrete policy actions and instruments to be carried out at all levels of the public institutions involved. While these missions should involve a range of public institutions, it is crucial that there is a strategic division of labour amongst them, with well-defined responsibilities for coordination and monitoring.

<sup>22</sup> A recent and flourishing body of literature has explored the connections between innovation and systems of innovation and social inclusion. Issues of social development are being studied and targeted in policy action under the heading 'social innovation'. Other recent correlated terms are 'innovation for the bottom of the pyramid' and 'pro-poor innovations'. With respect to sustainability, a minority of contributions seek to expand the concept of sustainability to a social dimension (Cozzens and Kaplinsky, 2009; Soares et al., 2014).

These considerations point to the need to adopt a pragmatic approach to defining missions. Missions chosen should reflect best practice, be feasible, draw on existing public and private resources, be amenable to existing policy instruments, and command broad and continuous political support. They should create a long-term public agenda for innovation policies, address a societal demand or need, and draw on the high potential of the country's science and technology system to develop innovations.

## 2.2 From directed policy to bottom-up experimentation across sectors

*"The design of a good policy is, to a considerable extent, the design of an organizational structure capable of learning and of adjusting behavior in response to what is learned."*

Richard Nelson and Sydney Winter, 1982

*"... shift from total confidence in the existence of a fundamental solution for social and economic problems to a more questioning, pragmatic attitude – from ideological certainty to more open-ended, eclectic, skeptical inquiry."*

Albert Hirschman, 1987

To a certain extent, providing a straightforward list of missions for a country contradicts the core element in successful mission-oriented programmes. Missions should be determined through a fine-tuned diagnosis of the problem and solution that involves stakeholders and draws on the strengths of the country's system of innovation and considers ways to overcome its weaknesses. Who decides the mission is a key issue that requires more thought. While

in the case of the moonshot mission, it was to a large extent a top-down mission led by President Kennedy, the effects of the mission – many of which are in our 'smart' products today – occurred through the bottom-up interaction between different types of organisations that took part in the challenge. Ironically, the modern-day obsession with commercialisation strategies has led to less commercialisation results than those policies that obsessed less with the result and more with the process. In this sense, mission-oriented thinking can learn from Hirschman's emphasis on 'policy as process' and the need to welcome serendipity and uncertainty – what he called the "hiding hand" (Hirschman, 1967).

The nature of bottom-up experimentation is a key industrial strategy requiring both horizontal and vertical policies, working together systemically. Traditionally, industrial strategy often focuses on (vertical) sectoral interventions. Until the end of the 1970s, this consisted of various measures ranging from indicative planning to the outright nationalisation of entire industries (e.g. steel, coal, shipbuilding, aerospace and so on).

Although certain sectors might be more suited to sector-specific strategies, there are good reasons for avoiding a sectoral approach, particularly when it is easily captured by specific interests. Not least, private lobbying interests may prevail in negotiating specific provisions with the government<sup>23</sup>, negatively influencing the industrial strategy with short-sighted indirect measures (e.g. tax credits) with the potential to waste public funds and create little or no additionality in terms of new investment. The patent box tax incentive (see note) repre-

23 Buchanan, J. M. (2003). "Public Choice: The Origins and Development of a Research Program", *Champions of Freedom*, vol. 31, pp. 13-22.

sents a typical example of these misconceived policies<sup>24</sup> since there is no reason to lower tax on monopoly profits. In countries where business investment in R&D (BERD) continues to be below the OECD average, sectoral policies risk allowing the private sector to continue to ask for subsidies or support, rather than to fundamentally transform.

*The case for building a modern industrial strategy on the identification of challenges, rather than sectors, is compelling and becoming increasingly recognised.* a mission-oriented approach uses specific challenges to stimulate innovation across sectors. Through well-defined missions – focused on solving important societal challenges related to climate change and environmental quality, demographic changes, health and well-being, mobility issues, etc. – the government has the opportunity to determine the direction of growth by making strategic investments throughout the innovation chain and creating the potential for greater spillovers across multiple sectors, including lower-tech ones<sup>25</sup>.

Interestingly, one of the most well-known missions in the history of capitalism – the Apollo man on the moon mission – sparked innovation across multiple high-tech and low-tech sectors, including textiles.

Germany's *Energiewende* programme for energy transition constitutes a model of how to implement an integrated strategy that addresses several sectors and technologies in the economy and enables bottom-up learning processes. With its missions to fight climate change, phasing-out nuclear power, improving energy security by substituting imported fossil fuel with renewable sources, and increasing energy efficiency, *Energiewende* is providing a direction to technical change and growth across different sectors through targeted transformations in production, distribution and consumption. This has allowed even a traditional sector like steel to use the 'green' direction to renew itself. Indeed, German innovation policy has placed pressure on steel to lower its material content through the use of a 'reuse, recycle and repurpose' strategy<sup>26</sup>.

24 Griffith, R., Miller, H. and O'Connell, M. (2010). "Corporate Taxes and Intellectual Property: Simulating the Effect of Patent Boxes", IFS Briefing Note 112, Institute for Fiscal Studies.

25 Foray, D., D. Mowery, and R. R. Nelson (2012). "Public R&D and Social Challenges: What Lessons from Mission R&D Programs?", *Research Policy*, 41: 1697-1702. Mowery, D. C., R. R. Nelson, and B. R. Martin. (2010). "Technology Policy and Global Warming: Why New Policy Models are Needed (Or Why Putting New Wine in Old Bottles Won't Work)", *Research Policy*, 39: 1011-1023.

26 BMUB (2016). "German Resource Efficiency Programme II"; available at: [http://www.bmub.bund.de/fileadmin/Daten\\_BMU/Pool/Broschueren/german\\_resource\\_efficiency\\_programme\\_ii\\_bf.pdf](http://www.bmub.bund.de/fileadmin/Daten_BMU/Pool/Broschueren/german_resource_efficiency_programme_ii_bf.pdf)  
Green Alliance (2015), "Circular Economy Scotland"; available at: <http://www.green-alliance.org.uk/resources/Circular%20economy%20Scotland.pdf>

### 3. Making and shaping markets not just fixing them

Understanding the dynamic nature of innovation systems and the key role that public agencies have in providing a lead engine, is hard to justify through market failure theory. The idea that the state is at best a fixer of markets has its roots in neoclassical economic theory, which sees competitive markets as bringing about optimal outcomes if left to themselves. This theory justifies government ‘intervention’ in the economy only if there are explicit *market failures*, which might arise from the presence of positive externalities (e.g. public goods like basic research, which require public-sector spending on science), negative externalities (e.g. pollution, which require public-sector taxation) and incomplete information (where the public sector may provide incubators or loan guarantees)<sup>27</sup>. In addition, the literature on systems of innovation has also highlighted the presence of system failures – for example, the lack of linkages between science and industry – requiring the creation of new institutions enabling those linkages (Lundvall, 1992).

And yet the recent history of capitalism tells a different story – one in which different types of public actors have been responsible for actively shaping and creating markets and systems, not just fixing them; and for creating wealth, not just redistributing it. Indeed, markets themselves are the outcome of interactions between both public and private actors, as well as actors from the third sector and from civil society. In this context, mission-oriented innovation policy is about the creation of new markets, not fixing old ones – and yet this framework has not debunked the market fixing policy framework. Indeed, even the systems of innovation literature (Lundvall, 1992) has not

fully divorced itself from a ‘fixing’ perspective, as the way it is often interpreted is in terms of fixing system failures (e.g. formulating the missing links between science and industry).

#### 3.1 Systems of innovation

*“The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies”*

Chris Freeman, 1987

*“... the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state.”*

Bengt-Ake Lundvall, 1992; p.12

Innovation policy is not just about funding R&D but creating systems which allow new knowledge to be diffused across an economy and create transformative change, including increases in productivity (Freeman, 1987; Lundvall 1992). A *narrow* perspective on systems of innovation can be differentiated from a *broad* perspective (Cassiolato, 2015): the *narrow* perspective is focused on the science and technology subsystem (which includes capacity-building, training and formal education, plus science- and technology-related services) and its relationship with the production and innovation subsystem (where firms mainly operate). The *broad* perspective includes other subsystems and contexts: for example, the subsystems of policy, promotion, representation and financing; demand (market segments); and the (geo)political and socio-economic context.

<sup>27</sup> Reviews of the impact of positive externalities and incomplete information on innovation financing are provided in Hall (2002), Hall and Lerner (2009) and more recent evidence is reviewed in Kerr and Nanda (2014). Government’s role in the face of negative externalities (climate change) is laid out in Jaffe et al., (2005).

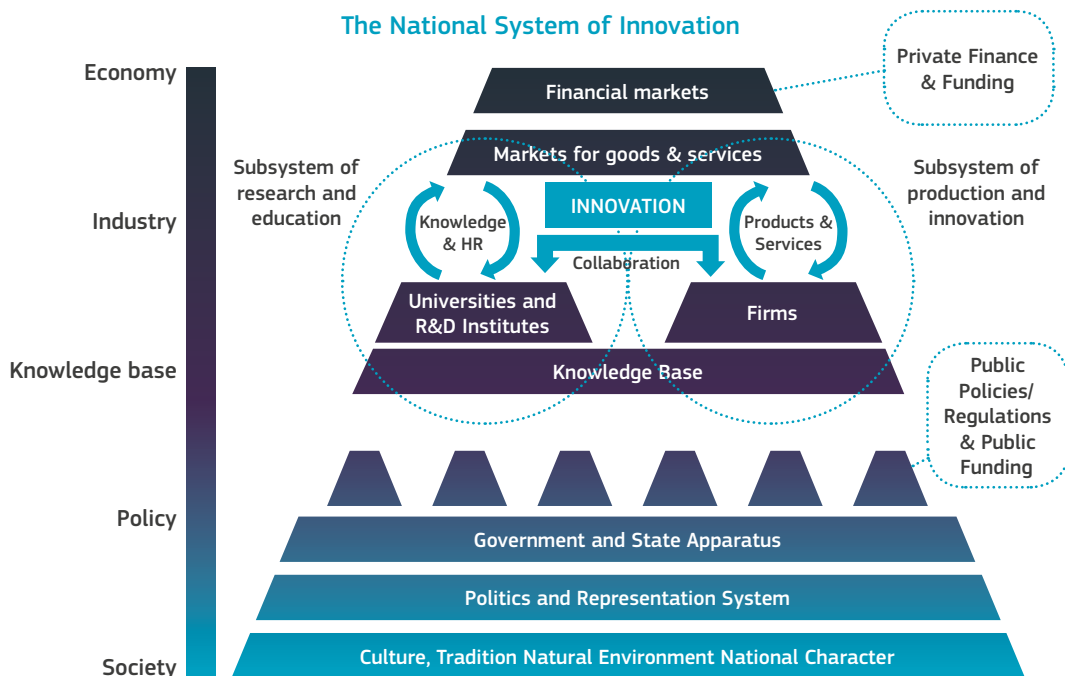
Figure II.4.2 depicts a generic national system of innovation. Each level sustains and influences the other. Although the depiction implies a linear hierarchical relationship, in reality, there are mutual causations and flat hierarchies. Thus, there is no uni-directional causality, for example, from policies or science to market strategies and innovation. Nor is there an implication that any layer or subsystem is more important than another.

At the basis of a national innovation system is the socio-economic, political, cultural and environmental context. The next layer up is the government and state apparatus, which is responsible for public policymaking and funding. This is the subsystem of public policies/regulations and public funding. Two other subsystems include

production and innovation, which is populated mainly by business firms and their R&D labs, and the research and education subsystem, which includes research and technology institutions (including universities and public R&D labs, as well as other education organisations).

These two subsystems operate on a broad knowledge base and may collaborate with each other. Firms in the innovation and production subsystem engage in market exchanges selling/buying goods and services to/from consumers/suppliers. Universities and research institutes engage in market exchanges for knowledge and human resources. Both subsystems may also draw on financial markets for funding and investments.

**Figure II.4.2** Representation of a national system of innovation



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Source: Authors' construction based on diagram prepared by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT, 2002)

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### 3.2 Nature of actors and of interactions

*Systems* and eco-systems of innovation (sectoral, regional and national) require dynamic links between the different *actors* and institutions (firms, financial institutions, research/education, public-sector funds, intermediary institutions) as well as horizontal links *within* organisations and institutions (Freeman, 1995). What must also be emphasised, and has not been in the literature on systems of innovation, is the nature of the actual actors and institutions required for innovation-led growth (Mazzucato, 2016a/b).

To stimulate the innovation process by shaping and creating technologies, sectors and markets, dynamic relationships must be developed which create trust between actors. It is essential in this process for the lead public organisation to galvanise the interests of relevant actors and organise itself so that it has the ‘intelligence’ to think big and formulate bold policies that create a sense of ownership among diverse public, private and academic stakeholders. It is also crucial to be able to implement the policies by coordinating the efforts of this network of stakeholders through the state’s convening power, the brokering of trust relationships, and the use of targeted policy instruments.

Because innovation is extremely uncertain, the ability to experiment and explore is key for a successful entrepreneurial state (Hirschman, 1967; Rodrik, 2004; Mazzucato, 2013). Therefore, a crucial element in organising the state for its entrepreneurial role is *absorptive capacity* (Cohen and Levinthal, 1990) or *institutional learning* (Johnson, 1992). Governmental agencies learn through a process of investment, discovery, and experimentation that is part of mission-oriented initiatives.

Other authors have referred to this experimentation and learning process as ‘smart specialisation’ (Foray et al., 2009). However, smart specialisation is used in connection with a market failure framework, so that it is seen as a discovery process for identifying bottlenecks, failures and missing links (that is, market failures or market gaps). Smart specialisation has not been employed in connection with a systemic perspective on innovation policies.

Key to mission-oriented innovation is exploration of the characteristics of innovation agencies which must be in place so that they can welcome uncertainty and build explorative capacity. Breznitz and Ornston (2013) focus on the role of peripheral agencies, arguing that when they become too central and better funded they lose their flexibility and ability for out-of-the-box thinking. While flexibility is no doubt important, it is also true that some of the most important innovation agencies in Europe and the United States have not been so peripheral, as can be seen by DARPA’s continued success in recent years. What seems to be even more important for these organisations is their degree of political independence. Indeed, Italy’s public holding company IRI (the Istituto per la Ricostruzione Industriale established in 1933) had its most successful phase before the 1970s when it was public and independent of political interference. It later became problematic when political parties got involved in its decision-making, and even worse, when it became privatised. The key lesson is that it is not about public or private but what kind of public and what kind of private.

It is also central to consider how market-shaping activities can be evaluated outside of a market failure framework to better capture the dynamic spillovers that occur with market shaping and creating policies, a topic we will return to later.

## 4. A developmental networked entrepreneurial state

In 'The State of Innovation', Block and Keller (2011) build the notion of a developmental network state by studying the host of different public organisations that have led to radical innovations (in various sectors, including pharma and IT), often associated with private sector entrepreneurship. The work is essential for understanding the active role of public institutions in directing innovation policy, not through top-down rigid planning, but through a decentralised interaction between different agencies across the entire innovation chain, which have been at the centre of United States competitiveness. It is precisely this competitiveness that is under threat today due to the United States government's cuts to those very agencies.

In 'The Entrepreneurial State' (Mazzucato, 2013), these lessons are used to reflect on more general principles, building a market-making/-shaping view of policy that goes beyond market fixing. Four key points are emphasised. They focus on the lead investment role of public agencies, taking on extreme risk in the face of uncertainty, which then generates animal spirits and investment in the private sector. These require different types of evaluation techniques to capture the crowd-in process. The key principles include:

- ▶ Investment along the entire innovation, including demand-side, policies
- ▶ Decentralised nature of public mission-oriented organisations (not top down)

- ▶ Risk-taking and investment not only during the downside of the business cycle
- ▶ Patient long-term strategic finance
- ▶ Considering a more equitable distribution on risk and rewards.

These are briefly reviewed below.

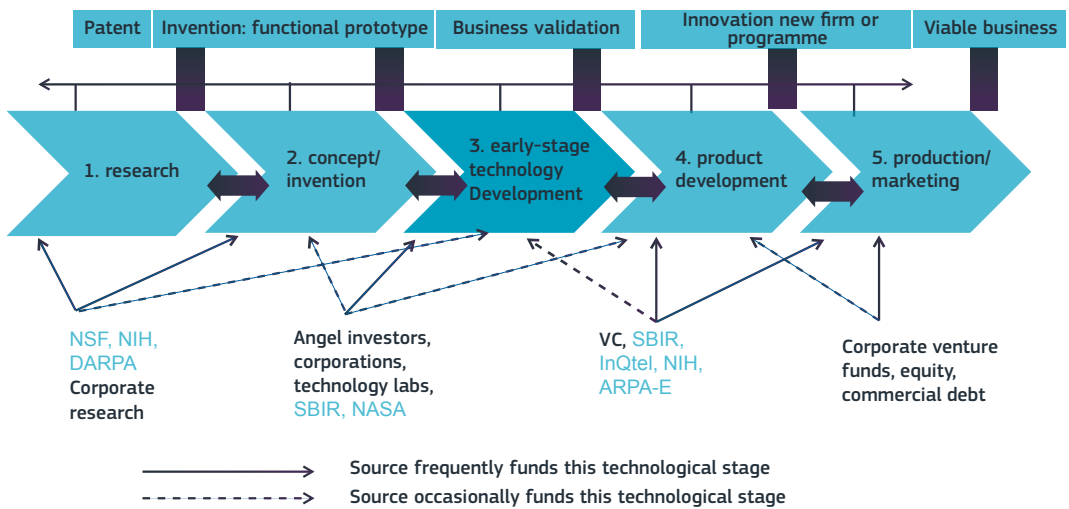
### 4.1 Investment along the entire innovation chain

Market failure theory justifies intervention when there are clear market failures, such as when there are positive externalities generated from 'public goods' like basic research. Yet while technological revolutions have always required publicly funded science, what is often ignored by the market-failure framework are the complementary public funds that were spent by a network of different institutions further on in the innovation process as well. In other words, the public sector has been crucial for both basic and applied research, and for providing early-stage high-risk finance to innovative companies willing to invest. It was also important for the direct creation of markets through procurement policy (Edler and Georghiou, 2007) and bold demand policies that have allowed new technologies to be diffused (Perez, 2013). Thus, Perez argues that without the policies for suburbanisation, mass production would not have had the effect it did across the economy.

Figure II.4.3 indicates (at the bottom) some of the key public agencies in the United States innovation landscape, including National Institutes of Health (NIH), NASA, DARPA, Small Business Innovation Research (SBIR) scheme, which historically has provided more early-stage high-risk finance to small and medium-sized companies than private venture capital (Keller and Block, 2012), as Figure 4 shows. And guaranteed government loans are regularly used to pump prime companies, such as the US\$ 465-million guaranteed government (DoE) loan received by Tesla to produce the ‘Tesla S’ car.

Downstream investments included the use of procurement policy to help create markets for small companies, through the public Small Business Innovation Research (SBIR) scheme, which historically has provided more early-stage high-risk finance to small and medium-sized companies than private venture capital (Keller and Block, 2012), as Figure 4 shows. And guaranteed government loans are regularly used to pump prime companies, such as the US\$ 465-million guaranteed government (DoE) loan received by Tesla to produce the ‘Tesla S’ car.

**Figure II.4.3** Mission-oriented finance along the entire innovation chain



Source: adapted from Auerswald/Branscomb, 2003

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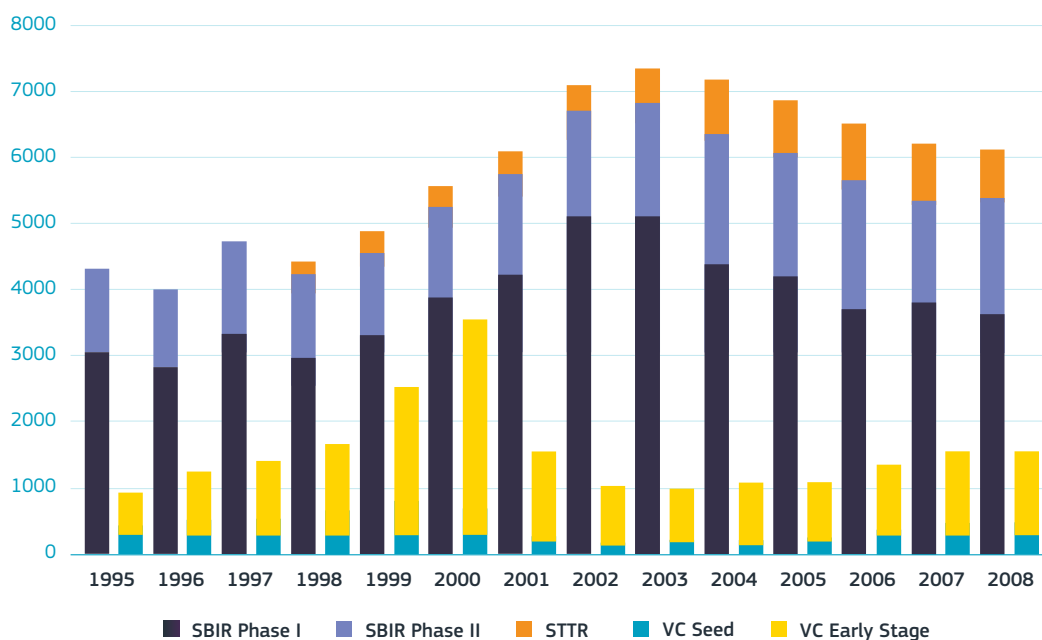


While it is a common perception that private venture capital funds start-ups, evidence shows that most high-growth innovative companies receive their early-stage high-risk finance from public sources, such as Yozma in Israel (Breznitz and Ornston, 2013); venture funds in public banks (Mazzucato and Penna, 2016b); and the SBIR programme funds in the United States (Keller and Block, 2012). While private venture capital is exit driven, seeking returns in three to five years (creating problems outlined in Lazonick and Tulum, 2011), these forms of public finance have been less risk-averse and more patient – thus better suited to the needs of innovation. This lesson does not seem to have been learned in various parts of the developed and developing world which continue to think that attracting venture capital (mainly through tax schemes, such as reductions in capital gains) will

foster innovation. In fact, the truth is that venture capital entered industries like the biotech sector in the late 1980s and early 1990s, while the high-risk capital-intensive investments had been done by the United States government in the 1950s and 1960s (Vallas et al., 2011).

In all these cases, government intervention was far from ‘neutral’, as the market failure framework would suggest. Instead, it deliberately targeted industries and even enterprises with a massive amount of public venture capital assistance. Similarly, in today’s renewable energy sector, entrepreneurs like Elon Musk have relied heavily on guaranteed loans from the United States Department of Energy, with the *LA Times* estimating that his three companies (Tesla, Space X and Solar City) together have received over US\$5 billion in public support.

**Figure II.4.4** Number of SBIR and STTR grants compared to private venture capital, 1995–2008



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Source: Block and Keller, 2012

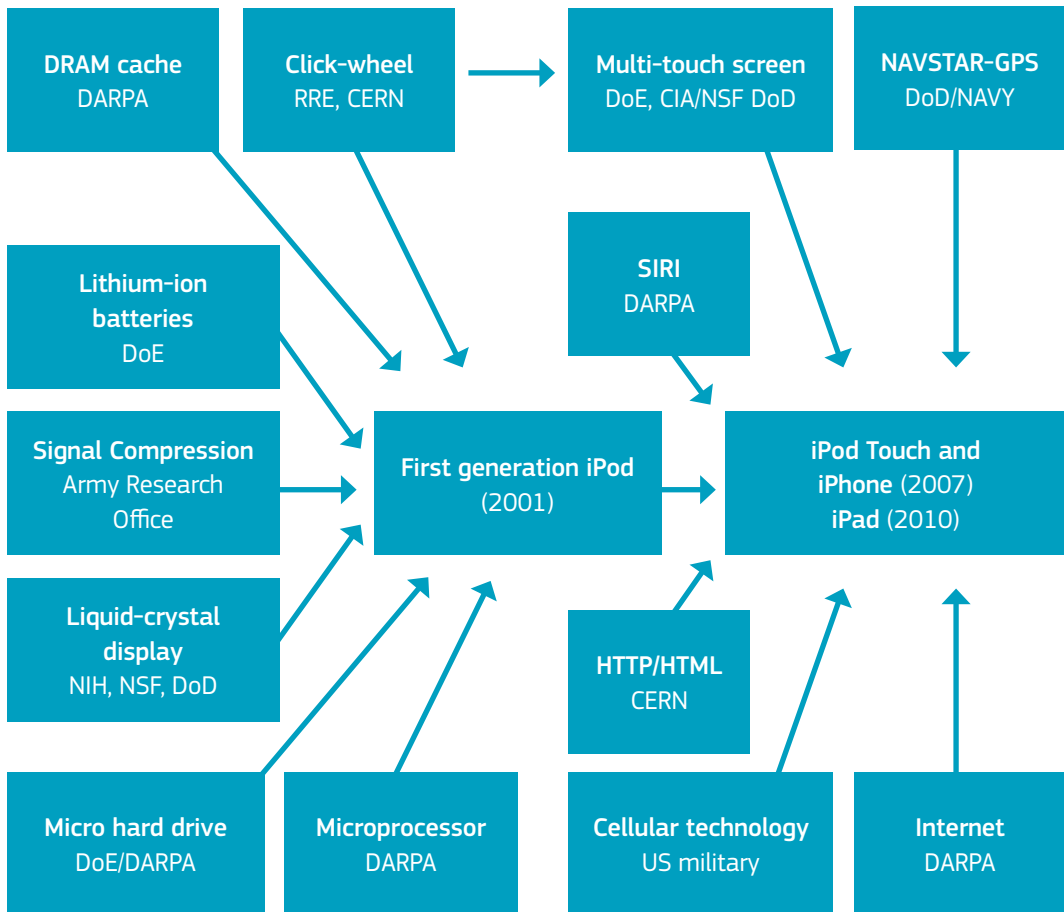
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### 4.2 Decentralised network of mission-oriented agencies

Crucial to this public funding was the nature of the organisations themselves, what Block and Keller (2011) have called a *developmental network state*. Better understanding the distribution of the agencies, the positioning across the innovation chain, and the balance between directive and bottom-up interactions is a key area for future study.

As Figure II.4.5 illustrates, in the case of IT, all of the technologies that have made Apple's i-products (iPhone, iPad, etc.) 'smart' were initially funded by different public-sector institutions: the internet by the Defense Activated Research Projects Agency (DARPA); the global positioning system (GPS) by the United States Navy; touchscreen display by the Central Intelligence Agency (CIA); and the voice-activated personal assistant Siri also by DARPA (Mazzucato, 2013a).

Figure II.4.5 Publicly funded technology in 'smart' phones



Source: Mazzucato (2013a), p. 109, Fig. 13.

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But key for our purposes is the fact that most agencies were indeed mission-driven: they did not see their job as fixing markets but as actively creating them. Mission statements can help direct public funds in ways that are more targeted than, for example, simply helping all SMEs. Examples of mission statements are:

- ▶ NASA's mission is to "Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth." (NASA 2014 Strategic Plan);
- ▶ "Creating breakthrough technologies for national security is the mission of the Defense Advanced Research Projects Agency (DARPA)";
- ▶ "NIH's mission is to seek fundamental knowledge about the nature and behavior of living systems and the *application* of that knowledge to enhance health, lengthen life, and reduce illness and disability".

