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[1] (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.

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 I.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[2].

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[3]. In some parts of Europe – especially at the regional level[4] – population is also declining[5]. 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[6] – 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[7]. 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[8].

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 Vanhuysse, 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[9,10,11]. 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 project 'Providing integrated health and social care for older persons'[12]. 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 Asia13. 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[14,15]. 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[16].

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).

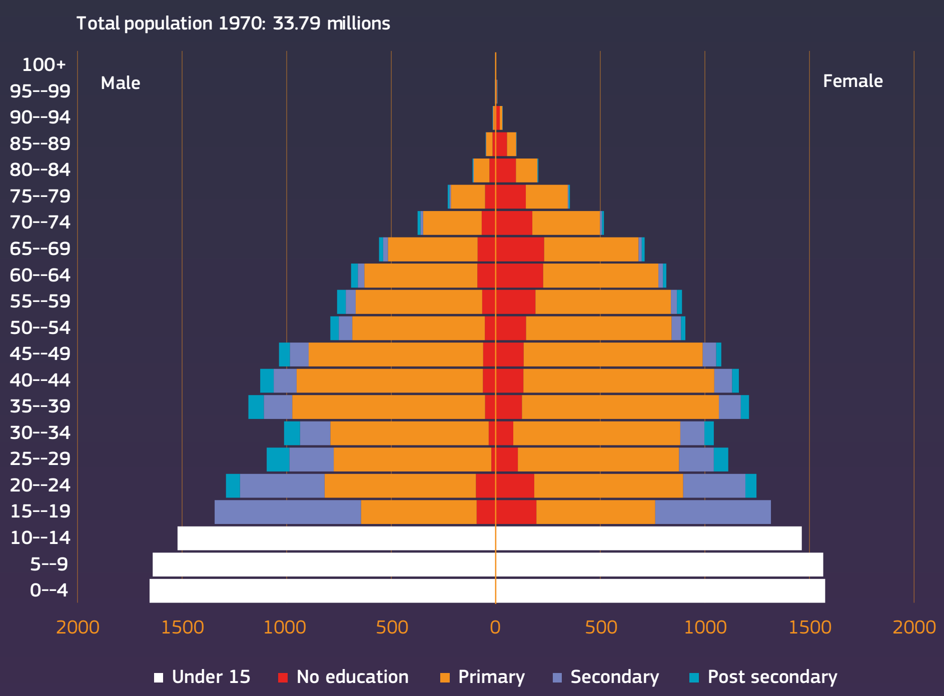
16 Peek, S.T.M. et al. Factors influencing acceptance of technology for aging in place: a systematic review. *Int. J. Med. Inform.* 83, 235-248 (2014).

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[17].

Figure A compares not only the age structure of past, present and future Spain, but also levels of educational attainment[18]. 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[19].

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

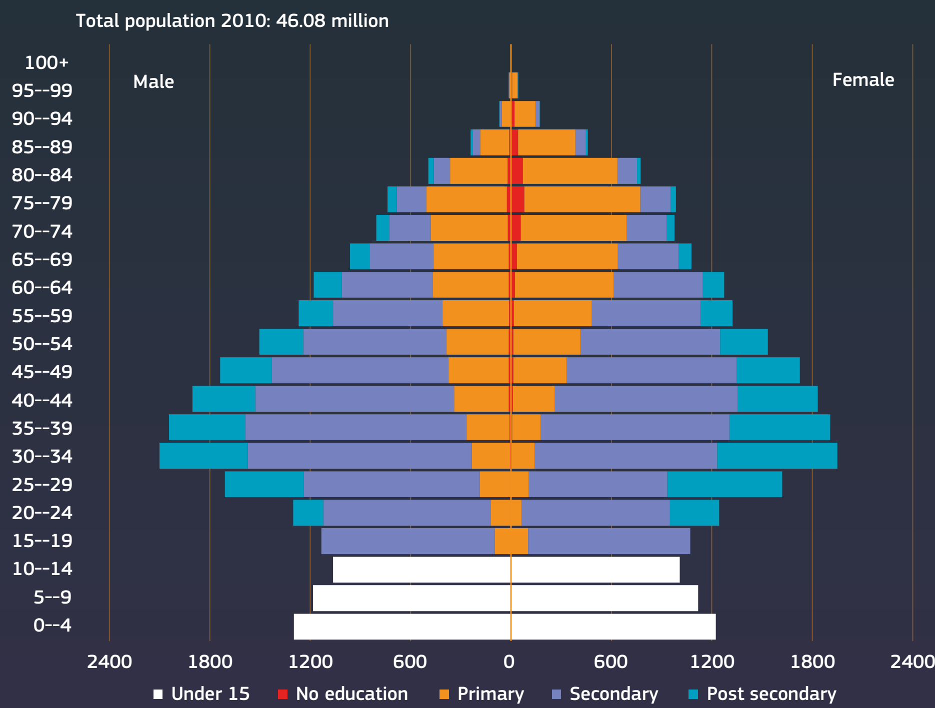


Source: WiC Data Explorer http://witt.null2.net/shiny/wic/
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/box_a_1970.xlsx

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).