Mission-oriented agencies are potentially better able to attract top talent as it is an 'honour' to work for them. By actively creating new areas of growth, they are also potentially able to 'crowd in' business investment by increasing business expectations about where future growth opportunities might lie (Mazzucato and Penna, 2015).

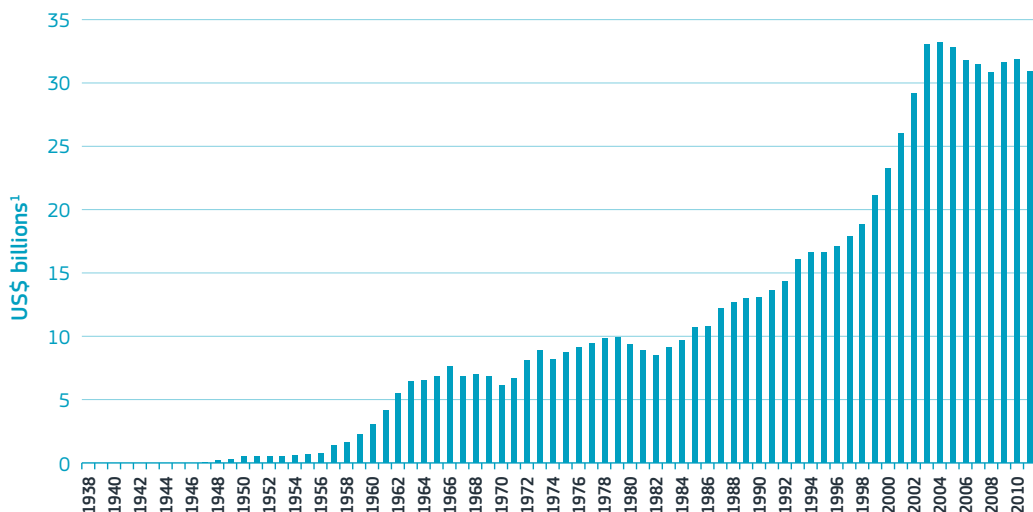
### 4.3 Risk-taking across the business cycle

Market failure theory foresees the need also to fix 'coordination failures' such as pro-cyclical spending in the business sector. Indeed, much of Keynesian economics mainly considers the

role of the state as essential in recessions (for its counter-cyclical role to prevent depressions), ignoring the fact that public financing of innovation has been just as important in boom periods. Evidence shows that mission-oriented agencies have been critical across the business cycle, and not only to stimulate investment during recessions. Among those agencies mentioned above, the NIH have spent billions on health R&D, stimulating what later became the biotechnology revolution in periods of both boom and bust. In the past, their budgets were increased, even during periods of sustained economic expansion (i.e. by Reagan during the mid-80s and then throughout the 90s). Indeed, the kinds of cuts by the United States government currently being experienced by innovation agencies, including cuts to Arpa-E and NIH, are without precedent, and are very likely to diminish United States competitiveness that has relied on their role as investors and innovators of first resort.

From 1936 to 2016, cumulative R&D expenditure by NIH amounted to more than US\$ 900 billion (in 2015 dollars), and annually has been above US\$ 30 billion since 2004. Concomitantly, research shows that around 75% of the most innovative drugs on the market today (the so-called 'new molecular' entities with priority rating) owe much of their funding to the NIH (Angell, 2004). Moreover, the share of NIH R&D expenditure in total United States federal outlays in R&D have constantly increased over the past 40 to 50 years. This suggests that the surge in absolute NIH-related R&D expenditure cannot simply be conceived as resulting from a generalised and proportional increase in total R&D expenditure by the government during downturns, or to simply levelling the playing field. Instead, it appears as a deliberate and targeted choice on where to direct public R&D funding.

Figure II.4.6 National Institutes of Health (NIH) – total budgets<sup>1</sup>, 1936-2011



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Source: [http://officeofbudget.od.nih.gov/approp\\_hist.html](http://officeofbudget.od.nih.gov/approp_hist.html)

Note: <sup>1</sup>in 2011 US\$ dollars.

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### 4.4 Patient finance: the importance of public finance

It is precisely due to the short-term nature of private finance that the role of public finance is so important in nurturing the parts of the innovation chain subject to long lead times and high uncertainty. While in some countries this has occurred through public agencies, such as DARPA and NIH (discussed above), in others patient finance has been provided through publicly owned development banks, otherwise known as state investment banks (SIBs).

SIBs have their historical roots in the Bretton Woods’ monetary agreements and the reconstruction plans for Europe following World

War II. The idea was to create an institution that promoted financial stability through a permanent flow of finance to fund the reconstruction plan and unleash agricultural production potential, thereby preventing the deleterious effects that speculative private finance could have on post-WWII economic recovery (World Bank, 2013). Following this rationale, the International Bank for Reconstruction and Development (IBRD) was created, providing its first loan to France in 1947<sup>28</sup>. Other national development banks were founded around that time, such as KfW in Germany (1948) (Schroeder et al., 2011), with the aim of channelling international and national funds to the promotion of long-term growth, infrastructure and modern industry. While in industrialised countries

28 World Bank, History [Online]; available at: <http://go.worldbank.org/65Y36GNQB0> [accessed 12/15/2015].

M. Schröder et al., op. cit.

these institutions focused on niche areas (such as aiding specific sectors), in developing countries SIBs such as the Brazilian BNDES initially promoted a catching-up agenda, with heavy investments in infrastructure (Torres Filho and Costa, 2012).

In subsequent decades, SIBs diversified their operations and focus. In the mid-1950s, KfW assumed the responsibility of providing finance for environmental protection and small and medium-sized enterprises (SMEs), roles that were intensified in the 1970s when it also began to target energy efficiency and innovation<sup>29</sup>. Other development banks followed suit: BNDES, for instance, created new credit lines for SMEs in the 1980s, and in the following decade began to experiment with financing programmes targeted at high-tech firms and innovation development<sup>30</sup>. By the 2000s, the China Development Bank (CDB) was one of the most active SIBs, investing in regional economic development and industrial catching-up; supporting and nurturing new ventures and innovation development; and, later in the decade, targeting finance to projects aimed at 'green growth' (Sanderson and Forsythe, 2013). Following the outbreak of the global financial crisis in 2007, SIBs across the world significantly promoted counter-cyclical credit, increasing their loan portfolio by 36% on average between 2007 and 2009, with some increasing their loans by more than 100% (Luna and Vincente, 2012).

While the traditional functions of state investment banks were in infrastructure in-

vestment, and counter-cyclical lending during the recession when private banks restricted credit (thus playing a classic Keynesian role), over time they have become more active as key players in the innovation system. They have provided the patient capital for innovative firms, and also focused on modern societal challenges with technological 'missions'. For example, SIBs have notably filled the vacuum left behind by private commercial banks since the outbreak of the crisis, more than trebling their investments in clean energy projects between 2007 and 2012<sup>31</sup>. A recent report by Bloomberg New Energy Finance finds that in 2013 state investment banks were the largest funders of the deployment and diffusion phase of renewable energy, outpacing investment from the private sector (Louw, 2011). The four most active banks are (in order) the Chinese Development Bank, the German KfW, the European Investment Bank (EIB), and the Brazilian BNDES. Examples of 'mission-oriented' investments include the European Investment Bank's EUR 14.7 billion commitment to sustainable city projects in Europe (Griffith Jones and Tyson, 2012), the efforts of KfW to support Germany's *Energiewende* policies through the greening and modernisation of German industries and infrastructures, China Development Bank's investments in renewable energies, and the technology fund put in place by BNDES to channel resources toward selected technologies in Brazil (FUNTEC)<sup>32</sup>. Figure II.4.7, for example, illustrates the way in which KfW has not only played a classical Keynesian counter-cyclical role, but has also directed that funding towards 'climate financing'.

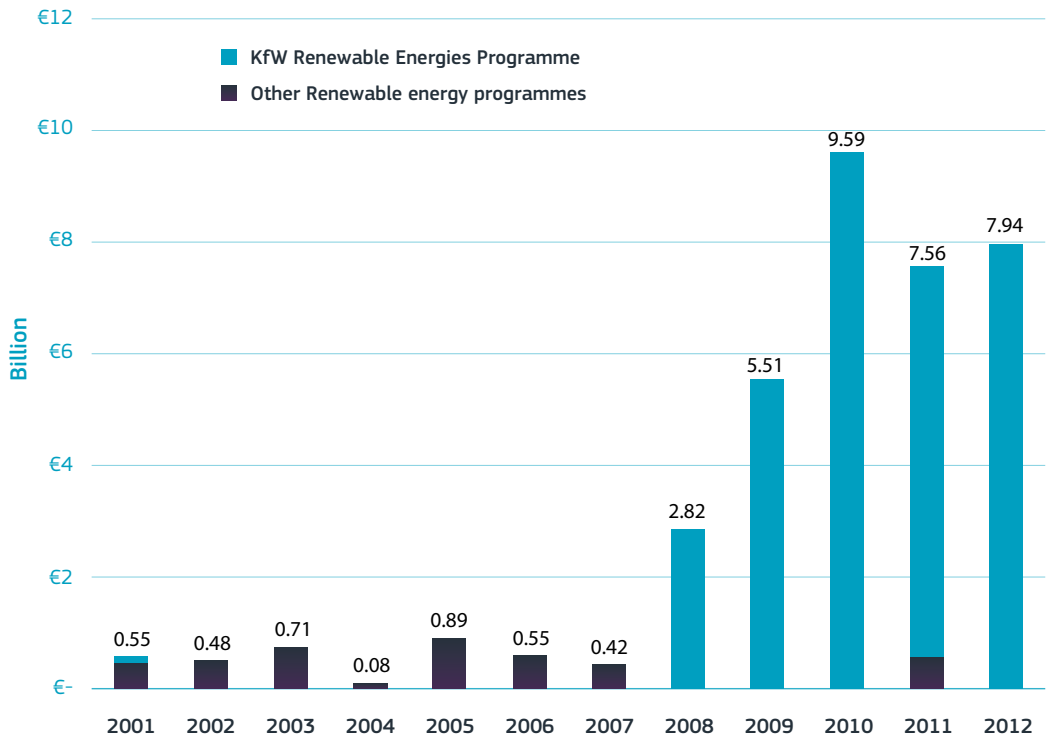
29 KfW, 'Annual Report 2008', Frankfurt am Main, 2009, KfW Group.

30 C.E. Branco, 'Apoio às Pequenas e Médias Empresas de Base Tecnológica: a Experiência do Contec', *Revista do BNDES*, Vol. 1, 1994, pp. 129-142; F.L.D. Sousa (ed.), 'Bndes 60 Anos: Perspectivas Setoriais', 2012, Rio de Janeiro: BNDES.

31 L.S. Fried, S. Shukla and S. Sawyer (eds.), 'Global Wind Report: Annual Market Update 2011', Global Wind Energy Council, March 2012.

32 BNDES 2012, 'Apoio À Inovação', 2012, Rio de Janeiro: BNDES.

Figure II.4.7 KfW Funding for industrial environmental and climate protection projects in Germany, 2001-2012



Science, Research and Innovation performance of the EU 2018

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## 4.6 Risks and rewards

More explicit consideration of these roles enables us to reflect on the degree to which the division of labour in risk-taking is or is not matched by a division of rewards, which would be expected if there is a *risk-return* relationship. It also helps us to better understand whether the eco-system is creating the right incentives. Is it the case that because some actors are putting in a lot, other actors have been given fewer incentives to do their share?

Innovation is highly uncertain: for every success (e.g. the internet) there are many failures. High failure rates are just as common upstream (in R&D projects) as downstream in the public financing of firms. It is thus essential to better understand how portfolios are managed in mission-oriented agencies – such as Yozma in Israel, Sitra in Finland or SBIR in the United States. This requires a lead investor understanding of public funds that goes beyond the need to correct for asymmetric information. It is not a matter of a lack of information, but rather the willingness to engage in big thinking and its underlying uncertainty.

Having a vision about the direction in which to drive an economy requires direct and indirect investment in particular areas, not just creating the horizontal (framework) conditions for change. Crucial choices must be made, the fruits of which will create some winners but many losers. For example, the United States Department of Energy recently provided guaranteed loans to two green-tech companies: Solyndra (US\$ 500 million) and Tesla Motors (US\$ 465 million). While the latter is often glorified as a success story, the former failed miserably and became the latest example in the media of government being inefficient and unable to *pick winners* (Wood, 2012). However, any venture capitalist will admit that for every

winning investment (such as Tesla) there are many losses (such as Solyndra). In making downstream investments, therefore, governments can learn from venture capitalists' portfolio strategies, structuring investments across a risk space so that lower risk investments can help to cover the higher risk ones. In other words, if the public sector is expected to compensate for the lack of private venture capital (VC) money going to early-stage innovation, it should at least be able to benefit from the wins, as private VC does. Otherwise, the funding for such investments cannot be secured. As argued in Mazzucato and Wray (2015), even if money could be secured for public investments endogenously (through money creation), it is desirable to allow the state to reap some of the rewards from its investments for several other reasons. Matching this type of spending with the corresponding return would provide a measure of efficiency, holding policymakers accountable; government net spending has limits dictated by the real resource capacity of the economy; and voters will be more willing to accept the (inevitable) failures if they see that those are compensated by important successes.

The public sector can use a number of return-generating mechanisms for its investments, including retaining equity or royalties, retaining a golden share of the IPR, using income-contingent loans, or capping the prices (which the taxpayer pays) of those products that emanate, as drugs do, from public funds (Mazzucato 2013). However, before exploring the details of each mechanism, it is crucial for the policy framework to even allow the question to be asked. In a market-shaping framework, does government have the right to retain equity more than in a market-failure framework? Are taxes currently bringing back enough return to government budgets to fund high-risk investments that will probably fail?

## 4.7 Learning the right lessons from ‘The Entrepreneurial State’

Weiss (2014) cautions on the role of United States public agencies in fostering innovation. She highlights the strong military and security interests that have shaped United States innovation policy, and the way that corporate interests have taken advantage of these.

It is right to be cautious. And it is precisely a wide debate about what it means to have mission-oriented thinking that can allow active public policy in innovation to be redirected towards societal needs (and the ‘wicked problems’ that connect health, sustainability, nutrition, education, and poverty), and not only military and security needs. By creating a more symbiotic relationship between the public and private sectors – focused on ‘additionality’ targets – the possibilities particular sectors have to capture innovation policy is reduced, as is the possibility that particular companies lobby for policies (including tax policies) which increase profits but do not help to generate public value. Understanding how the definition of missions can be opened up to a wider group of stakeholders, including movements in civil society, is a key area of interest. Indeed, to a large extent, it was the green movement in Germany (including but not restricted to the Green Party) that led to a slow cumulative interest in society about tackling green missions, such as that represented in the *Energiewende* agenda.

Understanding new, more democratic processes through which missions are defined and targeted is tied to rethinking the notion of public value. Indeed, part of building a market-shaping and creating framework that can guide mission-oriented thinking, that goes beyond the market-failure framework, involves rethinking public value beyond the notion of the ‘public good’. Too often, the public good concept has been used to limit and constrain the activities of public actors, immediately accusing ambitious policies of ‘crowding out’ private activity (Mazzucato and O’Donovan, 2016). But similarly, achieving public value cannot be the work of the public sector alone. Hence, opening up this process to include a wider set of stakeholders who can be involved in the definition of missions as well as the serendipitous process of how to achieve them, will be an exciting new area of analysis linked to 21st century innovation policy targeting grand challenges.

*“Public values are those providing normative consensus about (1) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled; (2) the obligations of citizens to society, the state, and one another; (3) and the principles on which governments and policies should be based” (Barry Bozeman, 2007, 13).*



## 5. Final thoughts: implementing mission oriented policies

The examples of history and future potential have led to growing interest in mission-oriented policy approaches from around the world. But questions remain about how to apply the lessons of history to the challenges of today.

When policymakers acted in this way in the past, they had to work outside established policy frameworks. What is needed is a policy framework they can work within: a new framework that can be used to justify, guide and evaluate mission-oriented innovation policies.

The challenge is to develop this new framework, along with the analytical tools, related policy apparatus, and new organisational capabilities to enable policy-makers to apply it in practice – in relation to different types of challenges and in different spatial or other contexts. To conclude this scoping paper, some general principles are listed below.

### 5.1 Linking innovation policy to the systemic characteristics of innovation

Innovation policy must build on the key characteristics of how innovation comes about: it is uncertain, cumulative, and collective (Lazonick and Mazzucato, 2012). Uncertainty means that agents concerned with innovation cannot calculate in advance the odds of success or failure – that is, results are unknown – and therefore in order to succeed they will also have to accept occasional failures and detours from the planned routes. **Cumulative** means that agents need to be patient and act strategically to accumulate competences and capabilities (learn) with a view to the long term. **Collective** means that all agents need to work together and thus bear certain degrees of risk; therefore, they are also entitled to share the rewards.

Policies based on a mission-oriented perspective are **systemic**, employing but going beyond science-push instruments and horizontal instruments. Mission-oriented policies employ an array of financial and non-financial instruments to promote the accomplishment of a mission across many different sectors, setting concrete **directions** for the economy, and deploying the necessary network of relevant public and private agents.

*A broad perspective* on the national system of innovation identifies **four subsystems**: (i) public policy and public funding; (ii) research and education; (iii) production and innovation; and (iv) private finance and funding. While all subsystems are in theory of strategic importance, the public policy and funding subsystem has traditionally led the process of socio-economic development and technical change.

To stimulate the innovation process by shaping and creating technologies, sectors and markets, **new relationships** must be developed and more trust created. The state must galvanise the interests of relevant actors and organise itself so that it has the ‘intelligence’ to think big and formulate bold policies that also create a sense of ownership among diverse public, private and academic stakeholders. It is also crucial to be able to implement the policies by coordinating the efforts of this stakeholder network through the state’s convening power, brokering trust relationships, and using targeted policy instruments.

Systemic mission-oriented policies must be based on a sound and clear **diagnosis** and **prognosis** (foresight). This requires not only the identification of missing links, failures and bottlenecks – the weaknesses or challenges of a national system of innovation – but also identification of the system’s strengths. Foresight is necessary to scrutinise future oppor-

tunities and to identify how strengths may be used to overcome weaknesses. This diagnosis should be used in devising concrete strategies, new institutions and new linkages in the innovation system. It may also be necessary to 'tilt' the playing field in the direction of the mission being pursued rather than 'levelling' it through such means as technologically neutral policies.

To fulfill a mission, a country requires an **entrepreneurial state**. This concept encapsulates the risk-taking role the state has played in the few countries that have managed to achieve innovation-led growth. It is through mission-oriented policy initiatives and investments across the entire innovation process – from basic research to early-stage seed financing of companies – that the state is able to have a greater impact on economic development.

The state must be able to **learn from experience** in mission-oriented innovation policy. In a market-failure framework, *ex-ante* analysis aims to estimate benefits and costs (including those associated with government failures) while *ex-post* analysis seeks to verify whether the estimates were correct and the market failure successfully addressed. A mission-oriented framework requires continuous and dynamic monitoring and evaluation throughout the innovation policy process.

Definitions of missions will increasingly require more involvement by stakeholders, both to gain democratic legitimacy (in an era in which it is threatened) and also to achieve a broader notion of public value than that which has been used.

## 5.2 Different types of capacity building

As highlighted in Mazzucato and Penna (2016a), different types of capacity building are central to mission-oriented policies:

**Scientific-technological capacity:** an appropriate scientific and technological knowledge base in the education and research subsystem;

**Demand capacity:** latent or effective (public or private) market demand, in terms of both purchasing power and need;

**Productive capacity:** an appropriate business base (for example, existing firms or entrepreneurs willing to take risks to establish an innovative firm) in the production and innovation subsystem;

**State capacity:** appropriate knowledge inside the public organisations formulating and executing the policies about the problem and solution being targeted and/or knowledge about 'who knows what and how';

**Policy capacity:** appropriate supply-side and demand-side policy instruments (strategically deployed), supported by complementary policies;

**Foresight capacity:** a fine-tuned diagnosis of the problem and solution, including an analysis of the current situation and future prospects for targeted technologies and sectors, formulated in terms of a well-defined mission and vision.

Successful mission-oriented policy experiments require all six factors in place whereas, in less successful areas, they require a more dynamic framing of key questions: less about picking or not picking, and more about the institutional and organisational capacity of forming broadly defined directions, through strategic deliberation; less about static cost-benefit metrics which so often result in accusations of 'crowding out' and more about dynamic assessment criteria that can nurture and evaluate market-shaping processes (so that ambitions are not immediately accused of crowding out). In this respect, four key

questions can guide the process of developing the new framework to justify, guide and evaluate mission-oriented innovation policies (discussion of the questions in Mazzucato, 2016a):

**Routes and directions:** how to use policy to actively set a change in direction; how to foster more dynamic (bottom-up) debates about possible directions to ensure enduring democratic legitimacy; and how to choose and define particular missions concretely, but with sufficient breadth to motivate action across different sectors of the economy.

**Organisations:** how to build decentralised networks of explorative public organisations which can learn by doing and welcome trial and error, with the confidence and capability to lead and form dynamic partnerships with private and third-sector partners; how to manage and evaluate progress, learning and adaptation; and how to use a portfolio approach to balance inevitable failure with success.

**Assessment:** how to evaluate the dynamic impact of public-sector market-creating investments, going beyond the static ideas embodied in cost/benefit analysis and ideas of ‘crowding in’ and ‘crowding out’ based on a richer conception of public-value creation; and how to develop new indicators and assessment tools to aid decision-making.

**Risks and rewards:** how to form new deals between public and private sectors so that rewards as well as risks are shared.

These questions provide a starting point for the new categories of thought required, with many more questions following in relation to application in particular contexts.

Figure II.4.8 below can be used to reflect on the practical steps that might be useful for mission-oriented organisations (with arrows being interpreted not linearly but in terms of key steps):

**Figure II.4.8** Practical steps to build mission-oriented thinking in innovation policy

Mission selection	How to select missions that have enduring and democratic legitimacy
Co-production	How to engage public, private and third sector actors in mission selection, implementation, learning and evaluation processes
Mission definition	How to define missions concretely but with sufficient breadth to motivate action across multiple sectors of the economy, enabling new types of interactions between public, private and third sectors, and over different time horizons
Dynamic capacities	How to develop new competencies and capabilities for dynamic change: ability to envision new futures and to accommodate risk-taking, experimentation and underlying uncertainty of the discovery process
Decision tools	How to develop new indicators and assessment tools to aid decision-making and evaluate impact, beyond the static cost/benefit framework
Managing future	How to manage inevitable failure as well as success by taking a portfolio approach
Sharing rewards	How to ensure rewards as well as risks are shared so that so that the growth generated is inclusive as well as smart

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# CHAPTER 11.5

# PRODUCTIVITY AND THE ROLE OF INTANGIBLES: FOCUS ON THE WORLD'S LARGEST R&D INVESTORS

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## 1. Introduction

The global productivity growth slowdown has raised concerns among policymakers and economists, and ignited an animated discussion on the causes. Scholars are actively debating the puzzling evidence of a slowdown in labour productivity growth, confronting theories which argue that such a slowdown is due either to mismeasurement issues of digital transformations (Syverson, 2016)<sup>33</sup> or to a more profound secular stagnation driven by innovation growth headwinds (Gordon, 2016)<sup>34</sup>. Others argue that behind the slowdown in aggregate productivity growth there has been a growing dispersion of productivity performance with some firms experiencing fast productivity gains, thanks to rapid technological progress, and others lagging behind (OECD, 2016). Andrews et al. (2016) identify the frictions in technological diffusion between frontier and non-frontier companies as one of the compositional effects determining the slowdown.

While the focus has been primarily on the contribution of the above-mentioned factors to the productivity slowdown, the role of intangible assets (other than ICT) in fostering productivity growth has been somewhat neglected. However, investment in intangible assets is rapidly growing, and in some cases this investment matches or exceeds investment in traditional physical

capital (OECD, 2011). The increase in international competition, the global diffusion of ICTs and the new digital era, and the growing value-creating activities of the business services sector have magnified the importance of intangible assets in areas such as business organisation, workplace practices and human capital (Breshnahan et al., 2002). Consequently, some studies have pointed to investment in intangible assets as an additional contributing factor to productivity and economic growth (Corrado et al., 2005, 2009; Goodridge et al., 2013).

By considering a unique sample of large R&D investors<sup>35</sup> – which are expected to be among the most productive companies worldwide – this chapter provides an in-depth description of the potential differences in productivity growth for firms located in different world regions and sectors of activity. To obtain a measure of firm-level productivity, we take the residual of a revenue function (multi-factor productivity, MFP) estimated with an instrumental variable approach<sup>36</sup>. Our empirical analysis adds to the existing evidence on firms' productivity dispersion, which until now has mainly focused on general or national-specific trends. Moreover, we develop an empirical framework to better understand the contribution of intangible assets, specifi-

33 Several studies have shown that ICT investments have had a significant impact on productivity growth both in Europe and in the United States (Colecchia and Schreyer, 2002; Edquist and Henrekson, 2006; van Ark, O'Mahony and Timmer, 2008). However, while ICT investment remained an important component of productivity growth, its relative contribution began to decrease after 2000 (Jorgenson et al., 2008), while multi-factor productivity continued to increase, in the United States and in some parts of Europe. This phenomenon shattered the confidence in the ability of official productivity data to accurately capture all the factors that affect economic growth, and emphasised the complexity of the link from technology to productivity.

34 Link and Siegel (2003) review the main factors contributing to the 1970s' productivity slowdown. A fundamental issue is whether the causes of the past slowdown were cyclical (e.g. due to changes in the composition of demand or to the utilisation of resources), or secular, due to technology-related investment. Some authors claim that it is more than a cyclical phenomenon and that structural factors, such as the inclusion in the labour market of economies with comparatively low productivity, are at the root of the impaired current European productivity growth (Gros & Mortensen, 2004; Colijn and van Ark, 2012).

35 A complete description of the data is provided in the Appendix.

36 The Appendix provides a detailed description of how we measure MFP and reports the estimated structural parameters.

cally R&D and knowledge capital (e.g. stock of patents), to firm-level productivity across different regions. Lastly, we focus on the EU-US productivity gap by comparing our results for firms located in the EU with those in the US.

The chapter is organised into five sections. Section 2 presents productivity trends for firms located in different world regions and sectors. Section 3 provides an empirical analysis that identifies the contribution of R&D and knowledge capital to productivity growth in different regions and sectors.

Section 4 combines the descriptive and analytical analyses to provide a more profound understanding of the reasons for the EU-US gap, as far as R&D capital and its relation with productivity are concerned. Finally, section 5 summarises the key findings and highlights some possible avenues for further research on how to unlock the productivity growth challenge. At the end of the chapter, we include a technical annex that describes the data, the construction of variables, and the methodology for calculating firm-level productivity.

## 2. Productivity trends among top R&D firms

### 2.1 Trends across world regions

Figures II.5.1 and II.5.2 display the dynamics and levels of the estimated MFP by macro-geographical regions. In particular, Figure II.5.1 shows the MFP averages over time for firms with headquarters in Europe, the United States, China, Japan and the rest of the world. China and Japan have opposing trends. Chinese firms<sup>37</sup> experienced the greatest increasing time trend, while the MFP of Japanese firms in the sample gradually diminished over time. The time trends of United States and EU R&D firms' MFPs are above the average for the whole sample, and increasing slightly. However, the MFP of United States R&D firms grew slightly faster.

Figure II.5.2 gives a perspective of both changes over time and the relative levels of productivity. Comparing the first and the last year of the period, the average MFP of the entire sample has not changed (2.7). Despite its growth,

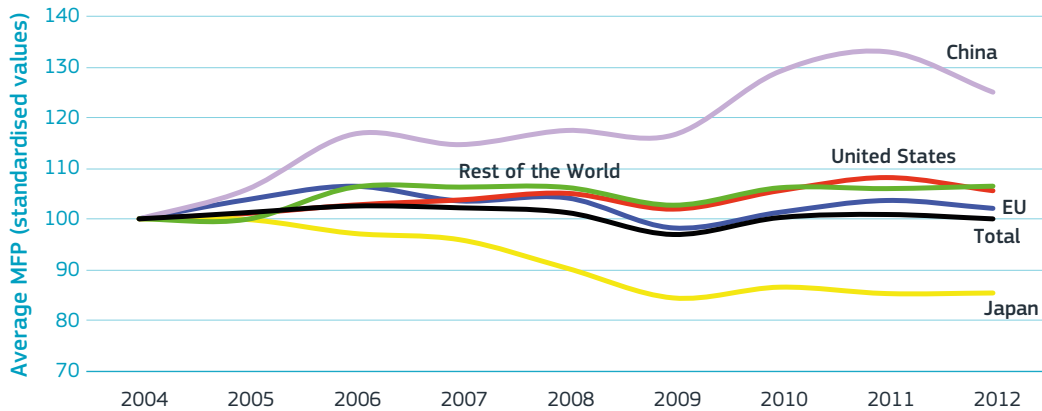
China's MFP is smaller (in absolute terms) than all the other regions. The average MFP growth between 2004 and 2012 was 8% for EU firms and 15.5% for the United States, further increasing the gap with the latter.

Figure II.5.3 shows the productivity trends in Europe for a selected number of countries (with a sample of at least 100 firms). Apart from Denmark and UK, the MFP of firms in the other countries lies below the EU average and has had no or negative productivity growth.

Overall, the productivity trend by regions seems to reflect the general macro-economic scenario: Chinese companies are growing faster than other companies; the productivity of United States firms is consistently higher than the EU, and Japanese firms are struggling with its lagging productivity. Taking into account the inhomogeneous representativeness per sector and country of our data, among European countries, Danish firms are growing faster than the rest.

37 In the estimation sample, there are 507 observations for China, 1718 for the EU, 4766 for the United States, 2901 for Japan, and 1245 for the rest of the world.

**Figure II.5.1 Multi-factor productivity (MFP) trend, 2004-2012<sup>1</sup>**



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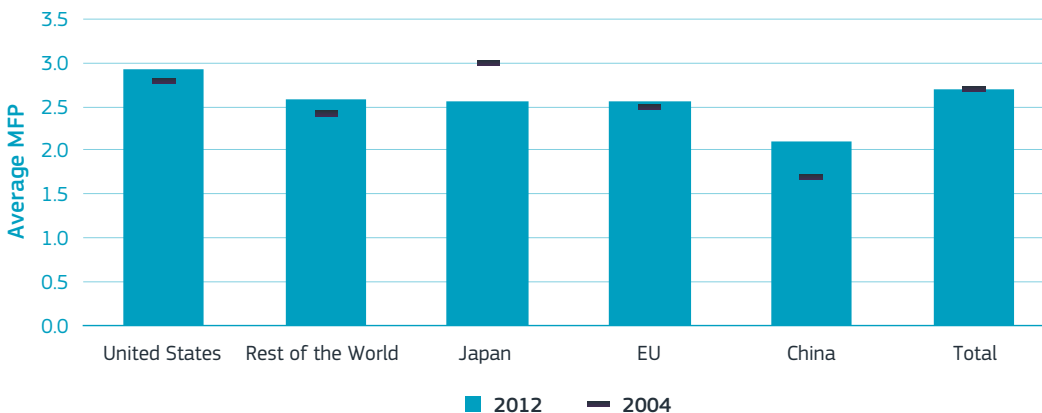
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Note: <sup>1</sup>Base year considered is 2004 = 100.

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**Figure II.5.2 Multi-factor productivity (MFP) levels, 2004 and 2012**



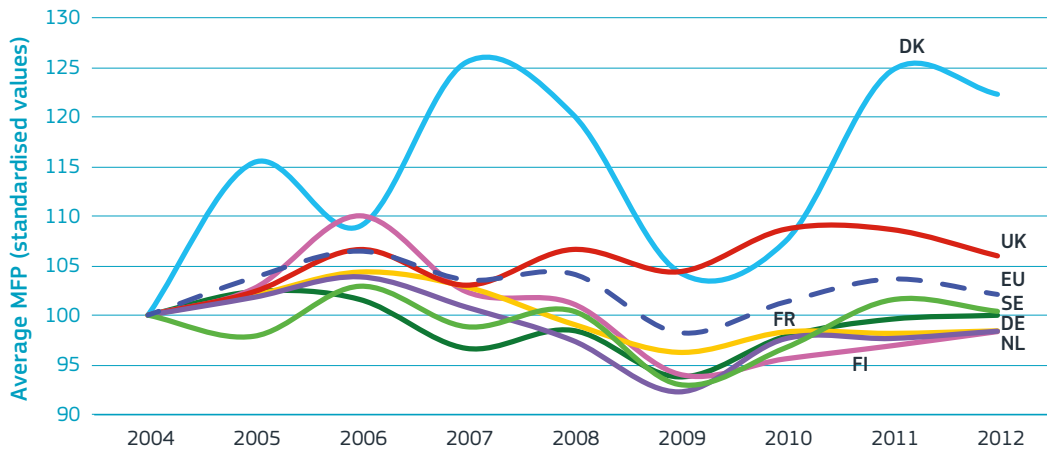
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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**Figure II.5.3 Multi-factor productivity (MFP) trend for selected EU Member States<sup>1</sup>, 2004-2012<sup>2</sup>**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Notes: <sup>1</sup>Only Member States with more than 100 observations were considered, representing 80% of the entire EU sample.

<sup>2</sup>Base year considered is 2004 = 100.

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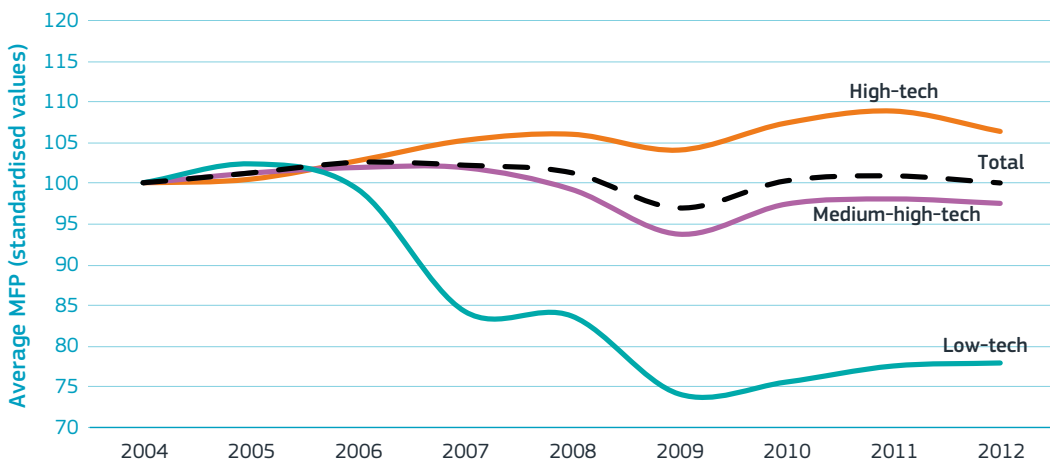
## 2.2 Trends across sectors

Figures II.5.4 and II.5.5 show the relative time trend and the absolute levels and changes of MFP by sector groups, namely high-tech, medium/high-tech and low-tech sectors<sup>38</sup>. R&D firms in high-tech sectors exhibit an increasing trend in MFP (Figure II.5.4). Conversely, the MFP of firms in medium/high- and low-tech sectors is declining over time, especially for low-tech firms. Figure II.5.5 shows that, in 2004, while firms in high- and medium/high-tech sectors had very similar levels of MFP, by 2012, high-tech firms were able to ramp up their productivity level by 18%, while medium/high- and low-tech firms' productivity fell by 7% and 39%, respectively.

Lowering the level of sectoral aggregation, Figures II.5.6 and II.5.7 show that the productivity of ICT and industrials companies does not grow over time, while firms in the health sector have experienced a rapid increase in their level of MFP. As Figure II.5.6 shows, on average, firms in the health, ICT, and industrials have higher levels of MFP.

These trends suggest that companies in the high-tech sector are the only ones enjoying rapid MFP growth, the main contributors to this being the health and ICT sectors.

**Figure II.5.4 Multi-factor productivity (MFP) by R&D intensity sector, 2004-2012<sup>1</sup>**



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Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

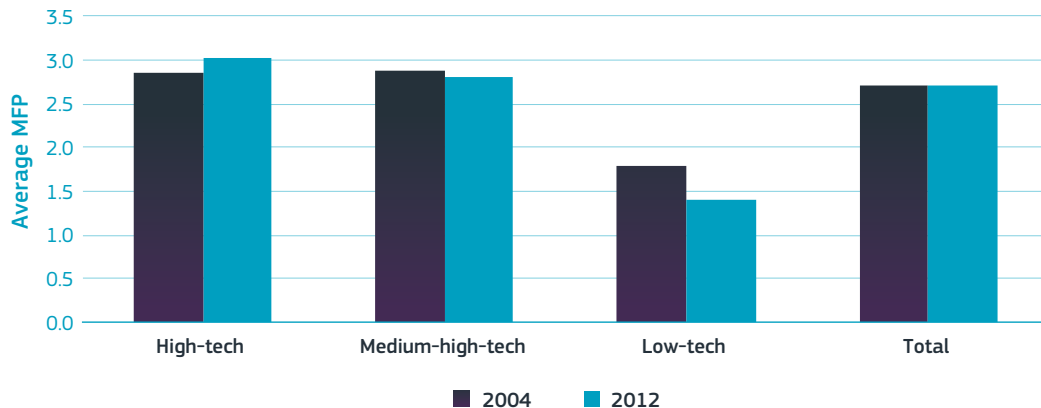
Note: <sup>1</sup>Base year considered is 2004 = 100.

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38 In Appendix, Table A.2 lists the business sectors by group. The choice of gathering firms in medium/low-tech and low-tech sectors is driven by the limited number of observations in these two sub-sector groups alone.



**Figure II.5.5 Multi-factor productivity (MFP) levels, by R&D intensity sector, 2004 and 2012**



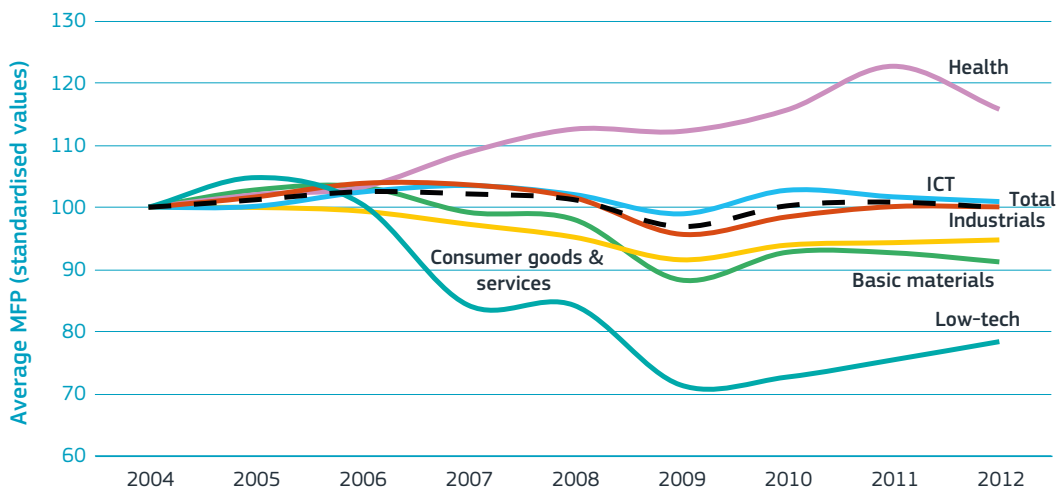
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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**Figure II.5.6 Multi-factor productivity (MFP), by disaggregated sector<sup>1</sup>, 2004-2012<sup>2</sup>**



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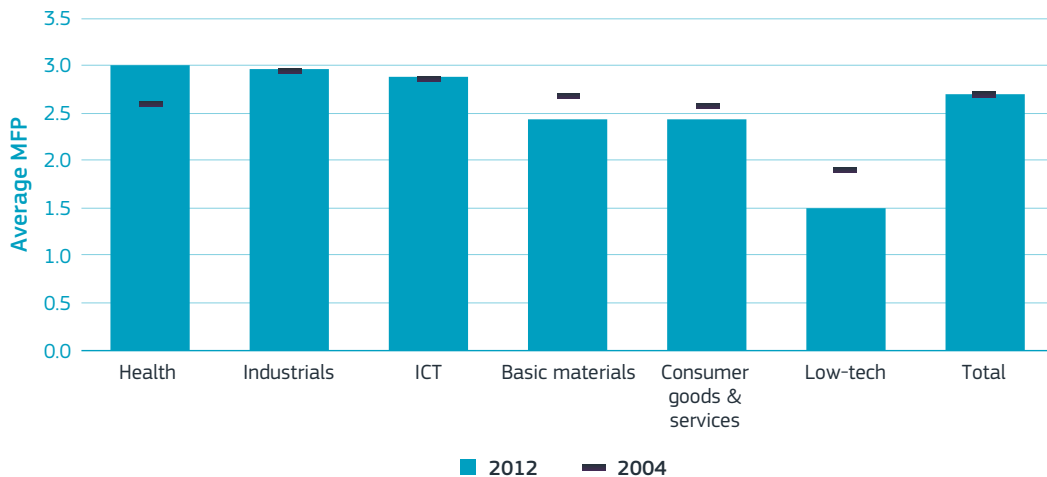
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Notes: <sup>1</sup>Derived from data for ICB sectors at 3 digit level. <sup>2</sup>Base year considered is 2004 = 100.

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Figure II.5.7 Multi-factor productivity (MFP) levels, by disaggregated sector<sup>1</sup>, 2004 and 2012



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Note: <sup>1</sup>Derived from data for ICB sectors at 3 digit level.

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### 3. Intangible assets and firm productivity growth

In this section, we report the estimates from the least squares regressions of equation (3) in the Appendix, which relates MFP to intangible capital by sector and geographical area, and to a time trend (trend=0,1,2,...; where 2004 is codified as 0). The range of intangible assets is broad and can be roughly classified into four types: computer-based assets (software, databases), human and social assets, economic competencies (brand equity, advertising and marketing), and innovative assets (such as R&D, trademarks and patents). This chapter is only concerned with the last type of intangible assets. More specifically, due to data availability, we focus on the role of R&D capital and patent capital as measures of innovative capital.

The effect of R&D on MFP is expected to be different from that of patents. Indeed, although the two measures of innovative assets are generally strongly correlated and interchangeably used as a proxy for knowledge capital, the intensity of patents is sector-specific<sup>39</sup> and their economic impact varies significantly from patent to patent (Griliches, 1980). While this latter issue is mitigated by taking transnational patents<sup>40</sup>, the sectoral impact of patent stock on productivity may differ from that of R&D.

Figure II.5.8 shows the results for R&D capital by sector and region. The first column (1) reports the average output elasticity of R&D for all sectors and regions. Overall, the partial elasticity of R&D is 0.078, meaning that

39 Patenting is negligible for innovations in most service industries (see Patel and Pavitt, 1995; Archibugi and Pianta, 1992).

40 See Appendix.

a 10% increase in R&D capital stock leads to a 7.8% increase in MFP<sup>41</sup>. The second column reports the results by sector. The returns to R&D are positive and statistically significant only in high- and medium/high-tech sectors. Finally, the third column shows the estimated

coefficients by macro-economic region. The responsiveness of MFP to changes in the R&D capital stock is largest in the United States and especially in the rest of the world (China is the main contributor to this effect). Also, firms' MFP exhibits a declining time trend.

**Figure II.5.8** Returns to R&D capital, by sector and by region, 2004-2012<sup>1 2</sup>

Dependent variable: MFP	(1)	(2)	(3)
R&D capital	0.078*** (0.01)		
R&D high-tech		0.084*** (0.02)	
R&D medium-high-tech		0.072*** (0.02)	
R&D low-tech		0.065 (0.04)	
R&D EU			0.071** (0.03)
R&D Japan			-0.008 (0.02)
R&D Rest of the World			0.206*** (0.04)
R&D United States			0.091*** (0.02)
Trend	-0.015*** (0.00)	-0.015*** (0.00)	-0.017*** (0.00)
Constants	2.074*** (0.17)	1.996*** (0.23)	2.177*** (0.37)
R2	0.221	0.221	0.231
N	10270	10270	10270

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Notes: <sup>1</sup>Sector and country dummies included but not reported. Firm clustered errors. <sup>2</sup>\*\*\* = p<0.01; \*\* = p<0.05; standard errors are given in parentheses.

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41. Using a different sample of the same dataset, Cincera and Veugelers (2014) find very similar results.

Figure II.5.9 shows the same results for the stock of patents as a measure of intangible capital. In general, the average effect for all firms in the sample is statistically significant and positive (2.9% increase in MFP for a 10% increase in patent stock), but smaller than the effect of R&D capital. Column 2 reports the estimated output elasticities to patents stock by sector. As with R&D

capital, the patent stock matters only for high- and especially for medium/high-tech sectors. The last column displays the results by different regions. Unlike the elasticity of R&D, the elasticity of patents is larger, on average, for EU firms and firms in the rest of the world (5.2% and 10.1%, respectively), while for the average United States firm the elasticity of the stock of patents is 3.3%.

**Figure II.5.9 Returns to patents stock<sup>1</sup>, by sector and by region, 2004-2012<sup>2,3</sup>**

Dependent variable: MFP	(1)	(2)	(3)
PAT capital	0.029*** (0.01)		
PAT high-tech		0.027* (0.01)	
PAT medium-high-tech		0.030** (0.01)	
PAT low-tech		0.036 (0.02)	
PAT EU			0.052*** (0.02)
PAT Japan			-0.017 (0.02)
PAT Rest of the World			0.101*** (0.04)
PAT United States			0.033** (0.02)
Trend	-0.015*** (0.00)	-0.015*** (0.00)	-0.015*** (0.00)
Constants	2.914*** (0.07)	2.925*** (0.08)	2.810*** (0.11)
R2	0.207	0.207	0.212
N	8767	8767	8767

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Notes: <sup>1</sup>Transnational patents (see appendix). <sup>2</sup>Sector and country dummies included but not reported. Firm clustered errors.

<sup>3\*\*\*</sup> = p<0.01; <sup>\*\*</sup> = p<0.05; <sup>\*</sup> = p<0.1; standard errors are given in parentheses.

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## 4. Focus on the EU-US productivity gap

In this section, we focus on the comparison between EU- and US-based firms, with the aim of shedding light on some of the characteristics that may be responsible, at least in part, for the gap in both productivity levels and productivity growth. The section is organised into three parts. The first part reports general trends of R&D and patent capital. The second part shows the differences in productivity between the top 10% and the bottom 90% of EU and United States firms. The third part compares sectoral productivity trends and breaks down differences in the relationship between productivity and innovation capital between United States and EU firms by sector group.

### 4.1 Differences in intangible intensity

Results from section 3 point to the central role played by innovation capital. To give some perspective on the trends in R&D and patents, Figures II.5.10 and II.5.11 compare the median values of R&D capital and the stock of patents per employee.

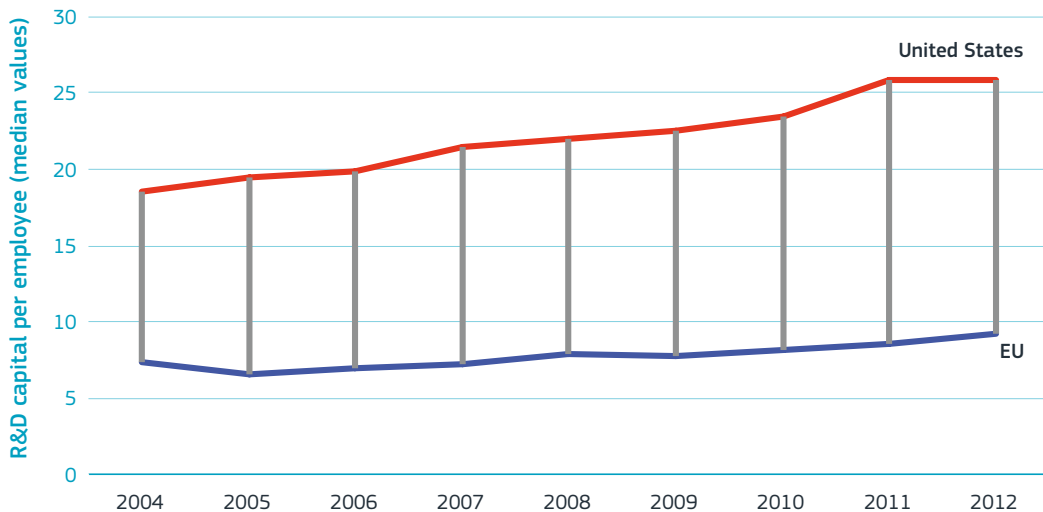
Figure II.5.10 shows how the US-EU gap in R&D capital per employee has been widening over the period considered, due to a more rapid growth in R&D capital accumulation by United States firms. Figure II.5.11 shows that both EU and United States firms exhibit a falling trend in patent accumulation intensity; however, EU

firms have decreased their accumulation of patents at a lower rate, resulting in a smaller EU-US gap in 2012 than in 2004.

Taking everything into account, R&D investment seems to be the contributing factor which sets the productivity of United States firms apart from that of EU firms. Indeed, not only is the gap in patent stock per employee decreasing over time (Figure II.5.10), but also EU firms are better than United States firms at appropriating from the returns to patents stock (see Figure II.5.9). As expected, Figure II.5.12 shows that while the R&D intensity of United States firms is increasing sharply over time, that of EU firms is stagnating.

Moreover, as mentioned in the introduction to this chapter, the relevance of intangible assets is accentuated by the shift from physical to knowledge capital accumulation. In this respect, Figure II.5.13 reports the average values of the ratio between R&D capital and physical capital. An average ratio larger than one indicates that firms are more R&D capital intensive; a ratio smaller than one indicates that firms are more physical capital intensive. The figure shows how United States firms have an R&D-to-physical-capital ratio larger than one, while EU firms have a smaller than one ratio. On average, the R&D capital intensity trend is increasing for both groups of firms.

Figure II.5.10 R&D capital per employee, 2004-2012



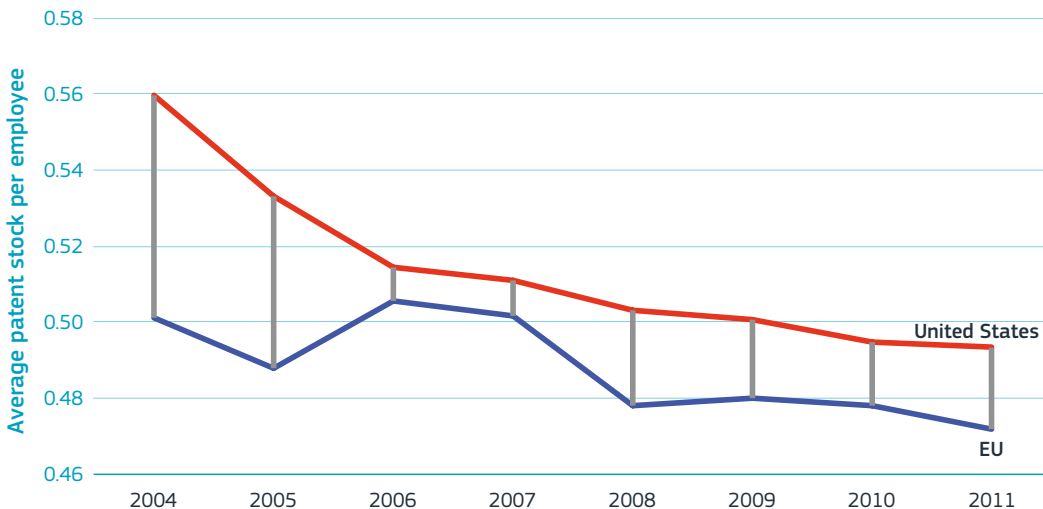
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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Figure II.5.11 Patent stock per employee, 2004-2011



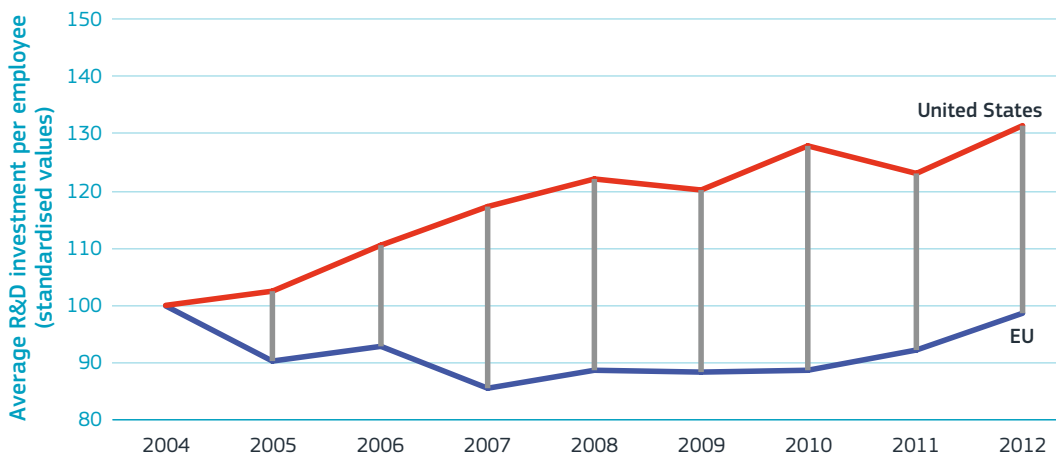
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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**Figure II.5.12 R&D investment per employee (2004=100), 2004-2012**



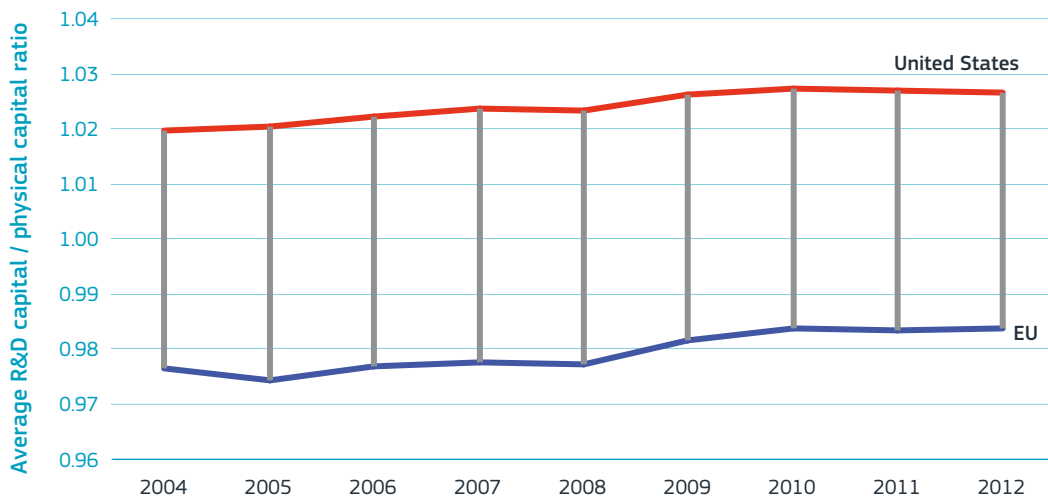
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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**Figure II.5.13 R&D capital to physical capital ratio, 2004-2012**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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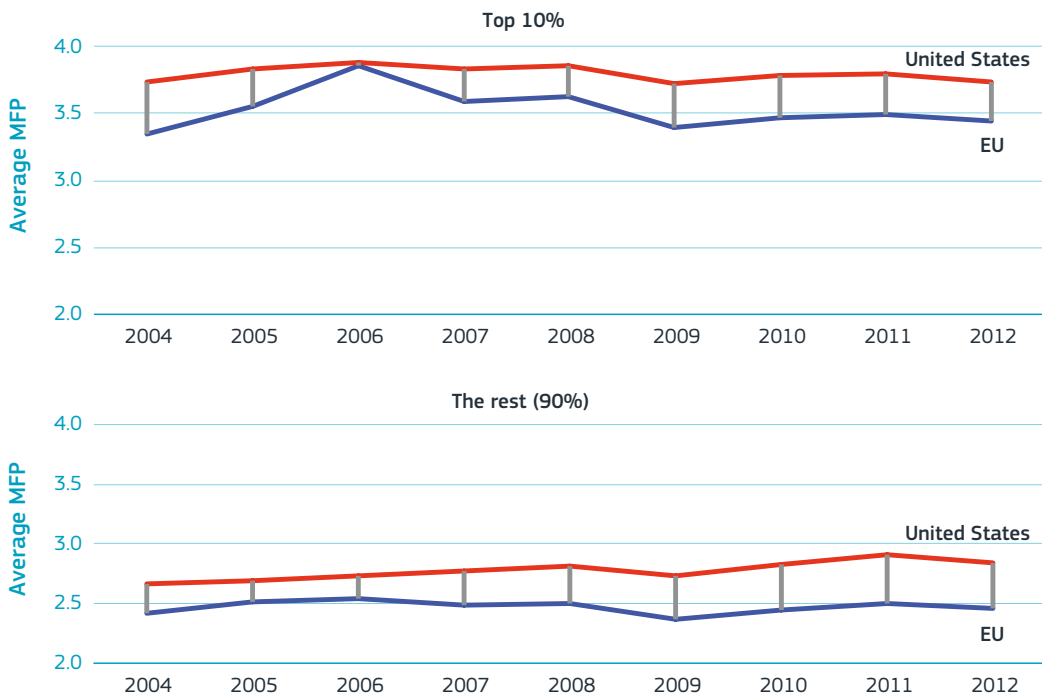
### 4.2 The gap between the most productive firms and the rest

In this subsection, we define as 'top 10' those firms with an average MFP larger than the top 10<sup>th</sup> percentile by sector, and compare the top 10% of firms with the rest. Overall, we find that the productivity gap between United States and EU firms is driven by the less productive ones, and that the divergence between more and less productive firms is decreasing over time.

The top panel in Figure II.5.14 shows that, among the most productive firms (top 10), there is a sig-

nificant gap between EU and United States MFPs. Unlike United States firms, EU companies experienced a growth spurt in 2006 (pre-crisis), when they had caught up with the MFP levels of the top United States R&D firms. However, the subsequent crisis had a larger impact on the MFP of EU firms, restoring the gap within three years. However, from 2009, the gap has been shrinking slowly. The bottom panel in Figure II.5.14 compares the rest of the companies across the two economies. First, unlike the top 10 firms, the MFP gap is increasing over time, as the MPF level in the bottom 90% only shows an increasing trend for United States firms.

Figure II.5.14 Multi-factor productivity (MFP) - top 10% of firms<sup>1</sup> and the rest, 2004-2012



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Note: <sup>1</sup>Top 10% are those firms whose average multi-factor productivity (MFP) is larger than the top 10<sup>th</sup> percentile by sector.

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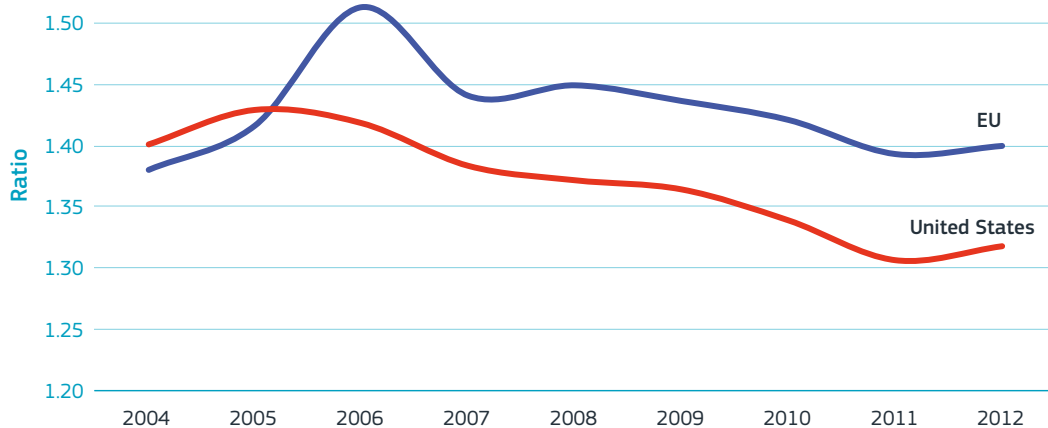
Figure II.5.15 reports the ratio between the MFP levels of the top 10 firms and the other EU and United States firms. A declining trend indicates that the difference in MFP between the most productive firms and the rest is decreasing over time. Although the difference is higher for EU than for United States firms, both sets of companies show a similar trend in the converging levels of productivity. These results differ from those of the OECD (2016) whereby they found an increasing divergence between the frontier and laggard firms. It is important to note, however, that our sample does not include small, local firms, but only considers large, international, R&D-focused firms operating in a highly competitive environment, where they need to defend their market power.

Finding a trend of convergence in productivity between the top 10% and the rest may be due to the said competition, as this has been shown to raise the productivity gains resulting from cost-reducing innovations (Willig, 1987) on the one hand, and from greater managerial efficiency, on the other (Nickell, 1996).

### 4.3 Sectoral differences in R&D and the impact of innovation capital on MFP

This subsection initially investigates the differences in R&D intensity and productivity across sectors, and then concludes with a quantile regression analysis of the effects of R&D and patents on MFP.

**Figure II.5.15** The ratio between multi-factor productivity (MFP) levels of the top 10 firms and the other firms, 2004–2012



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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### Descriptive analysis

In general, our descriptive findings suggest that, at the sectoral level, EU firms continue to be relatively specialised in medium-tech sectors (such as the automobile industry), and are slacking in new high-technology sectors when compared to United States firms (Cincera and Veugelers, 2014).

Figure II.5.16 shows the median values across firms and years of R&D capital per employee in EU and United States firms. The latter invest comparatively more in high- and low-tech sectors than EU firms.

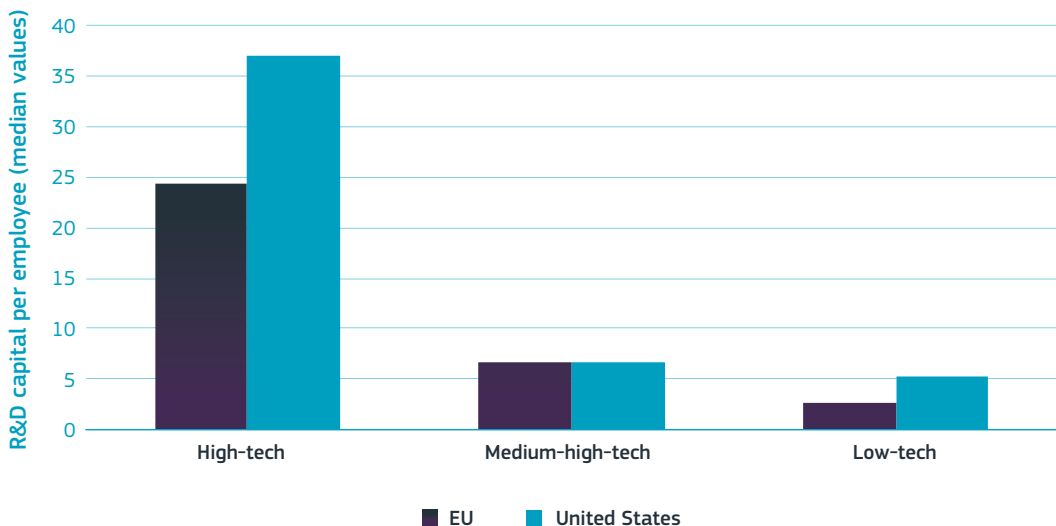
Figure II.5.17 reports the average values of MFP for each sector, comparing United States and EU firms in both 2004 and 2012. On the horizontal axis, Figure II.5.17 gives the values of MFP by sector for EU firms, while the vertical axis shows the value of MFP for United States companies. The left panel refers to 2004, the right panel to 2012. If a coloured disk, representing the average MFP per sector, is below the diagonal, its average MFP is higher for EU firms than for US. And vice versa:

if the disk is plotted above the diagonal, the average MFP is higher for United States firms.

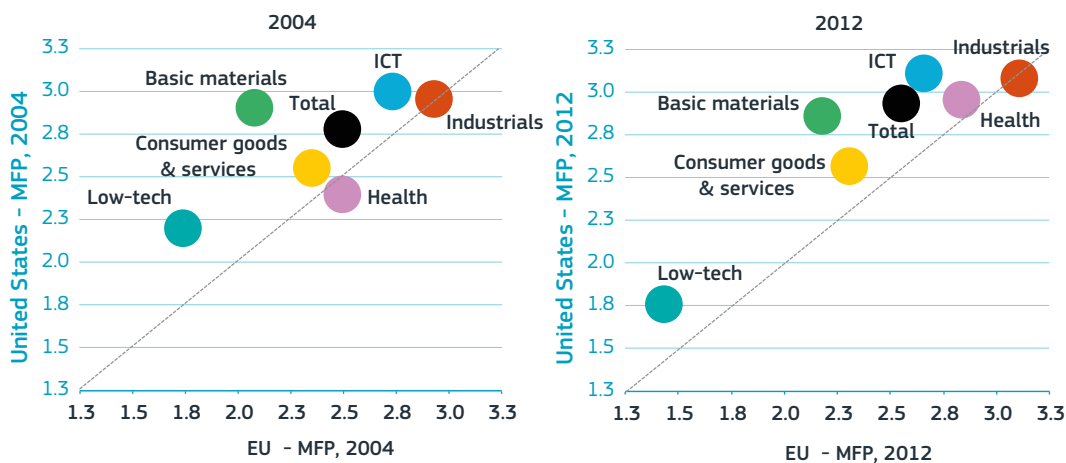
Looking at the two panels, in all sectors except industrials, the average MFP is higher for United States firms. Also, it can be seen how the sectoral averages have evolved over time. In particular, European firms have lost ground in the health sector but gained some in the industrials. The positioning of United States versus EU firms has not changed in any of the other sectors.

Figure II.5.18 compares the average levels of MFP in 2012 and 2004 between United States and EU firms. The graph is interpreted as follows: sectors below the diagonal had a higher average MFP in 2004 than in 2012; vice versa if sectors lie above the diagonal. The left panel shows how the EU average MFP fell in three sectors, among which is the ICT sector and consumer goods and services, which is key for the EU economy as it includes the automobile sector. By comparing the left (EU) and the right (US) panels, it is evident how the average level of MFP is more heterogeneous among European firms than United States ones.

Figure II.5.16 R&D capital per employee (median values) by sector, 2004-2012



**Figure II.5.17** Multi-factor productivity (MFP) levels by sector<sup>1</sup> - the EU compared to the United States, 2004 and 2012



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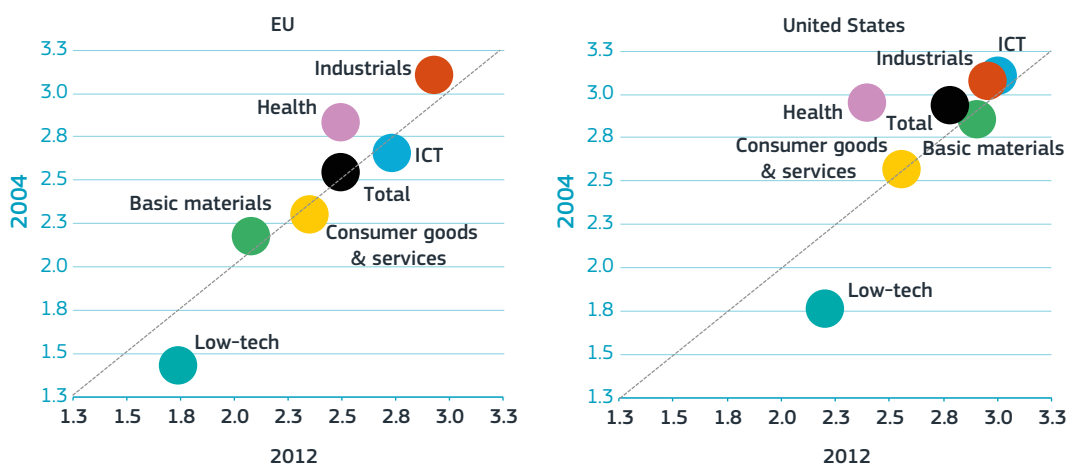
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Note: <sup>1</sup>Derived from data for ICB sectors at 3 digit level.

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**Figure II.5.18** Multi-factor productivity (MFP) levels by sector<sup>1</sup> in the EU and the United States, 2012 compared to 2004



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Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Note: <sup>1</sup>Derived from data for ICB sectors at 3 digit level.

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### R&D, patents and productivity: a quantile regression analysis

The empirical results suggest that an increase in R&D capital results in a proportionate increase in the productivity of United States high-tech firms and in a less-than-proportionate increase in the productivity of EU firms. In other words, while R&D capital for United States high-tech firms is a capital good with an increasing marginal productivity 'à la Arrow'<sup>42</sup>, it has a diminishing marginal productivity for EU high-tech firms and other sectors, where its characteristics are similar to physical capital. Patent capital, on the other hand, exhibits diminishing marginal productivity in all sectors except low-tech, where the most productive firm (US and EU) have positive elasticity to patents stock that increases with a firm's productivity.

Figures II.5.19 and II.5.20 report the results from a quantile regression analysis. Each figure has six panels which display the elasticity of both R&D capital (Figure II.5.19) and patent stock (Figure II.5.20) on MFP for United States (left) and EU firms (right), by R&D intensity sector.

The estimated elasticities of R&D capital for different sectors (Figure II.5.19) generally decrease as the productivity level increases. In other words, assuming that the level of R&D intensity is constant among firms per sector, the declining slope stems from the decreasing marginal productivity of R&D capital<sup>43</sup>. However, while in the

medium/high-tech sector both EU and United States firms have similar ranges and declining patterns of R&D elasticity, firms in the high- and low-tech sectors present different dynamics. In the high-tech sector, the R&D capital of EU firms behaves just like a physical asset which exhibits diminishing marginal returns. On the other hand, the R&D capital accumulated by United States firms seems to have a constant marginal productivity of R&D above a certain level of MFP (roughly the 25th percentile).

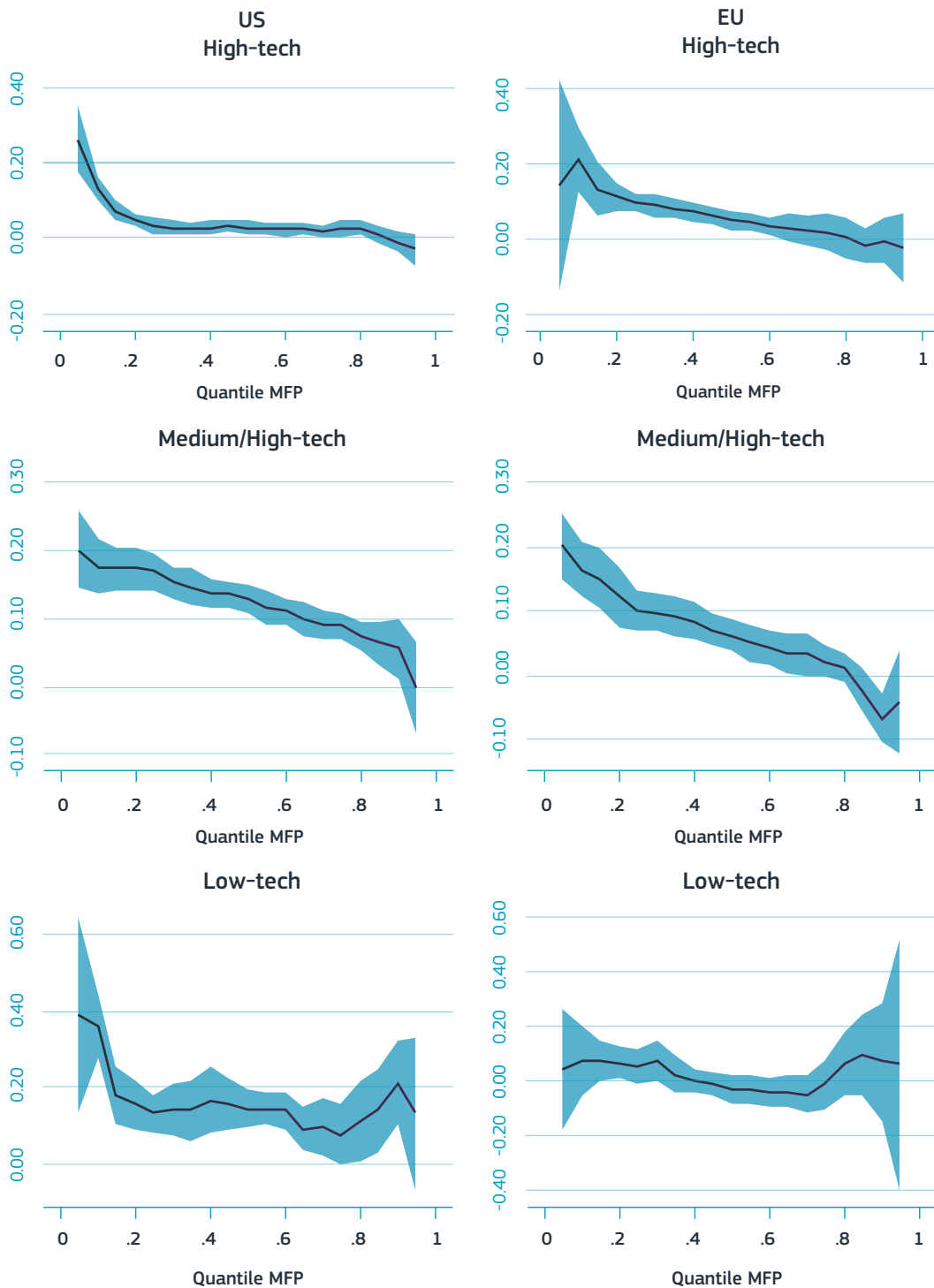
Lastly, the productivity of R&D among low-tech EU firms is zero, while that of United States firms is positive and exhibits constant marginal productivity for some levels of MFP (roughly between the 20th and 60th percentile).

Figure II.5.20 shows the estimated elasticity of patent capital. Similar to R&D capital, EU and United States firms in the medium/high-tech sector have similar diminishing elasticities to patents stock. In the high-tech sector, however, United States firms' marginal productivity of patents stock is totally unconditional on the volume of patents stock (from the 15th percentile onwards). In the low-tech sector, the most productive firms – United States and EU – have increasing patent capital elasticity, although low-tech United States firms start to reap the benefits of their knowledge investment from a relatively lower level of productivity compared to that of EU firms.

42 Arrow argued that increasing marginal returns on R&D arise because new knowledge is discovered as investment and production take place.

43 By definition, the elasticity of R&D capital is  $\theta_{R\&D} = MP_{R\&D}(R\&D/Y)$ , where  $MP_{R\&D}$  is the marginal productivity of R&D capital and  $R\&D/Y$  is the R&D intensity.

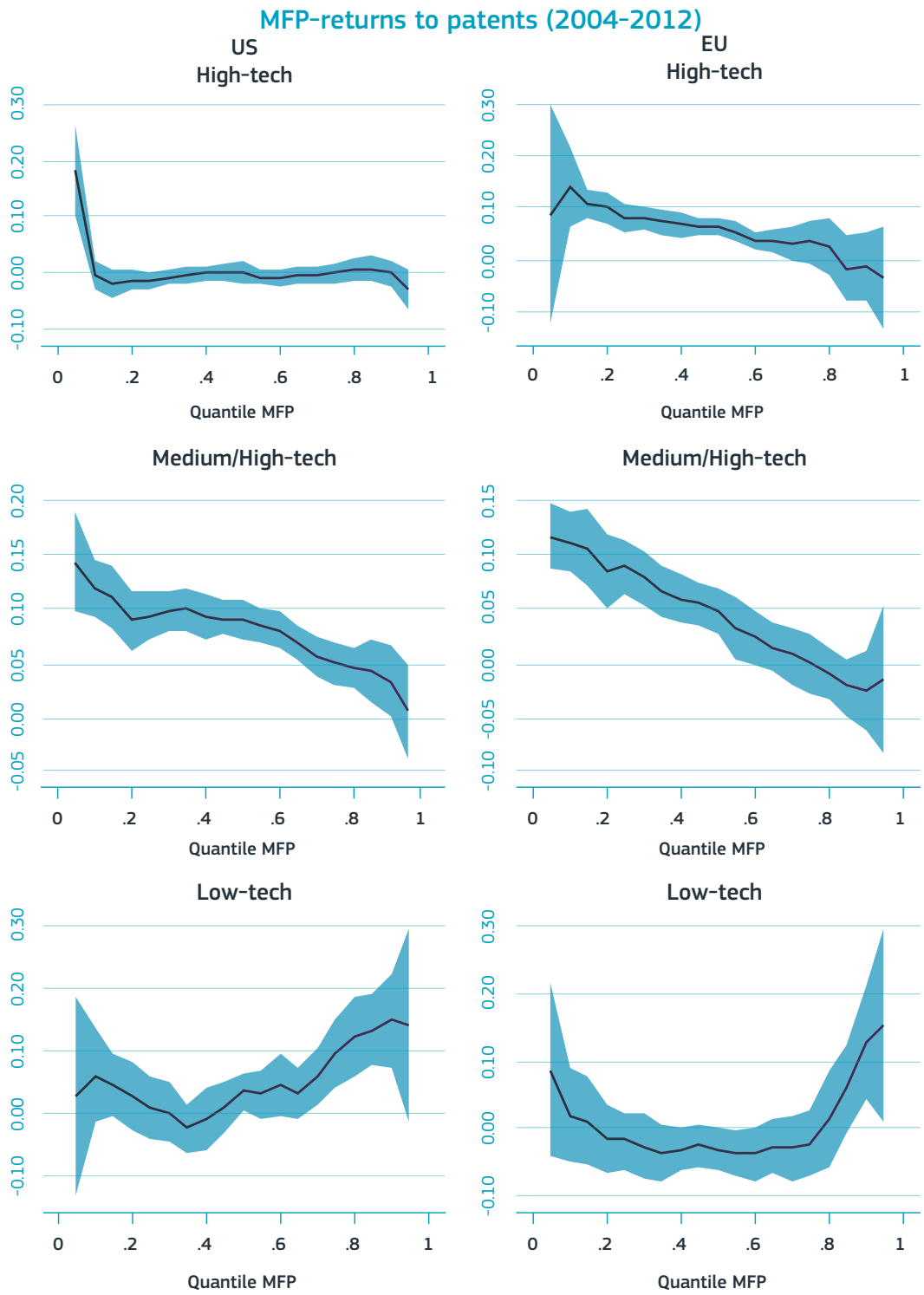
**Figure II.5.19** The relationship between R&D and MFP, by sector and region  
**MFP-returns to R&D capital (2004-2012)**



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Figure II.5.20 The relationship between patents and MFP, by sector and region



## 5 Conclusions and avenues for further research

This chapter contributes to the discussion on the global productivity slowdown by providing a more nuanced analysis about regional and sectoral differences in productivity growth patterns and by investigating the role of intangibles. It also provides a detailed comparison between the characteristics of EU and United States firms, with the aim of identifying potential reasons behind the increasing productivity gap between the two economies. Unlike previous studies, the analysis focuses on a unique sample of top international R&D investors, as they are key players in globalised economies. Although these firms may not be classified as the global frontier of productivity (Andrews et al., 2017), they are more than companies selling products. These top R&D multinational corporations are well-established giants which are a vehicle for global investment, market developments, and the mobilisation of knowledge generated across their worldwide corporate networks.

In the descriptive part of this chapter, we compare our estimated multi-factor productivity (MFP) across regions and sectors, using EU Industrial R&D Investment Scoreboard data for the top world 2000 R&D investors between 2004 and 2012. Overall, the productivity of the whole sample of firms did not budge over time. More specifically, the increase in productivity experienced by US, Chinese and EU firms has been balanced by the decrease in productivity by Japanese R&D investors. At the sectoral level, companies in the high-tech sector are the only ones enjoying a fast productivity growth, and the main contributors to this growth are the health and ICT sectors.

Scholars have attributed the recent United States productivity growth to the rapid expansion and application of technological knowledge (Corrado et al., 2005) and to invest-

ments in intangible capital. Results from the empirical analysis in Section 3 on the contribution of innovation capital (R&D and patents) to productivity confirm the importance of intangible assets, such as R&D and patents, as drivers of productivity growth. For example, a 10% increase in R&D capital stock (or in patents stock) leads to a 7.8% (2.9%) increase in MFP. However, the productivity gains from R&D and patents derive exclusively from high- and medium/high-tech sectors. At the regional level, United States and Chinese firms have the largest R&D elasticities, while Chinese and EU firms have the largest patents stock elasticities. Moreover, our results confirm the findings from previous studies that the output elasticity of R&D exceeds its factor share (8% versus 6%, respectively), that is to say the marginal productivity of R&D exceeds its cost.

Lastly, we focus on the comparison between EU and United States firms with the intent of shedding light on some of the characteristics that may be partly responsible for the productivity gap. EU firms are less productive than United States firms in almost all sectors and have lost ground in some sectors where they used to outperform the United States (i.e. health and industrials). Moreover, by defining as ‘top 10’ those firms with an average MFP larger than the top 10th percentile by sector, we can compare the top 10% of firms with the rest. Overall, we find that the productivity gap between United States and EU firms is driven by the less productive ones, and that the divergence between more and less productive firms is decreasing over time.

Also, we find that the gap in R&D capital intensity has been increasing over the period considered, due to a more rapid growth in United States firms’ R&D capital accumulation, while the gap in patents stock has narrowed in the

last three years of the period considered. This suggests that R&D investment may be one of the contributing factors that sets the productivity of United States firms apart from that of EU firms. Indeed, not only is the gap in patent stock closing, but EU firms also have a higher patents marginal productivity than United States companies.

Our empirical results from a quantile regression analysis suggest that an increase in R&D capital results in a proportionate increase in the productivity of United States high-tech firms and in a less-than-proportionate increase in the productivity of EU firms. In other words, the R&D capital of EU firms relies more on embodied knowledge and technologies, which are exploited by investing in new equipment, and exhibits characteristics that are more similar to physical capital, including the marginal productivity. On the other hand, patent capital exhibits diminishing marginal productivity in all sectors except the low-tech one, where the most productive firm (US and EU) have positive elasticity to patents stock that is growing with firms' productivity levels.

To sum up, our analyses indicate that some of the reasons behind EU firms' lagging productivity may be due to the structural anchoring of EU high-tech firms to capital-intensive manufacturing sectors. Indeed, most of the new high-tech firms have shifted their focus from the traditional production paradigm, where R&D and innovation are used to reduce production costs, to network efficiency, where technology is used to expand their network and meet new demands. New tech firms, such as Google, Amazon and Apple, are platforms that enable their users to connect, exchange and express their demands, which immediately translate into business opportunities.

This chapter's analysis and results give rise to a number of related open questions that we leave as avenues for future research, such as how the global decline in business dynamism affects the allocation of capital and labour across firms and consequently impacts productivity growth. Apart from global factors, there may be a number of additional Europe-specific factors, such as structural rigidities and framework conditions, which may help explain the US-EU productivity gap.



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## Appendix

### Data

To analyse the productivity trends across regions and sectors, and to investigate the role of intangible investments on productivity growth, this chapter considers a unique sample of companies. The EU Industrial R&D Investment Scoreboard<sup>44</sup> is a Scoreboard analysis of top corporate R&D investors worldwide, which the European Commission's Joint Research has conducted annually since 2004. The dataset contains economic and financial data of the top 2000 world R&D investors and covers the period 2004-2012. In particular, starting from the top-ranked companies for 2012, historical financial data are collected to analyse their trajectories along the time period considered. Data are collected from the companies' published accounts and refer to the ultimate parent company in the case of consolidated groups. The key variable of the EU R&D Scoreboard is a type of intangible investment, that is, the cash investment in R&D (as from international accounting standards) that the companies funded themselves, excluding those undertaken under contract for customers such as government or other companies.

In addition to R&D, data on net sales, operating profit, capital expenditure, number of employees and market capitalisation are reported. The EU R&D Scoreboard economic data are nominal and expressed in euros with all

foreign currencies converted at the exchange rate of the year-end closing date (31 December). The country attributed to a given company refers to the country where the headquarters are located. Although headquarters are concentrated in a relatively small set of countries, the subsidiaries of top corporate R&D investors are located in more than 200 economies, where the levels of risk and uncertainty may be different. However, corporate R&D performers seemingly concentrate the majority of their subsidiaries in the very same area where the headquarters are located.

In addition to R&D, as additional measures of intangible investment, we consider patents<sup>45</sup>, and we propose a new method to estimate the contribution of intangibles to productivity. For each firm, data on financials and R&D are matched to the number of transnational patents<sup>46</sup> from Patstat. The indirect measure of output elasticity of an intangible is discussed in the next section.

To construct the stocks of physical and knowledge (R&D and patents) capital, we use the well-known perpetual inventory method (PIM) with depreciation rates of 6% and 15% for physical and intangible capitals, respectively. Figure A.1 reports the summary statistics of net sales, capital and labour – used to estimate the MFP – and the two measures of intangible capital, R&D and patents stock.

44 <http://iri.jrc.ec.europa.eu/>

45 The seminal work of Corrado et al. (2005) provides a framework on how to integrate intangible capital into growth accounts, although the implementation and development of measuring intangible capital is still an area for investigation. Indeed, Sullivan and Wurzer (2009) argue that it is not clear how the value of intangibles should be measured in principle, as value itself is not even a clearly defined concept. To capture the value from intangibles, firm-level studies have used balance sheet data on intangibles (Corrado et al., 2009; Gatchev et al., 2009; Marrocu et al., 2011), R&D expenditure (Griliches, 1981; Hall, 1993; and more recently, Chan et al., 2002; Lev, 2004; Sougiannis, 2015; Goodridge et al., 2017), patents and trademarks (Sandner et al., 2011; Crass and Peters, 2014), and indirect measures based on earnings, such as the calculated intangible value (CIV; Stewart, 1995; Lev, 2004; Larkin, 2013; Clausen and Hirth, 2016).

46 See Frietsch and Schmoch (2010) for more information on the comparability of this type of patents.

**Figure A Summary statistics of main variables, 2004-2012**

Variable	Mean	Median	Standard deviation	Min	Max
Net sales (thousand euro)	7,172,374	1,558,998	19,380,611	3.0	357,000,000
Employees	25,175	6,863	54,534	1.0	961,000
Capital stock (thousand euro)	3,526,263	523,982	11,595,852	5.2	194,188,960
R&D stock (thousand euro)	1,199,349	245,070	3,508,389	33.8	41,947,620
Patents stock	309	44	1,029	0.0	18,386

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

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## Measures of MFP and intangibles

A common issue when estimating a firm's multi-factor productivity arises from the positive correlation between the observable input levels and the unobservable inputs and productivity shocks. When firms face a positive productivity shock, they demand a higher level of inputs in order to expand their production output. Conversely, when facing a negative shock, firms tend to decrease their demand for inputs and contract their production. A variety of methods have been proposed to tackle such simultaneous issues ranging from fixed effects (FE) to instrumental variables (IV) and control function (CF).

The CF approach relies on the availability of expenditure on materials. In our sample, information on this expenditure is available for less than 50% of the observations. Therefore, we adopt and compare results from FE and IV approaches.

A measure of MFP is retrieved from the following Cobb-Douglas production function:

$$(1) Y_{it} = I_{it}^{\theta_{INT}} X_{it}^{\theta_X} e^{\varepsilon_{it}},$$

where  $Y_{it}$  is the revenue of firm  $i$  at time  $t$ ,  $I_{it}$  is the intangible capital;  $\theta_{INT}$  is the production elasticity with respect to intangible capital;  $X_{it}$  is a set of tangible and observable inputs, namely, physical capital stock, and labour (number of employees);  $\theta_X$  is the production elasticity with respect to tangible inputs; finally  $\varepsilon_{it}$  is the unobservable idiosyncratic output shock.

Here, the ratio of output to classical inputs (labour and capital) is defined as multi-factor productivity (MFP). Therefore, rewriting eq. (1), we have

$$(2) \frac{Y_{it}}{X_{it}^{\theta_X}} = MFP_{it} = I_{it}^{\theta_{INT}} e^{\varepsilon_{it}},$$

taking logarithms, we can write the MFP as a function of intangible input

$$(3) \log(MFP_{it}) = \theta_{INT} \log(I_{it}) + \varepsilon_{it}$$

To obtain an estimate of  $\log(MFP_{it})$  we use an IV estimator with clustered errors by firm, using the lags (up to two years before) of physical capital and labour inputs as instruments. Moreover, given that we use revenue rather than output, the price variation may be correlated with the input choice. To solve this additional endogeneity issue, we follow Klette and Griliches (1996) and De Loecker (2011) and control the price and demand variation to remove any potential correlation between productivity shocks and all those factors that might have an impact on prices and demand, but are not related to productivity. Specifically, we take the weighted aggregated revenues by NACE sector (at 2-digit), using the firm market shares as weights.

To investigate the role of intangible capital on MFP (equation 3), we use two direct measures of intangibles: R&D and patents. Figure B reports the estimated revenue elasticity of labour and physical capital for three groups of firms, namely those in the high-tech, medium/high-tech and low-tech sectors. The choice of sectors is based on the number of observations per sector<sup>47</sup>.

Results show the elasticity of physical capital with respect to output is smaller in the high-tech sector than in medium/high and low-tech ones. This means that revenues in medium/high-tech and low-tech companies are more sensitive to changes in capital stock than to the number of employees.

The variable 'market demand' is the aggregated industry revenue, which is directly related to price mark-ups (De Loecker, 2011). On average, firms in low-tech industries charge a higher mark-up than in medium/high- and in high-tech. The time trend coefficient shows that only high-tech firms experienced an increasing trend in their revenues during the period 2004-2012. Finally, the estimated returns to scale  $\theta$  are increasing significantly for high-tech firms<sup>48</sup>, while remaining constant for the other two groups of firms.

47 As a robustness check, we tried grouping firms into high-, medium-, and low-tech, and there are no significant differences.

48 The returns to scale are estimated as  $(1 - \hat{\theta}_{\text{mkt dmnd}}) * (\hat{\theta}_{\text{EMP}} + \hat{\theta}_{\text{CAP}})$ .

**Figure B Main business sectors and number of observations by technology intensity<sup>1</sup>**

Sector	High R&D intensity	Medium-high R&D intensity	Low R&D intensity
	Aerospace & defence	Automobiles & parts	Alternative energy
	Biotechnology	Chemicals	Banks
	Computer hardware	Commercial vehicles & trucks	Beverages
	Computer services	Electrical components & equipment	Construction & materials
	Electronic office equipment	Electronic equipment	Electricity
	Health care equipment & services	General industrials	Fixed line telecommunications
	Internet	Household goods & home construction	Food & drug retailers
	Leisure goods	Industrial machinery	Food producers
	Pharmaceuticals	Other financials	Forestry & paper
	Semiconductors	Personal goods	Gas, water & multiutilities
	Software	Support services	General retailers
	Telecommunications equipment	Travel & leisure	Industrial metals & mining
			Industrial transportation
			Life insurance
			Media
			Mining
			Mobile telecommunications
			Nonlife insurance
			Tobacco
			Other
Number of observations	7731	7109	3154

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG JRC B.3

Note: <sup>1</sup>The technology intensity groupings were determined on the basis of R&D expenditure as % of sales.

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**Figure C Instrumental variables (IV) - estimates of production function<sup>1,2</sup>, 2004-2012**

Variable	High R&D intensity	Medium-high R&D intensity	Low R&D intensity
log(Emp)	0.760*** (0.04)	0.385*** (0.04)	0.381*** (0.07)
log(Cap)	0.274*** (0.04)	0.500*** (0.03)	0.481*** (0.05)
Market demand	0.082* (0.04)	0.124*** (0.04)	0.231*** (0.06)
Trend	0.025*** (0.01)	-0.026*** (0.00)	-0.040*** (0.01)
Constant	2.818*** (0.61)	2.989*** (0.55)	1.226 (0.77)
R2	0.827	0.858	0.865
N	3691	3366	1245
$\hat{\theta}$	1.126*** (0.05)	1.011*** (0.05)	1.121*** (0.08)

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Notes: <sup>1</sup>Sector and country dummies included but not reported. Firm clustered errors. <sup>2</sup>\*\*\* = p<0.01; \*\* = p<0.05; \* = p<0.1; standard errors are given in parentheses.

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# CHAPTER

# 11.6



# INTANGIBLE INVESTMENT AND INNOVATION IN THE EU: FIRM- LEVEL EVIDENCE FROM THE 2017 EIB INVESTMENT SURVEY<sup>49</sup>

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<sup>49</sup> A longer version of this chapter is published in the EIB Investment Report 2017/18.

## Executive summary

Investment in knowledge creation is one of the main drivers of long-term prosperity and inclusive economic growth for advanced economies. Innovation is expected to help address pressing societal challenges – including an ageing population, climate change and various health and environmental issues. New products, processes or services will have to be developed, creating new growth opportunities for firms as well as new skills needs and job opportunities for workers.

Firms' innovation activities are typically difficult to measure well. This chapter is based on the EIB Investment Survey (EIBIS), an annual survey with rich information on investment and finance activities of 12 500 firms in all 28 EU Member States. The survey also covers innovation activities with questions on the share of investment in intangible assets as well as that spent to develop or introduce new products, processes and services.

Results from EIBIS show that, when it comes to intangible assets, EU firms in manufacturing invest relatively more in R&D, while companies in services spend a higher share of investment on software and databases. Compared to large companies, small and medium-sized enterprises (SMEs) tend to place a larger share of their investment in intangibles, even after controlling for each country's industry make-up. More productive firms and exporters also invest more in intangibles. This suggests that intangible investments are key for innovation, productivity and economic growth. Firms that invest more in intangibles rely more on internal finance to finance their investments. They also tend to be less satisfied with external finance conditions and are more likely to be finance constrained.

There is a large variation across EU Member States and sectors in how much firms invest on developing or introducing new products, processes and services. Manufacturing firms, high productivity firms and exporters are more likely to introduce products that are new to the global market as they have to compete on international markets. The degree of innovation increases with the diversification of financial instruments: firms using several financial instruments are more likely to invest in R&D and in new products, processes or services compared to firms that use a more limited number of financing instruments.

Public policies in the EU should aim to foster innovation at the technological frontier. However, they should also support firms that adopt existing technologies and innovation diffusion across all companies. Policymakers should take into account the differences between firms which invest in intangibles or introduce new products, processes or services and those that do not, when they design and develop new schemes, in particular innovative financial instruments, to increase and diversify the sources of external finance for innovative firms. At the same time, the diversity of intangible assets should be emphasised so that policies do not only promote R&D investment or manufacturing firms but also innovation by firms in all sectors of the economy.

## 1. Intangible investment in the EIB Investment Survey

Investment in knowledge creation is one of the main drivers of long-term prosperity and inclusive economic growth for advanced economies. Innovation is expected to help address pressing societal challenges – including an ageing population, climate change and various health and environmental issues. New products, processes or services will have to be developed, creating new growth opportunities for firms as well as new skills needs and job opportunities for workers (OECD, 2016). An environment that facilitates investment in innovation and highly innovative firms will support an economy's competitiveness. The ecosystem should also enhance the effective diffusion, circulation, commercialisation and use of this knowledge, especially for firms that do not innovate at the technological frontier (European Commission, 2016).

Firms' innovation activities are typically difficult to measure well. This chapter is based on the EIB Investment Survey (EIBIS), an annual survey with rich information on investment and finance of 12 500 firms in all 28 EU Member States. The results use the second wave of the survey which was conducted in 2017 and refer to investments made by firms in the 2016 fiscal year. The survey covers innovation activities with questions on the share of investment spent on intangible assets as well as on that spent to develop or introduce new products, processes and services.

**The EIB Investment Survey (EIBIS) finds that, in 2016, 37% of investment went into intangible assets, while 63% went into fixed assets.**

The survey covers four different categories of intangible assets: R&D (including the acquisition of intellectual property); software, data, IT networks and website activities; training employees; and organisation and business process improvements. For fixed tangible assets, the two categories are: land, buildings and infrastructure; and machinery and equipment. EIBIS finds that, in 2016, 37% of total investment by non-financial corporations in the EU went into intangible assets, while 63% went into fixed assets<sup>50</sup>. While the share of intangible investment remained stable between 2015 and 2016, expenditure in intangibles went up together with an increase in total investment made by EU firms.

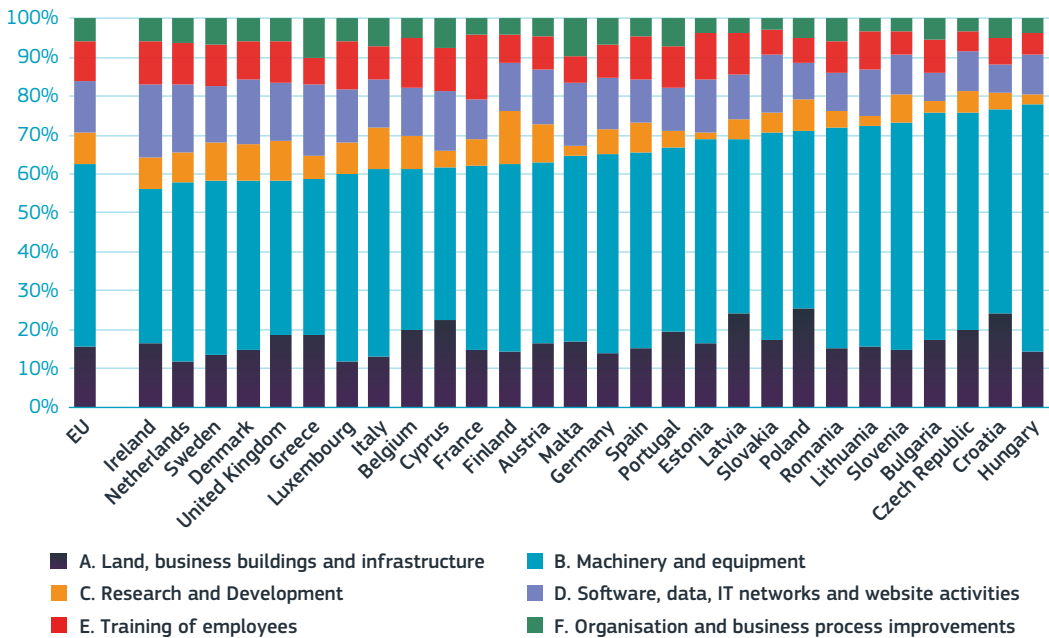
Machinery and equipment represent almost half (47%) of investment by non-financial companies in the EU in 2016. Land, business buildings and infrastructure account for 17% of total investment. Software and databases make up the largest component of intangible investment in the EU, representing around 13% of total investment, followed by employee training (10%), R&D (8%) and organisational and business process improvements (6%).

<sup>50</sup> Investment is highly correlated with fixed assets or turnover. This chapter uses data on the share of intangible investment in total investment, although the findings reported here are similar if intangible investment intensity is defined as the ratio of intangible investment to turnover (or to fixed assets).

There is substantial variation in the share of intangibles across EU Member States, ranging from less than 25% in Hungary, Croatia, Czech Republic and Bulgaria to more than 40% in Greece, the UK, Denmark, the Netherlands and Ireland (Figure II.6.1). The lower share of intangible investment in the Central, Eastern and South-eastern Europe (CESEE) region may be explained by firms in the region catching up in terms of investment in tangible fixed assets.

But across countries, differences in the share of intangible investment are not only driven by the industry composition in each Member State's economy. The higher share of intangible investment in the Northern countries may partly be due to the relatively favourable tax treatment and a better ecosystem for investment in intangibles in these countries. This suggests that there is room for public policy to give incentives to firms to invest more in intangibles in several EU economies.

**Figure II.6.1 Investment by area (%) in EU Member States<sup>1</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

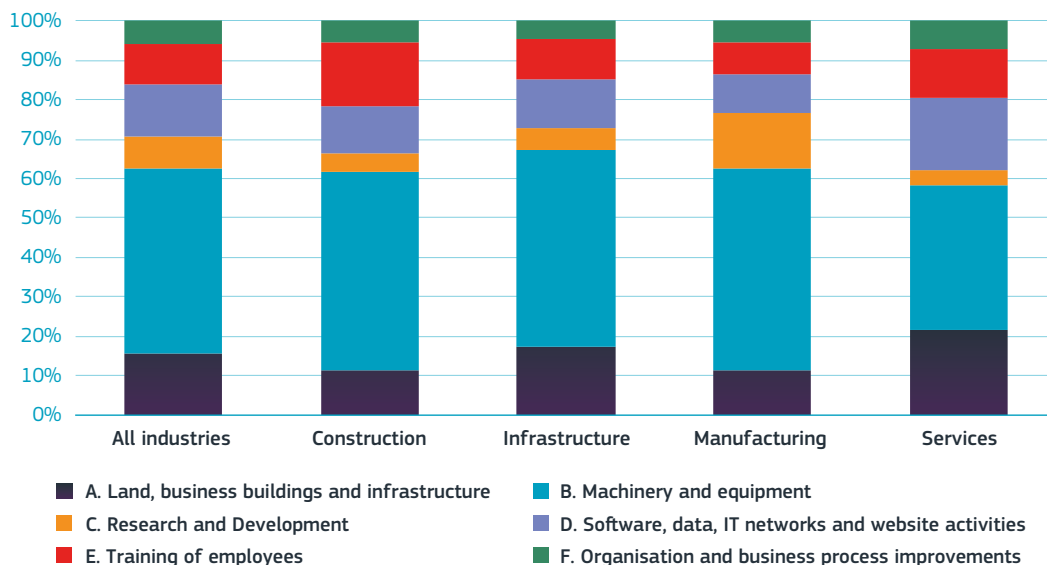
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Note: <sup>1</sup>EIB Investment Survey question: In the last financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings? Base: All firms which have invested in the last financial year (excluding don't know / refused responses). Countries are ordered according to share of intangible investment.

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_1.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_1.xlsx)

**Figure II.6.2 Investment by area (%) in industrial sectors in the EU<sup>1</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Note: 'EIB Investment Survey question: In the last financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings? Base: All firms which have invested in the last financial year (excluding don't know / refused responses).

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### Firms in manufacturing invest relatively more in R&D, while firms in services invest a higher share of investment in software and databases.

The share of intangible investment also varies across industries, with firms in infrastructure investing a third of their investment in intangibles, while this share is 42% for firms in services (Figure II.6.2). Construction is the only industry where there was a marked fall in the share of intangible investment, from 43% of total investment in 2015 to 38% in 2016.

Investments in software, data, IT networks and website activities are particularly relevant for firms in services as this may allow them to

adopt the latest technologies thereby differentiating them from their competitors. Software and databases is also the largest component of intangible investment for firms in infrastructure, which typically invest less in intangible than firms operating in other industries.

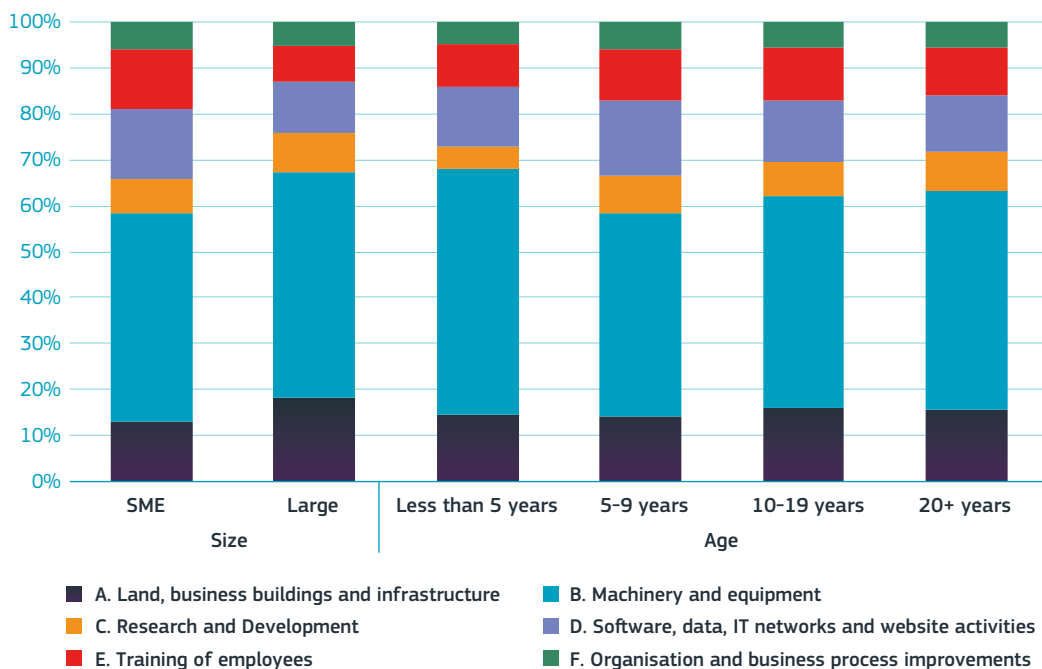
Manufacturing firms conduct much more R&D than the other industries, with R&D investment representing almost 15% of total investment. The share of R&D investment in construction and infrastructure is around 5% of total investment and less than 4% for services. At the same time, company training is the largest component of intangible investment for firms in construction, which could reflect an attempt to compensate for years of labour shedding.

### Compared to large companies, SMEs tend to invest a larger share of their investment in intangibles ...

While the size of the investments is much smaller for SMEs, they tend to invest a higher share in intangibles (42%) compared to larger firms – whose share is one-third (Figure II.6.3). The largest differences are for investment in

software and databases, and employee training. Remarkably, large firms and SMEs invest almost the same shares in R&D and in organisation and business process improvements. The share of intangible investment does not vary much with the company's age, except for very young firms (under five years old), which tend to invest a larger share in machinery and equipment.

**Figure II.6.3 Investment in the EU by area (%) in firms classified by firm size and firm age<sup>1</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Note: <sup>1</sup>EIB Investment Survey question: In the last financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings? Base: All firms which have invested in the last financial year (excluding don't know / refused responses).

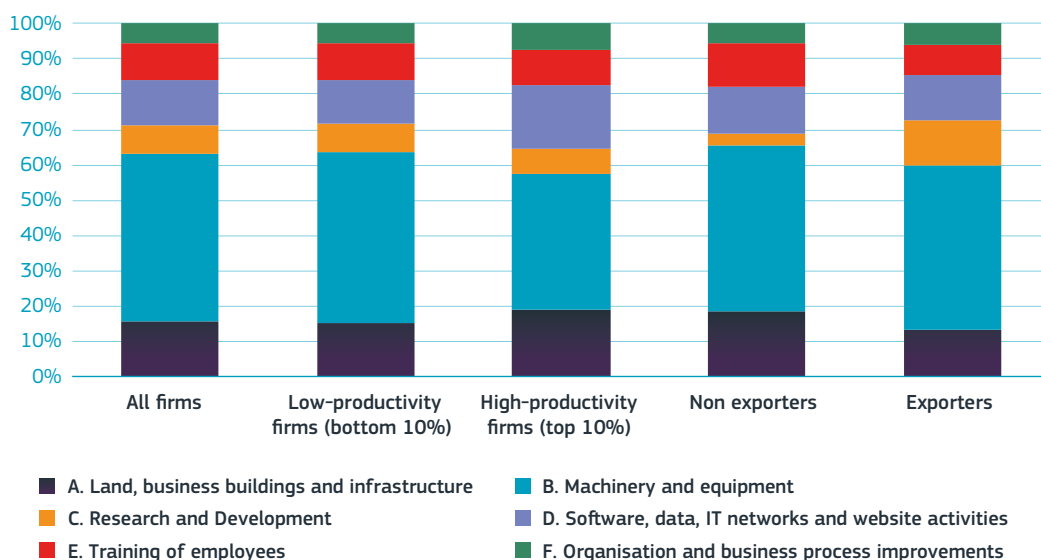
Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_3.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_3.xlsx)

... as well as more productive firms, which invest more in the four components of intangibles, especially in software and databases, and exporters, which invest more in R&D.

High-productivity firms tend to invest more in intangible assets (Figure II.6.4). While low-productivity firms invested less than 30% of their total investment in intangible assets, high-productivity

firms invested 50%<sup>51</sup>. In particular, high-productivity firms invest a much higher share in software, data, IT networks and website activities: almost 20% of total investment, compared to only 11% for low-productivity firms. But high-productivity firms also spend a higher share of investment in the other three intangible assets. The economic literature stresses that firms that export are more productive (Melitz and Redding, 2015): indeed, exporters tend to invest more in intangibles, especially in R&D.

**Figure II.6.4** Investment in the EU by area (%) in firms classified by level of productivity and export status<sup>1,2</sup>, 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Notes: <sup>1</sup>Total factor productivity is the residual of a pooled OLS regression where value added (in logarithm) is the dependent variable and the number of employees and fixed assets (both in logarithm) are explanatory variables. The regressions include the interactions of country and year (2015 and 2016) and are estimated separately for 7 different industries. High-productivity firms (top 10%) are defined as firms in the top 10% of the distribution of total factor productivity in 2016 (i.e. there are 10% of firms with high productivity in each country). Low-productivity firms (bottom 10%) are defined as firms in the bottom 10% of the distribution of total factor productivity within each country in 2016 (i.e. there are 10% of firms with low productivity in each country). Exporters are firms that directly exported goods and services to another country. <sup>2</sup>EIB Investment Survey question: In the last financial year, how much did your business invest in each of the following with the intention of maintaining or increasing your company's future earnings? Base: All firms which have invested in the last financial year (excluding don't know / refused responses).

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51 Regression analysis that takes into account the effects of country, industry, firm size and firm age also finds that firms that invest more in intangible assets (in particular R&D) tend to perform better.

Clearly, while the correlation between intangible assets and firm performance does not imply causation, this firm-level evidence is in line with the macroeconomic literature that finds the decisive role of intangible assets, and especially R&D, as a source of productivity growth (Thum-Thyssen et al., 2017). There is some evidence that the complementarities between investment areas also seem to matter. For instance, firms that invest in machinery and equipment and in employee training at the same time tend to have higher value added or higher turnover.

### **Firms that invest more in intangibles tend to rely less on external finance to finance their investments ...**

Given the increasing role of intangible investment as a source of economic growth for advanced economies, it is critical for effective policymaking to better understand how firms finance their investments in order to relaunch productive investments in the EU. Companies in the EU rely to a large extent on internal funds (62%) to finance their investment activities, while external finance represents only

36% of investment finance<sup>52</sup>. But there is some variation across sectors: infrastructure firms (42%) are more likely to rely on external funds, possibly because they have more collateral to access external finance. The share of external finance also varies with the development of the financial sector across countries: more than 40% of the investment done by firms in France, Belgium and Italy rely on external finance, while the share of external finance for investment activities is less than 20% in Greece and Cyprus.

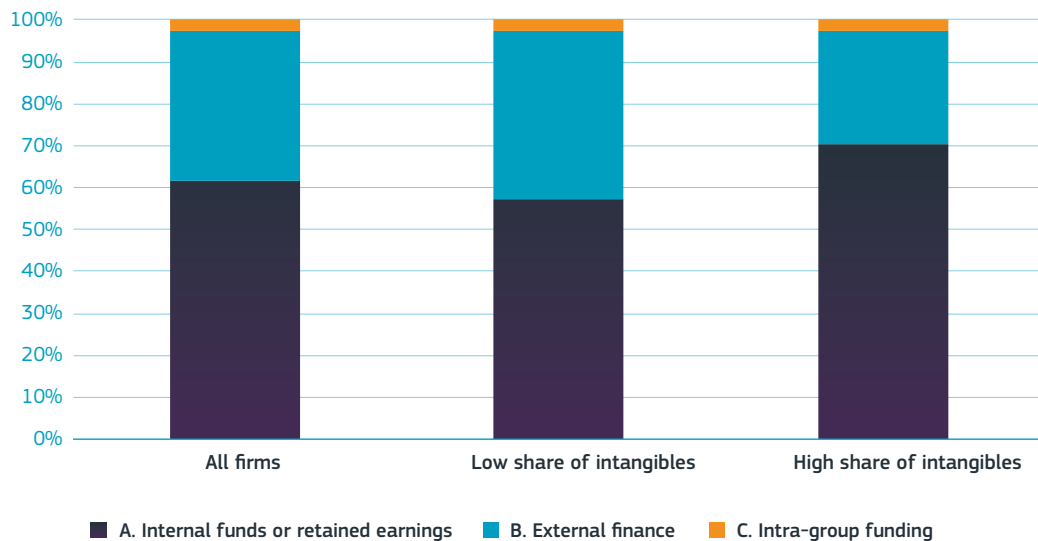
By comparing firms with high intangible investment intensity with those with lower intangible intensity we can identify any differences in the way firms finance their investment<sup>53</sup>. Firms that spend most of their investment on intangibles tend to rely more on internal finance, with a share of 71%, compared to those with lower intangible investment intensity – whose share of internal finance is only 57% (Figure II.6.5). This may also indicate that firms with high intangible investment intensity have more problems providing the requested collateral to access external sources of finance.

<sup>52</sup> See also Box 1 for a more in-depth analysis of the sources of finance and investment activities in R&D.

<sup>53</sup> Firms with high intangible investment intensity are defined as those that invest 50% or more in intangibles from total investment. In the EU, 34% of firms invest a majority of their investment in intangibles. This share varies across industry (ranging from 29% in infrastructure to 39% in services), country (ranging from less than 20% in Hungary, the Czech Republic, Slovakia and Croatia to more than 40% in Sweden and the UK), or firm size classification (larger firms tend to invest less in intangible assets). The results are similar when using a different threshold to define high intangible investment intensity (e.g. above the median of intangible intensity in each country).



**Figure II.6.5 Investment in the EU by sources of finance (%) in firms classified by intangible investment intensity<sup>1,2</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Notes: <sup>1</sup>Firms with a high share of intangible investment invest 50% or more of their investment into intangible assets.

<sup>2</sup>EIB Investment Survey question: Approximately what proportion of your investment in the last financial year was financed by each of the following? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

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**... and are typically less satisfied with the conditions of external finance accessed and are more likely to report that they are finance constrained.**

There are also substantial differences in the satisfaction with external finance between firms with high intangible investment intensity and those with low intangible investment intensity. Firms who invest more in intangibles are more likely to report that they are dissatisfied with the conditions for external finance that they accessed. This holds true along different dimensions of external finance, particularly regarding the amount obtained, the cost of funding and the collateral requirements.

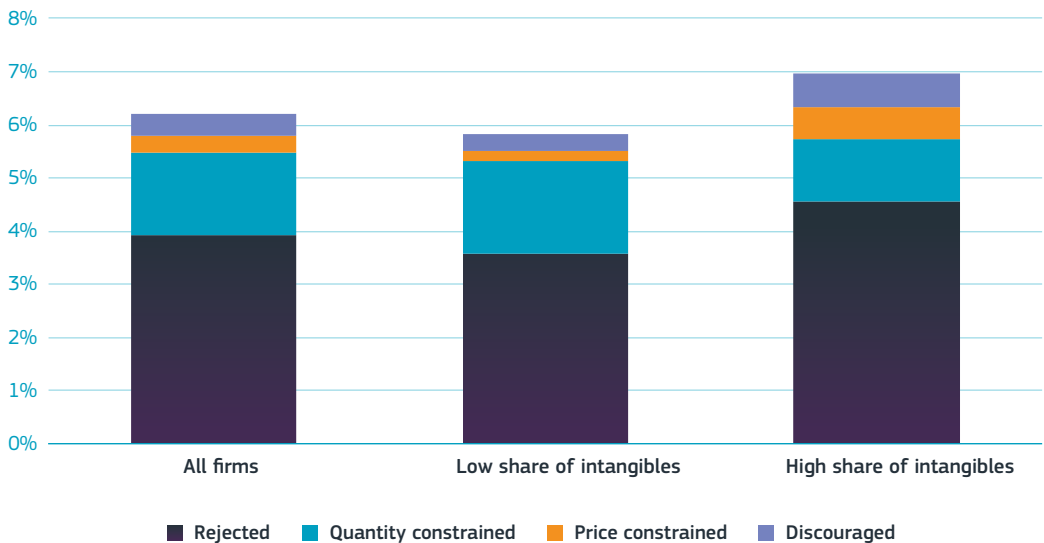
Firms with high intangible intensity do not only report being less satisfied with the conditions for external finance they access, but are also more likely to be financially constrained (Figure II.6.6). Finance-constrained firms can be classified in four categories (Figure II.6.7): those that were unable to access finance when seeking it (“rejected”); firms receiving less than they asked for (“quantity constrained”); those which did not seek external finance because they thought that the borrowing costs would be too high (“price constrained”); and firms which did not seek external finance because they thought that they would be turned down (“discouraged”).

When they apply for external finance, firms with high intangible intensity report being rejected much more frequently. They are also more likely to report that they found the loan offer too expensive or that they simply did not apply because they were discouraged. While more productive firms and exporters are *less* likely to be finance constrained, firms that invest more in intangible assets are *more* finance constrained. This could be linked to the fact that intangible assets cannot always be used as collateral.

Policymakers should take into account the differences between firms that invest little and those that invest a lot in intangible assets when they design and develop new schemes, in particular innovative financial instruments, to support intangible investment in the EU. Differences include the fact that they are more

productive and export more, the lower share of external finance for firms that invest more in intangibles, or that they are more likely to be financially constrained. Clearly, some new policy measures could be developed to increase and diversify the sources of external finance for firms that invest in intangibles. More generally, the strong association between intangible investment and productivity at both the firm-level and the macroeconomic level indicates that there is scope for governments to take policy measures to make investment in intangible assets more attractive for firms in the EU. At the same time, the diversity of intangible assets and their complementarity should be emphasised so that public policies do not only promote R&D investment or manufacturing firms, but also cover other intangible investment by firms in all sectors of the economy.

**Figure II.6.6 % share of firms in the EU that are financially constrained, by category and classified by intangible Investment intensity<sup>1</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

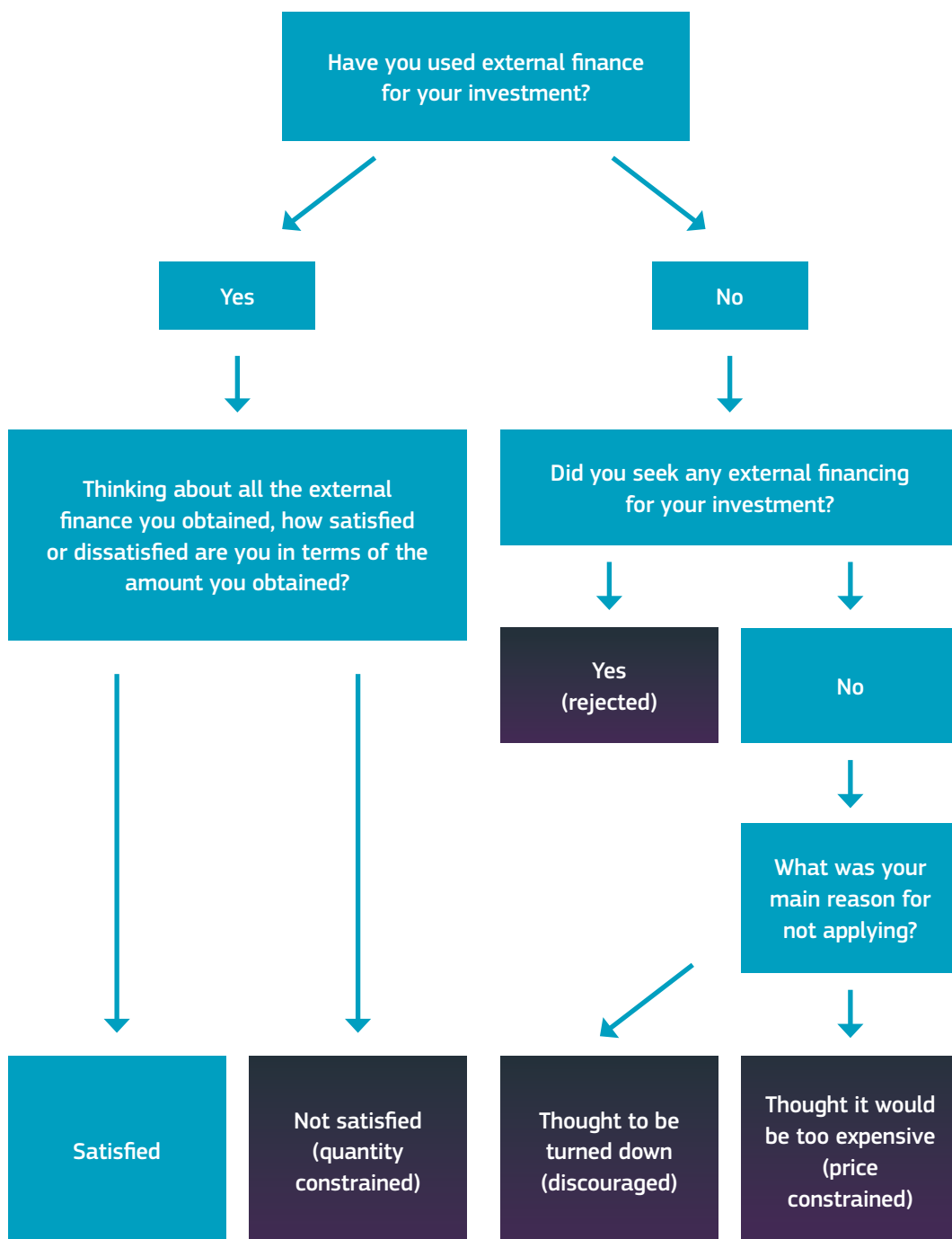
Data: EIB Investment Survey.

Note: <sup>1</sup>Firms with a high share of intangible investment invest 50% or more of their investment into intangible assets.

Base: All firms which invested in the last financial year (excluding don't know / refused responses).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_6.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_6.xlsx)

Figure II.6.7 An indicator of finance-constrained firms with EIBIS



Source: EIB (2017).

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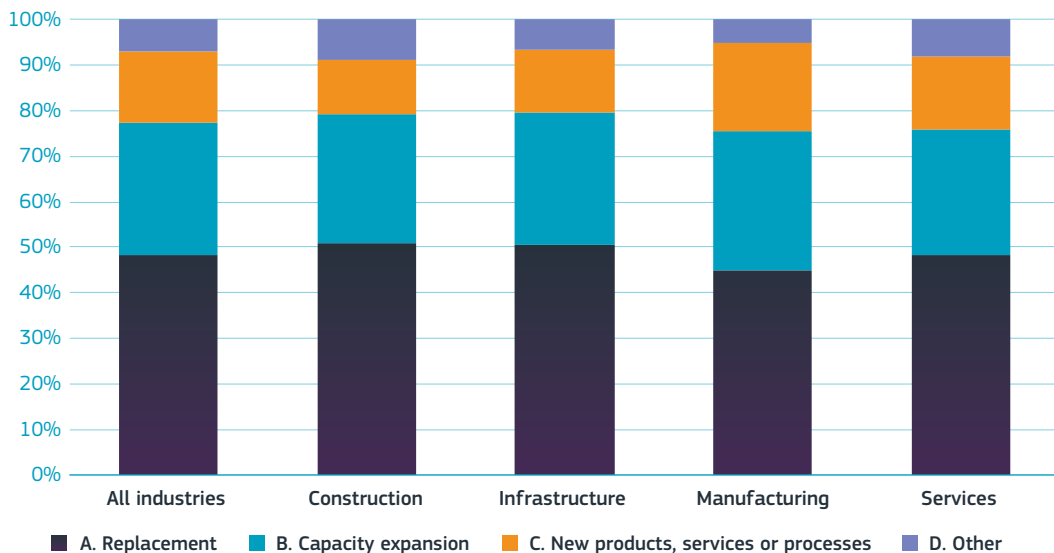
## 2. Investing in new products, processes or services

In addition to R&D and intangible investment, EIBIS asks a question about the share of investment spent on different investment purposes. In 2016, almost half (48%) of total investment was spent on replacing existing buildings, machinery, equipment and IT (Figure II.6.8), while around 29% went into capacity expansion and 16% was spent on developing or introducing new products, processes or services. Clearly, replacement remains the investment priority for firms in the EU.

**Compared to other sectors, firms in manufacturing tend to spend a higher share of their investment on developing or introducing new products, processes and services ...**

When discussing innovation, the category that is more directly relevant is whether firms invest to develop or introduce new products, processes or services. Firms in manufacturing tend to spend more on new products, with a 19% share of total investment compared to services (16%), infrastructure (14%) and only 12% of total investment in construction. While there is little variation in the share of investment for different purposes across firm size, older firms tend to spend a higher investment share on replacement and a lower share on capacity expansion (Figure II.6.9). However, older firms do not spend less on developing or introducing new products, processes or products, which suggests that new products, processes or services do not only come from young and small firms.

**Figure II.6.8 Investment in the EU by purpose as % of total investment<sup>1</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

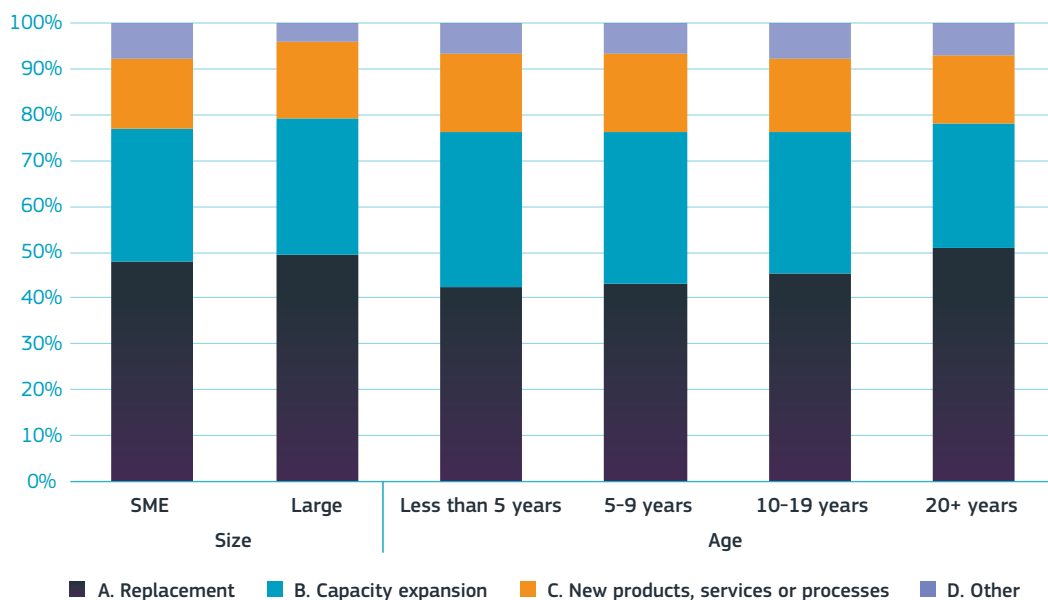
Note: <sup>1</sup>EIB Investment Survey question: What proportion of the total investment in the last financial year was for...? Base: All firms which invested in the last financial year (excluding don't know / refused responses)

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_8.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_8.xlsx)

More productive firms and exporters invest a larger share of investment in developing or introducing new products, processes or services (Figure II.6.10). And this pattern is not only driven by manufacturing firms, which indicates that firms wanting to remain at the technological or productivity frontier and needing to compete with firms from other countries in export markets must invest in new products to maintain their market share.

The variation in investment purposes across countries is also substantial (Figure II.6.11). The share of investment spent on developing or introducing new products, processes or services varies from less than 12% of total investment in Slovenia and Slovakia to more than 18% in Denmark, Finland and Italy. Firms operating in different EU Member States have different investment priorities due to the economic cycle but also to more structural features of the economy, such as the concentration and competition in some specific industries, as well as the public support provided to innovative firms.

**Figure II.6.9** Investment in the EU by purpose as % of total investment in firms classified by size and firm age<sup>1</sup>, 2016



Science, Research and Innovation performance of the EU 2018

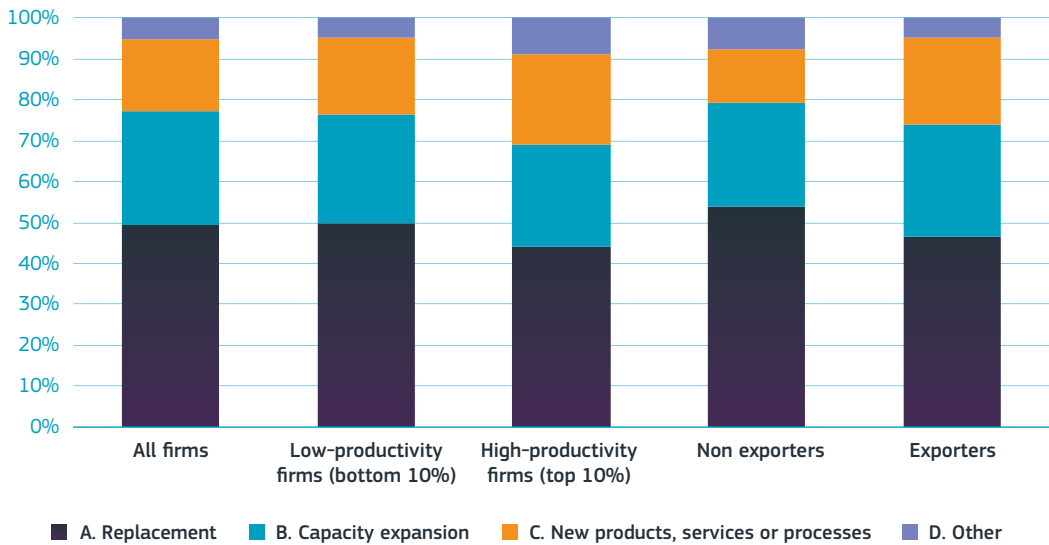
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Note: EIB Investment Survey question: What proportion of the total investment in the last financial year was for...? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_9.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_9.xlsx)

**Figure II.6.10 Investment in the EU by purpose as % of total investment in firms classified by level of productivity and export status<sup>1,2</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

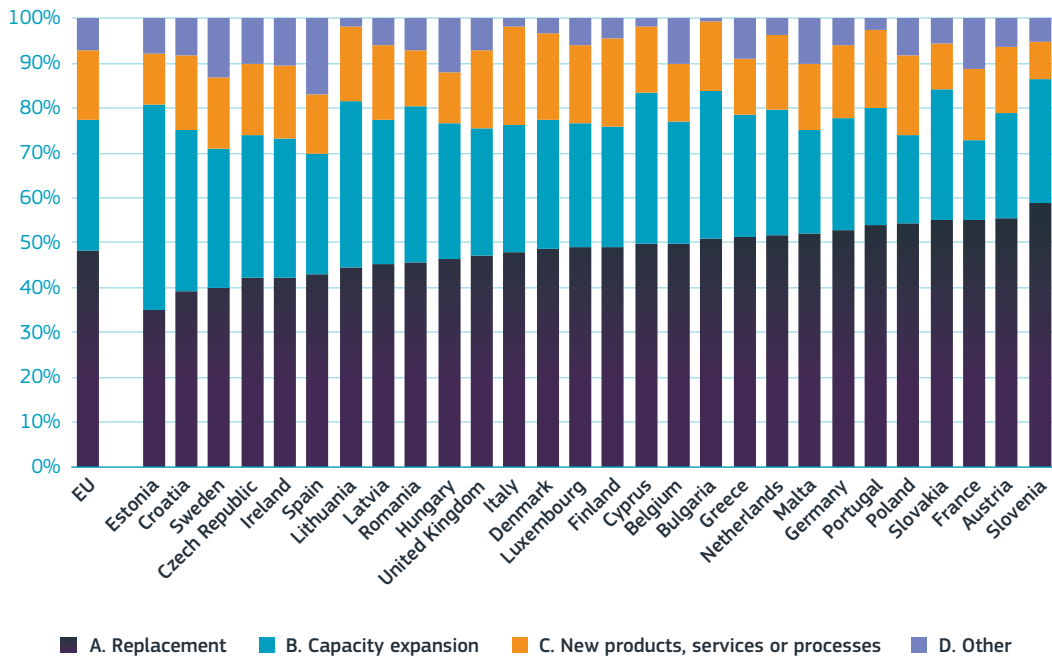
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
 Data: EIB Investment Survey.

Notes: <sup>1</sup>Total factor productivity is the residual of a pooled OLS regression where value added (in logarithm) is the dependent variable and the number of employees and fixed assets (both in logarithm) are explanatory variables. The regressions include the interactions of country and year (2015 and 2016) and are estimated separately for 7 different industries. High-productivity firms (top 10%) are defined as firms in the top 10% of the distribution of total factor productivity in 2016 (i.e. there are 10% of firms with high productivity in each country). Low-productivity firms (bottom 10%) are defined as firms in the bottom 10% of the distribution of total factor productivity within each country in 2016 (i.e. there are 10% of firms with low productivity in each country). Exporters are firms that directly exported goods and services to another country.

<sup>2</sup>EIB Investment Survey question: What proportion of the total investment in the last financial year was for...? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

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**Figure II.6.11 Investment by purpose as % of total investment, by EU Member State<sup>1</sup>, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Note: <sup>1</sup>EIB Investment Survey question: What proportion of the total investment in the last financial year was for...? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_11.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_11.xlsx)

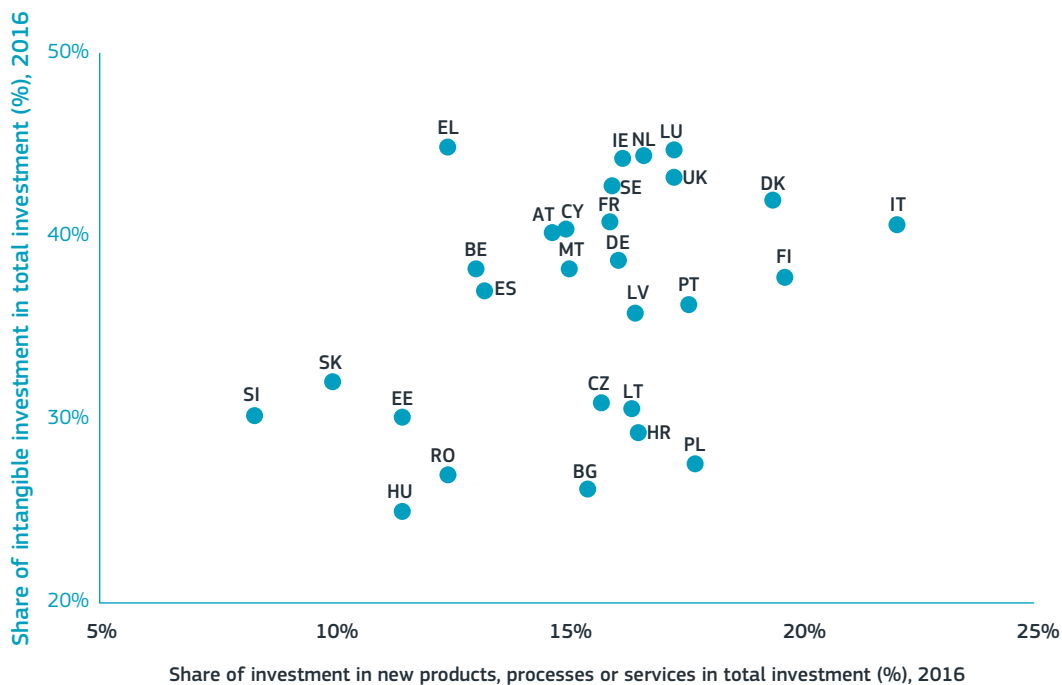
### ... and their innovation activities are correlated with investment in intangibles.

There is a positive correlation between the share of investment of the total investment spent on intangibles (R&D, company training, organisational capital, and software and databases) and the share invested in developing or introducing new products, services or processes (Figure II.6.12)<sup>54</sup>. When looking at the different components of intangible assets, R&D investment is the main driver of this positive correlation between intangible assets and investing in the development or introduction

of new products, processes or services. However, investments in organisation and business process improvements matter as well, across all sectors. In addition, investing in software and databases is also relevant for firms in services and infrastructure. This emphasises yet again the importance of the complementarity across intangible assets for firm innovation, suggesting that public policies aiming to support innovation in the EU should not only promote R&D investment.

Given the increasing role of intangible investment as well as the need to develop and introduce new products, processes or services to maintain the

**Figure II.6.12 % share of investment in new products, processes or services<sup>1</sup> and % share of investment in intangible - EU Member States, 2016**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

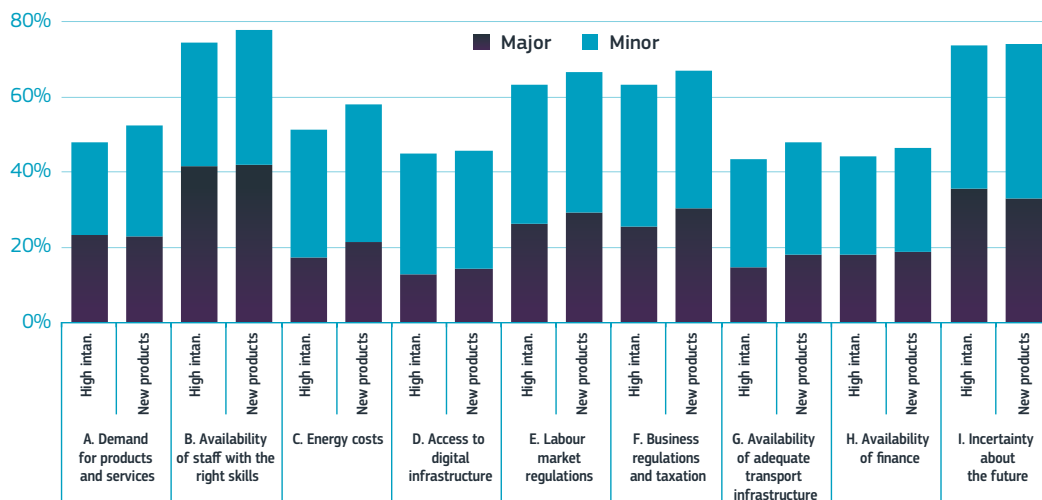
Note: <sup>1</sup>EIB Investment Survey question: What proportion of the total investment in the last financial year was for developing or introducing new products, processes or services? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_12.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_12.xlsx)

54 The results also hold true in a regression at the firm level that controls the effects of country, sector, firm size and firm age.



**Figure II.6.13** Long-term obstacles to investment for firms in the EU that invest more than 50% in intangibles or for firms in the EU that invest in developing or introducing new products, processes or services - % share of firms<sup>1,2</sup>, 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Notes: <sup>1</sup>Firms with a high share of intangible investment invest 50% or more of their investment into intangible assets.

Firms with "new products" invest into developing or introducing new products, processes or services. <sup>2</sup>EIB Investment Survey question: Thinking about your investment activities, to what extent is each of the following an obstacle? Is a major obstacle, a minor obstacle or not an obstacle at all?

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competitiveness of EU firms, it is important to understand the constraints that hold back investment for innovative firms. EU firms consider uncertainty about the future and the availability of staff with the right skills as the main structural barriers to investment, with more than two-thirds considering them to be an obstacle to their investment activities. The majority of EU firms consider that business regulations and taxation, labour market regulations, and energy costs are also serious long-term obstacles.

A focus on firms with a high share of intangible investment and on those that develop new products, processes or services suggests that innovative firms tend to face similar long-term obstacles (Figure II.6.13), which is likely to be driven by the high correlation between the two

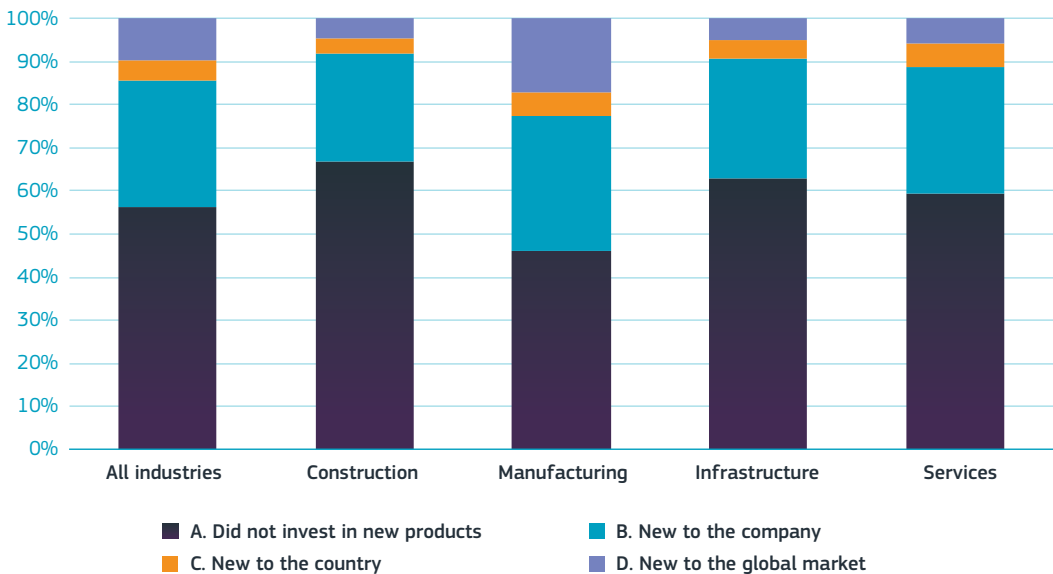
measures of innovative activities. Importantly, some structural barriers to investment are more severe for innovative firms than for the remaining EU companies. For instance, innovative firms – especially those that develop or introduce new products, processes or services – are much more likely to report that the availability of staff with the right skills is an obstacle to investment. In addition, labour market and business regulations also tend to be more serious constraints for innovative firms. At the same time, they are less likely to report energy costs as a long-term obstacle. Differences in the severity of obstacles experienced by firms that invest in intangible and in new products, processes or services, compared to those that do not, should be taken into account when developing policy measures to support innovation in the EU.

### There is a large variation in innovative activities across EU Member States and sectors, with manufacturing firms much more likely to introduce products that are new to the global market.

Firms in manufacturing are more likely to introduce products, processes or services that are new to the global market (Figure II.6.14). This is partly driven by the fact that manufacturing firms conduct more business R&D and are more likely to export their goods and services. In fact, high-productivity firms and exporters tend to develop and introduce more products that are new to the country and global market, suggesting that innovation at the technological frontier is especially relevant for them if they want to remain competitive (Figure II.6.15).

However, innovation does not necessarily need to come through the development or introduction of products, processes or services that are new to the global market. Firms can also adopt existing technologies. For instance, in Italy and Portugal, where the majority of the firms invested in introducing and developing new products, processes and services, more than two-thirds of the innovators consider that the new products were new to the company only (as opposed to new to the country or new to global markets). At the same time, in some countries where a few firms invested in new products, processes or services – such as Spain or Slovenia – the small number of innovators consider that the new products are new to the global market (Figure II.6.16). But, in addition to innovation at the technological frontier, it is vital for all EU countries to foster innovation diffusion, too, so that all firms move closer to the frontier.

**Figure II.6.14 Investment in the EU in new products, processes or services new to the company, the country or global market as % of total investment<sup>1</sup>, 2016**



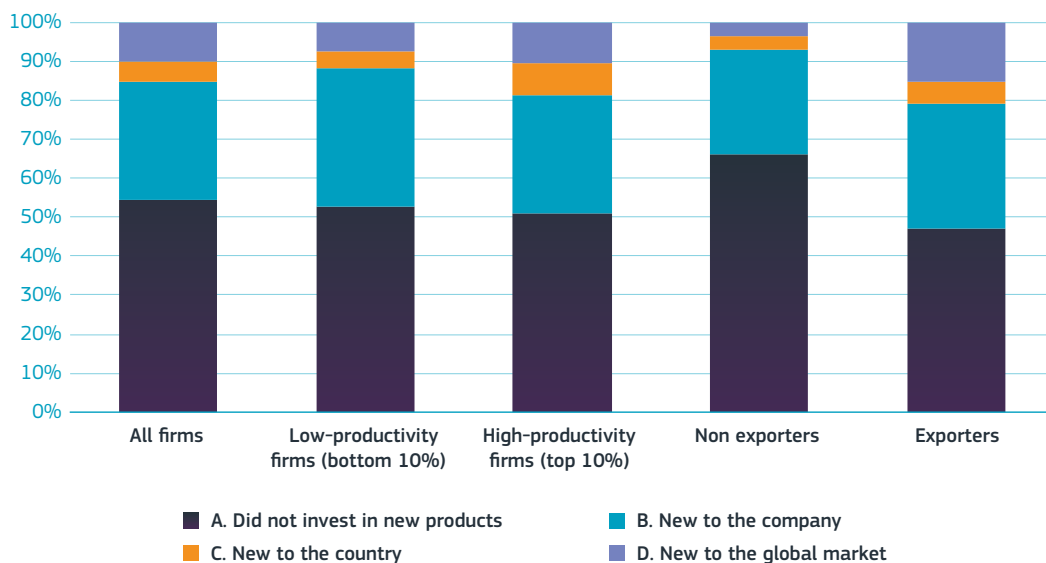
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: EIB Investment Survey.

Note: <sup>1</sup>EIB Investment Survey question: Were the new products, process or services new to...? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

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**Figure II.6.15** Investment in the EU in new products, processes or services new to the company, the country or global market as % of total investment in firms classified by level of productivity and export status<sup>1,2</sup>, 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies  
Data: EIB Investment Survey.

Notes: <sup>1</sup>Total factor productivity is the residual of a pooled OLS regression where value added (in logarithm) is the dependent variable and the number of employees and fixed assets (both in logarithm) are explanatory variables. The regressions include the interactions of country and year (2015 and 2016) and are estimated separately for 7 different industries. High-productivity firms (top 10%) are defined as firms in the top 10% of the distribution of total factor productivity in 2016 (i.e. there are 10% of firms with high productivity in each country). Low-productivity firms (bottom 10%) are defined as firms in the bottom 10% of the distribution of total factor productivity within each country in 2016 (i.e. there are 10% of firms with low productivity in each country). Exporters are firms that directly exported goods and services to another country. <sup>2</sup>EIB Investment Survey question: Were the new products, process or services new to...? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

Stat. link: [https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_ii\\_6\\_15.xlsx](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_ii_6_15.xlsx)

To explore further the role played by finance in EU firms' innovation activities, Box 1 (prepared by Annalisa Ferrando and Senad Lekpek) introduces a cluster analysis which links various financing instruments firms use when investing in their innovation behaviour. The analysis shows that firms with diversified financial instruments are significantly more likely to invest in R&D activities and develop products new to the market or globally new compared to those

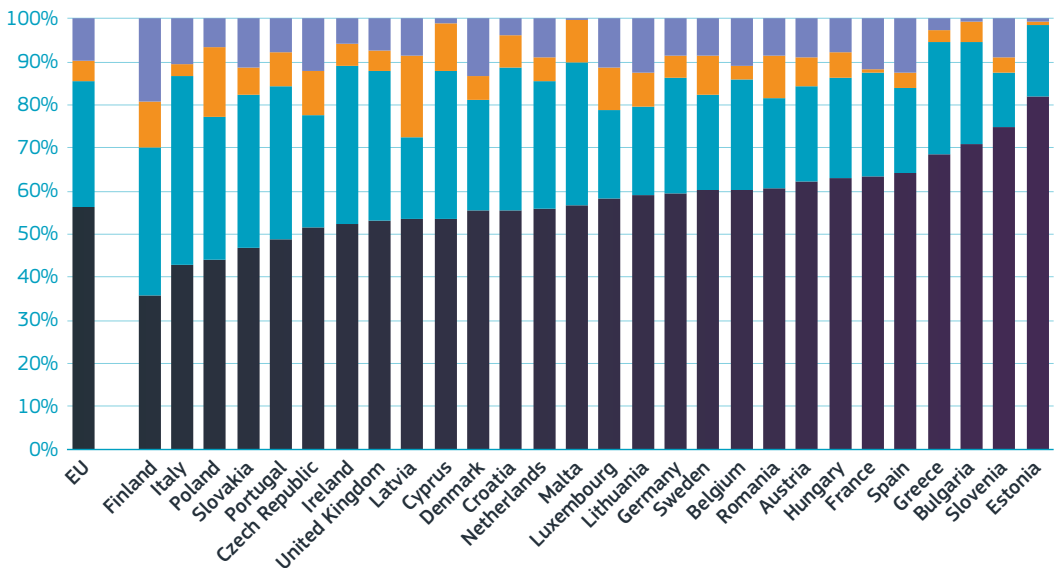
using fewer financing instruments (e.g. those that only use internal finance or bank-related products). In addition, it suggests that innovative firms are less likely to rely entirely on bank financing and use mostly internal financing.

Policymakers should support the diffusion of innovation by all firms so that the benefits of innovation are not concentrated in a limited number of companies. The EIB (2017), espe-

cially the chapter by Veugelers et al., introduces different types of innovators and discusses how they finance their innovative activities. While there is a debate among policymakers on the best way to increase incentives for investment in intangible assets and innovation through different financial instruments (including direct funding with public procurement and grants and indirect funding such as R&D tax incentives), the results in EIB (2017) suggest that grants are positively associated with innovative activities. At the same time, countries

with more favourable tax treatment for intangible investment tend to have more innovative firms. This suggests that the incentives provided by public authorities would appear to go in the right direction. But to better understand whether – and through which mechanisms – public support can lead to intangible investment and innovation, further analysis is needed to identify the policy measures that work best in different EU Member States and how to adapt them to the local context.

**Figure II.6.16** Investment in new products, processes or services new to the company, the country or global market as % of total investment, by EU Member State<sup>1</sup>, 2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: EIB Investment Survey.

Note: <sup>1</sup>EIB Investment Survey question: Were the new products, process or services new to...? Base: All firms which invested in the last financial year (excluding don't know / refused responses).

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## BOX 1: Access to finance and the innovativeness of EU firms<sup>55</sup>

*Annalisa Ferrando and Senad Lekpek*

We use cluster analysis to group EU firms using information on their financing decisions in order to understand the link between finance and innovation. We identify seven financing clusters and show that the degree of innovativeness increases with the diversification of financial instruments: firms that use several financing instruments are more likely to invest in R&D activities and develop new products compared to those which use a more limited number of financing instruments.

### Identifying clusters of financing instruments for EU firms

Cluster analysis divides data into groups in a way that firms inside the groups are homogenous while the groups are very distinct from each other. We use cluster analysis to identify groups of firms that use similar financing instruments. The clusters are formed using firm-level data from EIBIS. The survey includes questions on choices of finance for firms in the EU. First, they were asked what percentage of their investment was financed: 1) internally; 2) externally; and 3) using intra-group funding. Second, firms were asked whether their external financing included one or more of the following options: 1) bank loans excluding subsidised bank loans, overdrafts and other credit lines; 2) other terms of bank finance including overdrafts and other credit lines; 3) newly issued bonds; 4) newly issued equity; 5) leasing or hire purchase; 6) factoring/invoicing discounting; 7) loans from family/friends/business partner; 8) grants; and 9) other types of finance not otherwise specified. These financing instruments were used as variables for identifying different firm clusters.

The empirical analysis is based on data from the 2016 wave of the EIBIS survey which refers to investment decisions in 2015. Of the 12 500 enterprises interviewed, 9067 answered the relevant questions for cluster identification.

**Seven distinct clusters are identified<sup>56</sup>.** Figure A presents the clusters by starting with those using a mix of finance instruments and moving towards clusters that use fewer financing options.

- ▶ **Mixed financed (intra group):** this cluster comprises 270 (3%) firms that use a mix of up to 10 different financing instruments relying in particular on intra-group financing (used by all firms in the cluster).
- ▶ **Mixed financed (grants):** this cluster includes 482 (5.3%) firms that use all 11 financing instruments with a special focus on grants (support from public sources) which are used by all firms in this cluster.
- ▶ **Mixed financed:** this cluster includes 1165 (12.8%) firms that use a mix of up to 11 financing instruments.
- ▶ **Asset/debt-backed financing:** this cluster consists of 1000 (11%) firms that rely on asset-backed financing. Specifically, all firms in this cluster use leasing or hire purchase.
- ▶ **Internal/bank loan financing:** this cluster includes 1325 (14.6%) firms that use internal funding and bank loans to finance their investment activities.

55 This analysis will be published in the EIB Investment Report 2017/18.

56 The algorithm used to identify the clusters is the Ward's method – a type of hierarchical clustering technique. To test the validity of the cluster solution we use the Elbow criteria proposed by Hair et al. (2010).

- ▶ **Internal financing only:** this cluster is the largest one in our study, comprising 4554 (50.2%) firms that finance their investment activities using internal funding.
- ▶ **Bank financing only:** the last cluster includes 271 (3%) firms that rely solely on bank financing.

**Figure A: Cluster composition**

	Mixed financed (intra- group)	Mixed financed (grants)	Mixed financed	Asset/ debt-backed financing	Internal/ bank loans financing	Internal financing only	Bank financing only	Pearson Chi <sup>2</sup>
Internal	54.1%	89.2%	83.9%	80.8%	100%	100%	0 %	3927.4**
Intra-group	100%	2.3%	1.7%	0%	0%	0%	0%	8119.6**
Bank loans	31.9%	50.4%	44.7%	35.0%	100%	0%	100%	5810.2**
Other bank finance	12.2%	20.1%	67.6%	0%	0%	0%	0%	5087.1**
Newly issued bonds	0%	1.9%	4.7%	0%	0%	0%	0%	330.0**
Newly issued equity	1.1%	1.2%	3.3%	0%	0%	0%	0%	220.2**
Leasing/ hire purchase	20.4%	23.2%	37.7%	100%	0%	0%	0%	6299.7**
Factoring/ invoicing	5.2%	8.7%	21.3%	0%	0%	0%	0%	1450.0**
Family/ friends	1.5%	6.2%	19.5%	0%	0%	0%	0%	1382.3**
Grants	1.1%	100%	0.9%	0%	0%	0%	0%	8817.4**
Other	1.1%	0.6%	5.8%	0%	0%	0%	0%	415.4**
N	270	482	1165	1000	1325	4554	271	9067
Percentage of firms	3.0%	5.3%	12.8%	11.0%	14.6%	50.2%	3.0%	

Pearson's chi-square test: \*\*p < 0.01, \*p < 0.05. The results are based on EIBIS16 survey data, referring to year 2015.

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## What are the main characteristics of firms belonging to different clusters?

Figure B presents the distribution of firm size (number of employees) for the seven clusters in our study. The figure shows that, in general, the mixed financed clusters include larger firms compared to clusters that use fewer financing instruments. For instance, 72% of firms in the Mixed financed (intra-group) cluster are large firms, 21% are medium, 5% are small, and only 1% belongs to the micro-firm size category. Similarly, in the Mixed financed (grants) cluster, 51% of companies are large, 29% are medium, 16% are small and 3% are micro firms. On the other hand, in the Bank financing cluster, 27% of firms are large, 23% are medium, 35% are small and 15% are micro-size firms.

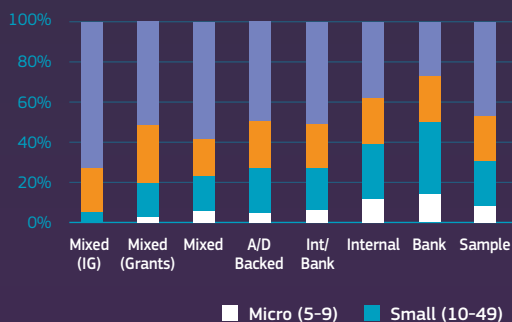
Looking at the sectoral composition, Figure C shows there are no striking differences across the seven clusters, except in the Asset/debt-backed financing cluster where firms come less often from

the services sector and more often from infrastructure. This is not surprising as leasing is more common for infrastructure firms that have more tangibles compared to service-sector companies.

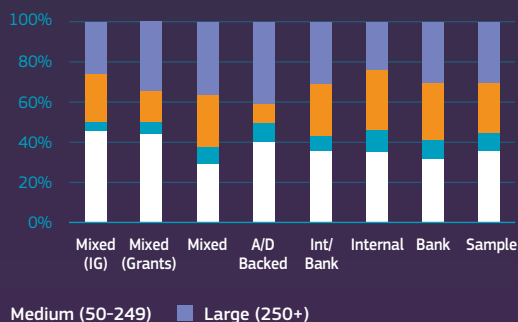
The distribution of firms in terms of their age does not differ significantly across different clusters. Similarly, when looking at the profitability of firms, in most of the clusters the fraction of firms operating at a loss is between 7% and 10%, while the remainder operate at a profit. The exception is the Mixed financed (intra-group) cluster where 36% of firms operate at a loss.

Figure D presents the financing clusters composition in the three country groups. In cohesion countries, firms are more likely to be in the internally financed cluster, and less likely to be in the bank-related financing clusters (bank financing only and internal/bank financing). Furthermore, firms from cohesion countries belong more often to the cluster that relies in particular on support from public sources of finance (Mixed financed - grants).

**Figure B: Firm size by financing clusters (weighted percentages)**



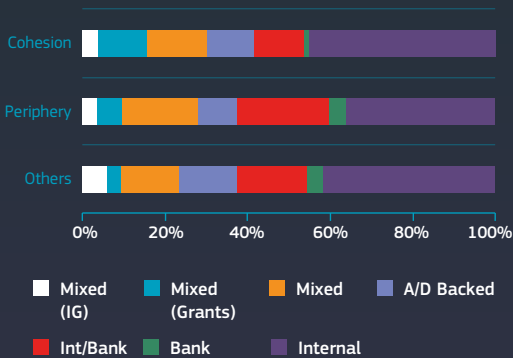
**Figure C: Sectoral breakdown of financing clusters (weighted percentages)**



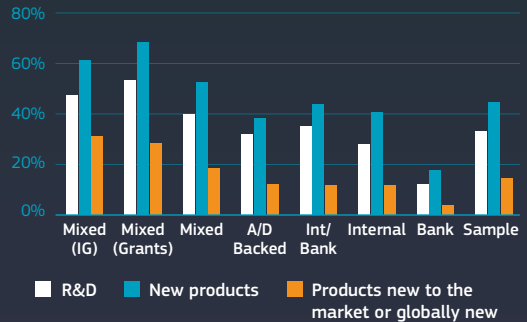
Note: EIBIS16 survey data, referring to year 2015.

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[https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_C.png](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_C.png)

**Figure D: Country groups and financing clusters**



**Figure E: Firm innovativeness by financing clusters**



Note: EIBIS16 survey data, referring to year 2015.

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[https://ec.europa.eu/info/sites/info/files/srip/partii/partii\\_6/figure\\_E.png](https://ec.europa.eu/info/sites/info/files/srip/partii/partii_6/figure_E.png)

### Financing instruments clusters and the innovativeness of EU firms

This section investigates whether the heterogeneity of firms across the innovation dimension is related to the firm finance mix. In Figure E, we plot three indicators of firm innovativeness for the seven financing clusters. The indicators show the fraction of firms that: 1) invested in research and development activities; 2) issued products new to the company; and 3) issued products new to the market or globally new. The figure shows that all three indicators are higher for firms with a more diversified financing mix. For instance, the percentage of firms that invest in R&D activities is 47% for the Mixed (intra-group) and 54% for the Mixed (grants) clusters, while the average for Bank financing and Internal financing clusters is 12% and 28%, respectively. Similarly, the fraction of firms issuing new products is 62% for the Mixed (intra-group), 69% for the Mixed (grants), and 53% for the Mixed financed cluster, while in the remaining cluster the percentage of firms issuing new products is lower. Finally, in the Mixed financed clusters the share of firms developing products new to the market or globally new ranges between 18% and 31%, compared to only 3% to 12% in the remaining clusters.

Next, to further investigate the link between firm innovativeness and finance, we run a logistic regression model. This allows us to control for the differences in firm size, age, industry and country. We use the three innovativeness indicators as dependent variables and finance clusters as independent variables. Figure F presents the results which suggest that firms in the Bank financing cluster are less likely to have invested in R&D activities compared to the Internal financing cluster (omitted – reference category). Firms in Internal/bank loans and Asset/debt-backed clusters are not significantly different from the internally financed firms. On the other hand, firms in Mixed financed and Mixed financed (grants) cluster are significantly more likely to invest in research and development activities. When it comes to issuing new products, firms in the Bank financing only cluster are less likely to have new products than the internally financed firms, while firms in all three mixed financed clusters are more likely to have new products than the internally financed firms. Similarly, firms in the three mixed financed clusters are more likely to issue products that are new to the market or globally new.



Figure F: Firm innovation and financing clusters

	R&D	New products	Products new to the market or globally new
Bank financing only	-0.13**	-0.19***	-0.08***
	(0.06)	(0.05)	(0.02)
Internal/bank loans financing	0.05	0.03	0.01
	(0.03)	(0.03)	(0.02)
Asset/debt-backed financing	0.00	-0.05	-0.02
	(0.04)	(0.04)	(0.03)
Mixed financed	0.07**	0.09**	0.05*
	(0.03)	(0.04)	(0.03)
Mixed financed (grants)	0.20***	0.22***	0.12***
	(0.04)	(0.04)	(0.04)
Mixed financed (intra-group)	0.07	0.16**	0.15***
	(0.06)	(0.06)	(0.05)
Observations	8139	8212	7827
Pseudo R2	0.148	0.073	0.093

Reported are marginal effects estimated after logistic regression. Omitted (reference) category is the Internal financing cluster. Robust standard errors in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Controls include firm size, age, country and industry dummies. The results are based on EIBIS16 survey data, referring to year 2015.

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# **METHODOLOGICAL ANNEX**

## Symbols and abbreviations

### Country codes

BE	Belgium	EU	European Union
BG	Bulgaria	IS	Iceland
CZ	Czech Republic	NO	Norway
DK	Denmark	CH	Switzerland
DE	Germany	ME	Montenegro
EE	Estonia	MK	The former Yugoslav Republic of Macedonia
IE	Ireland	AL	Albania
EL	Greece	RS	Serbia
ES	Spain	TR	Turkey
FR	France	BA	Bosnia and Herzegovina
HR	Croatia	MD	Moldova
IT	Italy	UA	Ukraine
CY	Cyprus	AM	Armenia
LV	Latvia	GE	Georgia
LT	Lithuania	IL	Israel
LU	Luxembourg	TN	Tunisia
HU	Hungary	ERA	European Research Area
MT	Malta	US	United States
NL	Netherlands	JP	Japan
AT	Austria	CN	China
PO	Poland	KR	South Korea
PT	Portugal	RU	Russian Federation
RO	Romania	IN	India
SI	Slovenia	BR	Brazil
SK	Slovakia	ZA	South Africa
FI	Finland	Row	Rest of the World
SE	Sweden		
UK	United Kingdom		

### Other abbreviations

- : 'not available'
- 'not applicable' or 'real zero' or 'zero by default'

## Science, Research and Innovation performance report

### Gross domestic product

*Definition:* Gross domestic product (GDP) data have been compiled in accordance with the European System of Accounts (ESA 2010).

*Source:* Eurostat

### Purchasing Power Standards (PPS)

*Definition:* Financial aggregates are sometimes expressed in Purchasing Power Standards (PPS), rather than in euro based on exchange rates. PPS are based on comparisons of the prices of representative and comparable goods or services in different countries in different currencies on a specific date.

*Source:* Eurostat

### Value Added

*Definition:* Value added is current gross value added measured at producer prices or at basic prices, depending on the valuation used in the national accounts. It represents the contribution of each industry to GDP.

*Sources:* Eurostat, OECD

### Venture capital

*Definition:* Venture capital is a form of private equity (equity investment into private companies not listed on the stock exchange) focused on start-up companies. It can be classified in three different stages:

*Seed:* Funding provided before the recipient company has started mass production and distribution, generally contributing to achieve a clear definition of the product.

*Start-up:* Funding provided to companies to start mass production and distribution to allow coverage of initial capital expenditure. This

stage of funding is provided once the product or service is already defined.

*Later-stage:* Funding provided for an operating company.

Venture capital figures provided in the report are **market statistics**, i.e. the aggregation is made according to the location of the recipient company regardless of the location of the source of funds.

*Source:* Invest Europe

### Investments in Information and Communication Technology (ICT)

*Definition:* ICT investment is defined as the acquisition of equipment and computer software that is used in production for more than one year. ICT has three components: information technology equipment (computers and related hardware); communications equipment; and software.

*Source:* OECD, DG JRC

### Multi-factor productivity (MFP) (or Total factor productivity – TFP)

*Definition:* Multi-factor productivity (MFP) relates a change in output to several types of inputs, notably labour and capital. It is a measure of the efficiency in the combination of production resources in output creation. MFP is often measured residually, as that change in output that cannot be accounted for by the change in combined inputs.

*Source:* OECD, Eurostat

### Labour share

*Definition:* The labour share is the part of national income which is allocated to labour income. It relates to the capital share, the part of national income which goes to capital.

*Source:* OECD

## Gini coefficient

*Definition:* The Gini coefficient is a measure of dispersion of the income distribution of a country to capture inequality.

## Economic competences

*Definition:* Economic competences are a category of intangible assets that include investments in brand equity, firm-specific human capital, organisational capital and market research.

*Source:* Corrado et al (2005)

## R&D intensity

*Definition:* Gross domestic expenditure on R&D (GERD) as % of gross domestic product (GDP).

*Source:* Eurostat, OECD

## Gross domestic expenditure on R&D

*Definition:* Gross domestic expenditure on R&D (GERD) is defined according to the OECD Frascati Manual definition. GERD can be broken down by four sectors of performance:

- ▶ (i) Business enterprise expenditure on R&D (BERD);
- ▶ (ii) Government intramural expenditure on R&D (GOVERD);
- ▶ (iii) Higher education expenditure on R&D (HERD);
- ▶ (iv) Private non-Profit expenditure on R&D (PNPERD).

GERD can also be broken down by four sources of funding:

- ▶ (i) Business enterprise;
- ▶ (ii) Government;
- ▶ (iii) Other national sources;
- ▶ (iv) Abroad.

*Source:* Eurostat, OECD

## Public expenditure on R&D

*Definition:* For the purposes of this publication, public expenditure on R&D is defined as

government intramural expenditure on R&D (GOVERD) plus higher education expenditure on R&D (HERD).

*Source:* Eurostat, OECD

## Business R&D intensity

*Definition:* Business enterprise expenditure on R&D (BERD) as % of gross domestic product (GDP).

*Sources:* Eurostat, OECD

## Inward BERD

*Definition:* The indicator refers to the R&D expenditures of foreign-owned firms.

## Public R&D intensity

*Definition:* Public expenditure on R&D (GOVERD plus HERD) as % of GDP.

*Source:* Eurostat, OECD

## Government budget appropriations for R&D

*Definition:* Government budget appropriations for R&D (GBARD) encompass all R&D spending allocations met from sources of government revenue foreseen within the budget.

*Source:* Eurostat

## Tax incentives for R&D

*Definition:* Governments in many countries provide tax support for R&D with the aim of promoting R&D investment in the economy by granting preferential tax treatment of eligible R&D expenditures, especially to business enterprises. Tax incentives reduce the amount of tax owed by business enterprises. The extent to which business enterprises can reduce their tax liability may be related to the amount of eligible R&D expenditures incurred in the reference period. In general, tax incentives can take the form of a tax allowance, an exemption, a deduction or a credit. Tax allowances,



exemptions and deductions are subtracted from the tax base before the tax liability is computed – they reduce the taxable amount before assessing the tax. A tax credit is an amount subtracted directly from the tax liability due from a business enterprise after the liability has been computed.

*Source:* OECD

## Framework Programme

*Definition:* The Framework Programme for Research and Technological Development is the EU's main instruments for supporting collaborative research, development and innovation in science, engineering and technology. The first Framework Programme was launched in 1984. The eight Framework Programme, known as Horizon 2020 (H2020) covers the period 2014–2020.

*Source:* DG Research and Innovation

## Structural Funds

*Definition:* Structural Funds are funds intended to facilitate structural adjustment of specific sectors, regions, or combinations of both, in the European Union. Structural Funds for RTDI include data from sectors involving research and development, technological innovation, entrepreneurship, innovative ICT and human capital.

*Source:* DG REGIO

## The NUTS classification of regions

*Definition:* The nomenclature of statistical territorial units (NUTS) is a single coherent system for dividing up the European Union's territory in order to produce regional statistics for the Community. NUTS subdivides each Member State into a whole number of regions at NUTS 1 level. Each of these is then subdivided into regions at NUTS level 2 and these in turn into regions at NUTS level 3.

*Source:* Eurostat

## High-tech and medium-high-tech manufacturing

*Definition:* High-tech manufacturing (HT) includes the following sectors (NACE Rev.2 codes – 2 digit level are given in brackets): manufacture of basic pharmaceutical products and pharmaceutical preparations (C21), manufacture of computer, electronic and optical products (C26). Medium-high-tech manufacturing includes the following sectors (NACE Rev. 2 codes – 2 digit level are given in brackets): manufacture of chemicals and chemical products (C20), manufacture of electrical equipment (C27), manufacture of machinery and equipment (C28), manufacture of motor vehicles, trailers and semi-trailers (C29), manufacture of other transport equipment (C30).

*Source:* Eurostat

## Knowledge-Intensive Activities (KIAs)

*Definition:* Knowledge-Intensive Activities (KIAs) are defined as economic sectors in which more than 33% of the employed labour force has completed academic-oriented tertiary education (i.e. at ISCED 5 and 6 levels). They cover all sectors in the economy, including manufacturing and services sectors, and can be defined at two and three-digit levels of the statistical classification of economic activities.

*Source:* Eurostat

## Knowledge-Intensive Services (KIS)

*Definition:* Knowledge-intensive services (KIS) includes the following sectors (NACE Rev.2 codes are given in brackets): water transport (H50), air transport (H51), information and communication (J), financial and insurance activities (K), professional, scientific and technical activities (M), employment activities (N78), public administration and defence; compulsory social security (O), education (P), human health and social work activities (Q), arts, entertainment and recreation (R).

*Source:* Eurostat, OECD

## Knowledge-Intensive Services exports

*Definition:* Exports of knowledge-intensive services are measured by the sum of credits in EBOPS (Extended Balance of Payments Services Classification) 207, 208, 211, 212, 218, 228, 229, 245, 253, 260, 263, 272, 274, 278, 279, 280, 284.

*Source:* UN

## Higher Education

ISCED (International Standard Classification of Education)

ISCED 5: Tertiary education (first stage) not leading directly to an advanced research qualification.

ISCED 5A: Tertiary education programmes with academic orientation.

ISCED 5B: Tertiary education programmes with occupation orientation.

ISCED 6: Tertiary education (second stage) leading to an advanced research qualification (PhD or doctorate).

*Source:* Eurostat

## Human Resources for Science and Technology (HRST), R&D personnel and researchers

The Canberra Manual proposes a definition of HRST as people who either have higher education or are employed in positions that normally require such education. HRST applies to people who fulfil one or other of the following conditions:

- ▶ a) Have successfully completed education at the tertiary level in an S&T field of study (HRSTE - Education);
- ▶ b) Not formally qualified as above, but employed in an S&T occupation where the above qualifications are normally required (HRSTO - Occupation).

HRST Core (HRSTC) refers to people with both tertiary-level education and an S&T occupation.

Scientists and engineers are defined as ISCO<sup>1</sup> categories 21 (physical, mathematical and engineering science professionals) and 22 (life science and health professionals).

The Frascati Manual proposes the following definitions of R&D personnel and researchers:

- ▶ R&D personnel: "R&D personnel in a statistical unit include all persons engaged directly in R&D, whether employed by the statistical unit or external contributors fully integrated into the statistical unit's R&D activities, as well as those providing direct services for the R&D activities (such as R&D managers, administrators, technicians and clerical staff).";
- ▶ Researchers: "Researchers are professionals engaged in the conception or creation of new knowledge. They conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods.". R&D may be either the primary function or a secondary function. It may also be a significant part-time activity.

Therefore, the measurement of personnel employed in R&D involves two exercises:

- ▶ Measuring their number in headcounts (HC) whereby the total number of people who are mainly or partially employed in R&D are counted;
- ▶ Measuring their R&D activities in full-time equivalence (FTE): the number of people engaged in R&D is expressed in full-time equivalents on R&D activities (= person-years).

*Source:* Eurostat

## Job-to-job mobility

*Definition:* Mobility (job-to-job mobility) of employed HRST is built up by considering the number of HRST employed in the years T-1 and T, that have changed jobs during the

1 International Standard Classification of Occupations

twelve month period. It is expressed as a proportion of the total number of HRST employed in year T.

*Source:* Eurostat

## Public and Private sector researchers

*Definition:* For the purposes of this publication, Public sector researchers refer to researchers in the government and higher education sectors. Private sector researchers refer to researchers in the business enterprise and private non-profit sectors.

*Source:* Eurostat, OECD

## Patent Cooperation Treaty (PCT) Patents

*Definition:* The Patent Cooperation Treaty (PCT) is an international treaty, administered by the World Intellectual Property Organization (WIPO), signed by 133 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single “international” patent application instead of filing several separate national or regional applications. Indicators based on PCT applications are relatively free from the “home advantage” bias (proportionate to their inventive activity, domestic applicants tend to file more patents in their home country than non-resident applicants). The granting of patents remains under the control of the national or regional patent offices. The PCT patents considered are ‘PCT patents, at international phase, designating the European Patent Office’. The country of origin is defined as the country of the inventor. If one application has more than one inventor, the application is divided equally among all of them and subsequently among their countries of residence, thus avoiding double counting.

*Source:* OECD

## Scientific Publications

*Definition:* Scientific publications (articles and reviews only) published by the unit of analysis included in the Web of Science database. Several counting methods can be applied in the calculation of bibliometric indicators. For instance, when author affiliations in a publication involve several countries, the publication count per country can be done assigning a complete publication to each country participating in the publication (full counting), or another option could be to fractionalise the publication according to the total number of different countries (fractional counting).

*Source:* CWTS based on Web of Science database; treatments and calculations: CWTS

## Public-Private co-publications

*Definition:* Number of public-private co-authored research publications. For the calculation of this indicator CWTS identifies and classifies author affiliations belonging to the private sector. The ‘private sector’ is delineated as for-profit business companies, but excluding private-sector education institutions and hospitals/clinics. Most of the private sector organisations therefore operate in manufacturing industries. Any publication with the participation of a ‘private sector’ organisation in collaboration with at least another organisation non-classified as being part of the ‘private sector’, will be considered a ‘public-private co-publication’. The public-private co-publication has been assigned to the location/s of the business company(ies).

*Source:* CWTS based on Web of Science database

## Citations and highly cited publications

*Definition:* Scientific [citation](#) is providing detailed reference in a scientific publication, typically a [paper](#) or book, to previously published (or occasionally private) paper. The citation count includes the number of times the publication was

cited by specific articles from the journals that the CWTS publication-based classification system covers. The first indicator most used in this report refers to the scientific publications within the 10% (or 1%) most cited scientific publications worldwide as percentage of total scientific publications of the country. The second indicator refers to the world share of highly-cited scientific publications and examine the scientific publications within the 1% (or 10%) most cited scientific publications worldwide as % of total scientific publications of the country.

An important methodological aspect regarding the citation indicators (both citations and highly cited publications) has to do with the normalisation of citation counts by scientific field. The normalisation is based on the CWTS publication-based classification system, which leads to much more fine-grained delineation of fields than Web of Science classification scheme and therefore more accurate citation impact scores. The classification is an in-house developed and it is publicly available (through <http://www.leidenranking.com>).

*Source:* CWTS based on Web of Science database

### Open access publications

*Definition:* There is no commonly agreed definition on open access publication. However, the definition developed at the Budapest Open Access Initiative (2002) is often used as a reference:

'Free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. The only constraint on reproduction and distri-

bution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited.'

*Source:* Science-Metrics [Archambault, E; Amyot, D; Deschamps, P; Nivoli, A; Provencher, F; Rebout, L; Roberge, G (2014) Proportion of Open Access papers published in peer-reviewed journals at the European and World levels-1996-2013]

In this report, the two main Open Access categories ('Gold' and 'Green') are considered. A publication is categorise as Gold Open Access if it is published in journals included in the Directory of Open Access Journals (DOAJ), complemented with other Gold Open Access journal lists like CrossRef, etc. For the Green Open Access publications, a 'harvester' approach will be developed and implemented at CWTS, able to collect scientific publications from open directories and repositories.

### Gold open access

Open access publishing - payment of publication costs is shifted from readers (via subscriptions) to authors. These costs are usually borne by the university or research institute to which the researcher is affiliated, or by the funding agency supporting the research.

### Green open access

Self-archiving: the published article or the final peer-reviewed manuscript is archived by the researcher in an online repository before, after or alongside its publication. Access to this article is often delayed ('embargo period') at the request of the publisher so that subscribers retain an added benefit.

*Source:* CWTS based on Web of Science database

## Innovation Output Indicator

$$I = w_1 \times \text{PCT} + w_2 \times \text{KIA} + w_3 \times \text{COMP} + w_4 \times \text{DYN}$$

where

PCT = Number of patent applications filed under the Patent Cooperation Treaty per billion GDP; Patent counts are based on the priority date, the inventor's country of residence and fractional counts (Eurostat/OECD).

KIA = Employment in knowledge-intensive activities in business industries (including financial services) as % of total employment; Knowledge-intensive activities are defined, based on EU Labour Force Survey data, as all NACE Rev.2 industries at 2-digit level where at least 33 % of employment has a higher education degree (ISCED5 or ISCED6) (Eurostat).

$$\text{COMP} = 0.5 \times \text{GOOD} + 0.5 \times \text{SERV}$$

GOOD = High-tech and medium-high-tech products exports as % of total exports (Eurostat (COM-EXP)/UN(Comtrade))

SERV = Knowledge-intensive services exports as % of total service exports (exports of knowledge-intensive services are measured by the sum of credits in EBOPS (Extended Balance of Payments Services Classification) 207, 208, 211, 212, 218, 228, 229, 245, 253, 260, 263, 272, 274, 278, 279, 280 and 284 (UN/Eurostat))

DYN = Employment in fast-growing firms in innovative business industries, excluding financial services

$$\sum_s (CIS^{score} \times KIA^{score})_s \frac{E_{sC}^{HG}}{E_C^{HG}}$$

where

$(CIS^{score} \times KIA^{score})_s$  = Innovation coefficient of sector  $s$ , resulting from the product of Community Innovation Survey and Labour Force Survey scores for each sector at EU level.

$E_{sC}^{HG}$  = The employment in fast-growing firms in sector  $s$  and country  $C$ .

$E_C^{HG}$  = The employment in fast-growing firms in country  $C$ .

$w_1, w_2, w_3, w_4$  = The weights of the component indicators, fixed over time, and statistically computed in such a way that the component indicators are equally balanced.

Source: DG Research and Innovation – Unit for the Analysis and Monitoring of National Research and Innovation Policies

## Community Trademark System (CTM)

*Definition:* The Community trade mark system allows the uniform identification of products and services by enterprises throughout the EU. A unique procedure applied by the Office for Harmonization in the Internal Market (OHIM) allows them to register trademarks which will benefit from unitary protection and be fully applicable in every part of the Community. The CTM system is unitary in character. A CTM registration is enforceable in all member states.

*Source:* OHIM

## Community Design System (CD)

*Definition:* A design is the outward appearance of a product or part of it, resulting from the lines, contours, colours, shape, texture, materials and/or its ornamentation. The design or shape of a product can be synonymous with the branding and image of a company and can become an asset with increasing monetary value. A registered Community design (RCD) is an exclusive right that covers the outward appearance of a product or part of it. Community Trademarks and Design refer to trade mark and design protections throughout the European Union, which covers 28 countries. The Office for Harmonization in the Internal Market (OHIM) is the official office of the European Union for the registration of Community Trademarks and Designs.

*Source:* OHIM

## Small and medium-size enterprises (SMEs)

*Definition:* Small and medium-size enterprises (SMEs) are defined as enterprises having fewer than 250 employees.

*Source:* Eurostat, OECD

## High-growth enterprise

*Definition:* A high-growth enterprise (growth by 20 % or more) is an enterprise with an average

annualised growth greater than 20% per year over a three-year period. Growth can be measured by the number of employees or by turnover.

A high-growth enterprise (growth by 10 % or more) is an enterprise with average annualised growth in number of employees greater than 10% per year over a three-year period ( $t - 3$  to  $t$ ) and having at least 10 employees in the beginning of the growth ( $t - 3$ ).

*Source:* Eurostat

## Gazelle

*Definition:* A gazelle is a high-growth enterprise that is up to 5 years old.

*Source:* Eurostat

## Unicorn company

*Definition:* A unicorn is a private company with a post-money (i.e. "after funding") valuation at more than US\$ 1bn.

*Source:* Based on CrunchBase

## Innovative enterprises

*Definition:* These are enterprises that introduce new or significantly improved products (goods or services) to the market or those that implement new or significantly improved processes. Innovations are based on the results of new technological developments, new combinations of existing technology, or the use of other knowledge acquired by the enterprise.

Product innovative enterprises are those who introduced new or significantly improved goods and/or services with respect to their capabilities, user friendliness, components or sub-systems. Changes of a solely aesthetic nature and the simple resale of new goods and services purchased from other enterprises are not considered as innovation.

Process innovative enterprises implemented new or significantly improved production process, distribution method or supplying activity.

Organisational innovative enterprises implemented a new organisational method in the enterprise's business practices, workplace organisation or external relations.

Marketing innovative enterprises implemented a new marketing concept or strategy that differs significantly from enterprises' existing marketing methods and which has not been used before. It requires significant changes in product design or packaging, product placement, product promotion or pricing and excludes seasonal, regular and other routine changes in marketing methods.

*Source:* Eurostat

## Transformational entrepreneurship

*Definition:* Transformational entrepreneurship concerns those new businesses that from the onset have the ambition to become big and that provide "disproportionately large contributions to net job creation" (Haltiwanger, 2014) and that invest, proportionally, more in R&D than older ones (Surowiecki, 2016). Many times, transformational entrepreneurship is opposed to subsistence entrepreneurship, whose ambition is to gain some measure of financial independence, but not to scale up and grow in large numbers.

*Source:* Lerner, J and Stern, S (2010)

## Entrepreneurial intention

*Definition:* Percentage of population aged 18-64 who are latent entrepreneurs and intend to start a business within three years.

*Source:* Global Entrepreneurship Monitor

## Opportunity-driven entrepreneurship

*Definition:* The index is calculated as the ratio between the share of persons involved in improvement-driven entrepreneurship and the

share of persons involved in necessity-driven entrepreneurship.

*Source:* European Innovation Scoreboard 2017

## NASDAQ-100 Technology sector Index

*Definition:* equal weighted index based on the securities of the NASDAQ-100 Index that are classified as Technology according to the Industry Classification Benchmark (ICB) classification system.

*Source:* Nasdaq

## Ease of doing business

*Definition:* The Ease of doing business indicator is a composite indicator that ranks economies according to how conducive to business operation the regulatory environment is<sup>2</sup>. The index is obtained by aggregating 10 indicators covering different topics included in Doing Business by the World Bank<sup>3</sup>, namely:

1. Starting a business
2. Dealing with construction permits
3. Getting electricity
4. Registering property
5. Getting credit
6. Protecting minority investors
7. Paying taxes
8. Trading across borders
9. Enforcing contracts
10. Resolving insolvency

Overall, the index measures the time, the cost and the procedures involved in doing a business. The aggregate index and each indicator are reported as distance from the frontier on a scale 0-100, where a value of 100 represents the best possible outcome across all dimensions, therefore the higher the value, the better the performance of a country is.

<sup>2</sup> See <http://databank.worldbank.org/data/reports.aspx?source=2&type=metadata&series=IC.BUS.EASE.XQ>.

<sup>3</sup> See <http://www.doingbusiness.org/methodology>, including details on the assumptions made about the characteristics of business activities, on the limitations of using national data and on the subindicators contributing to define each of the ten indicators composing the aggregate index.



### Ease of starting a business

*Definition:* The indicator measures the costs, the time and the procedures required to start up and operate an industrial or commercial business<sup>4</sup>. It is one of the sub-indexes composing the Ease of doing business index.

### Ease of resolving insolvency

*Definition:* It measures "the time, cost and outcome of insolvency proceedings involving domestic entities as well as the strength of the legal framework applicable to judicial liquidation and reorganization proceedings"<sup>5</sup>. The time needed for creditors to recover their credit is expressed in calendar days, the cost is expressed as a share of the value of the debtor's estate. It accounts for the time needed for a creditor to recover their credit measured in calendar years while the cost is expressed as a share of the value of the debtor's estate. It is one of the sub-indexes composing the Ease of doing business index.

### Ease of enforcing contracts

*Definition:* It measures the time and cost needed to resolve a commercial dispute through a local court. The implementation of good practices to improve the court system is also considered to provide an assessment of the quality of the judicial process<sup>6</sup>. It is one of the sub-indexes composing the Ease of doing business index.

Source: World Bank

### The Global Competitiveness Index

*Definition:* The Global Competitiveness Index (GCI) is produced by the World Economic Forum as a summary measure of the competitiveness of economies. In particular, competitiveness is defined as "the set of institutions, policies, and factors that determine the level of productivity of a country"<sup>7</sup>. The index is obtained via the aggregation of 12 different dimensions of competitiveness and in turn each of them is composed by several indicators. Some caution needs to be taken when using these indicators, since most of them are obtained via a survey to business representatives.

Source: World Economic Forum

#### Global Competitiveness Index: public institutions

*Definition:* This index accounts for the public component of the institutions pillar, measuring the efficiency of the legal and administrative framework within business and individuals have social and economic interactions. The more efficient the public institutions are, the more the incentives for productive and growth enhancing investments in an economy. The index is constructed as a summary measure of 16 indicators representing 5 different dimensions of the quality of public institutions: Property rights (2 indicators), Ethics and corruption (3 indicators), Undue influence (2 indicators), Government efficiency (5 indicators) and Security (4 indicators).

4 See <http://www.doingbusiness.org/Methodology/Starting-a-Business>.

5 See <http://www.doingbusiness.org/Methodology/Resolving-Insolvency>.

6 See <http://www.doingbusiness.org/Methodology/Enforcing-Contracts>.

7 See <http://reports.weforum.org/global-competitiveness-index-2017-2018/appendix-a-methodology-and-computation-of-the-global-competitiveness-index-2017-2018/> for the Methodological and Computational appendix of the Index and as a technical reference for all the GCI indicators presented in this Appendix.



### **Global Competitiveness Index: government efficiency**

*Definition:* It is a sub-dimension of the public institutions index, and summarises five characteristics of the efficiency, accountability and burden of governmental provision of services: wastefulness of government spending, burden of government regulation, efficiency of legal framework in settling disputes, efficiency of legal framework in challenging regulations and transparency of government policy-making.

### **Global Competitiveness Index: goods market efficiency**

*Definition:* The index measures how efficiently good markets can produce and trade products and services. It is a summary measure of 16 indicators capturing the degree of competition, the legal and regulatory framework, taxation aspects and demand driven competitive advantage:

1. Intensity of local competition
2. Extent of market dominance
3. Effectiveness of anti-monopoly policy
4. Effect of taxation on incentives to invest
5. Total tax rate
6. Number of procedures required to start a business
7. Time required to start a business
8. Agricultural policy costs
9. Prevalence of trade barriers
10. Trade tariffs
11. Prevalence of foreign ownership
12. Business impact of rules on FDI
13. Burden of customs procedures
14. Imports as a percentage of GDP
15. Degree of customer orientation
16. Buyer sophistication

### **Global Competitiveness Index: competition environment**

*Definition:* It is a summary index of the degree of competition in an economy. While it draws from the "goods market efficiency" index of the GCI, it does not follow the original categorisation of competition which includes 14 out of 16 indicators. It is constructed by averaging three indicators only: intensity of local competition, extent of market dominance and effectiveness of anti-monopoly policy. The indicators selected above narrow the spectrum of analysis and allow for a stricter definition of competition.

### **Global Competitiveness Index: intellectual property rights protection**

*Definition:* The indicator measures the extent of protection of intellectual property rights in a country, based on a survey conducted on business representatives. It is one of the components of the public institutions index.

### **Global Competitiveness Index: labour market efficiency**

*Definition:* The index provides a measure of the efficiency and flexibility of labour markets in allocating workers to their most effective tasks in the economic system, as well in providing them with the right incentives on the job place while promoting workers performance and boosting the capacity of a country to attract and retain talents. The two sub-dimensions of the index are flexibility (5 indicators) and efficient use of talent (5 indicators).

**Global Competitiveness Index:  
ease of access to loans**

*Definition:* The indicator aims at measuring the capacity of a national financial sector to allocate resources to the investment with the higher returns to boost productivity and growth. It measures how easy is for business to have access to loans. It is part of the financial market dimension of the GCI index.

*Source:* World Economic Forum

**Summary index of single market  
integration in the EU**

*Definition:* The index provides a measure of integration of member states in the EU single market, by summarising freedoms in the Single Market, the adoption of EU legislation and comparing economic performance of member States with the overall EU economy<sup>8</sup>. It includes the following indicators:

1. Percentage of exports of goods to the EU to GDP
2. Percentage of imports of goods from the EU to GDP
3. Percentage of exports of services to the EU to GDP
4. Percentage of imports of services from the EU to GDP
5. Percentage of GDP of FDI inflow from the EU
6. Percentage of GDP of inward FDI stock from the EU
7. Percentage of GDP of outward FDI flow to the EU

8. Percentage of GDP of outward FDI stock to the EU
9. Percentage of EU Directives not implemented or implemented only partially or incorrectly into national law
10. Difference between unit nominal labour costs of Member State and the core EU average
11. Difference between per capita GDP of Member State and the core EU average 6%
12. Difference between interest rates of long-term bonds of Member State and the core EU average
13. Difference between VAT rates of Member State and the core EU average 8%
14. Difference between purchasing power in Member State and the core EU average

*Source:* LE Europe, based on Eurostat data

**Transposition deficit**

*Definition:* This index measures the share of Single Market directives non transposed in Member States over the total of directives adopted by the EU.

*Source:* Single Market Scoreboard 2017

**Compliance deficit**

*Definition:* This index measures the share of Single Market directives incorrectly transposed in Member States over the total of directives adopted by the EU.

*Source:* Single Market Scoreboard 2017

<sup>8</sup> See [http://www.amchameu.eu/sites/default/files/amcham\\_eu\\_single\\_market\\_web.pdf](http://www.amchameu.eu/sites/default/files/amcham_eu_single_market_web.pdf).

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*The "Science, Research and Innovation performance of the EU, 2018" (SRIP) analyses Europe's performance dynamics in science, research and innovation and its drivers, in a global context. The Report combines a thorough indicator based macroeconomic analysis with deep analytical research dives into hot policy topics. The aim of the Report is to build a robust narrative that speaks to an audience of both Research and Innovation and Economics and Finance policy-makers and analysts.*

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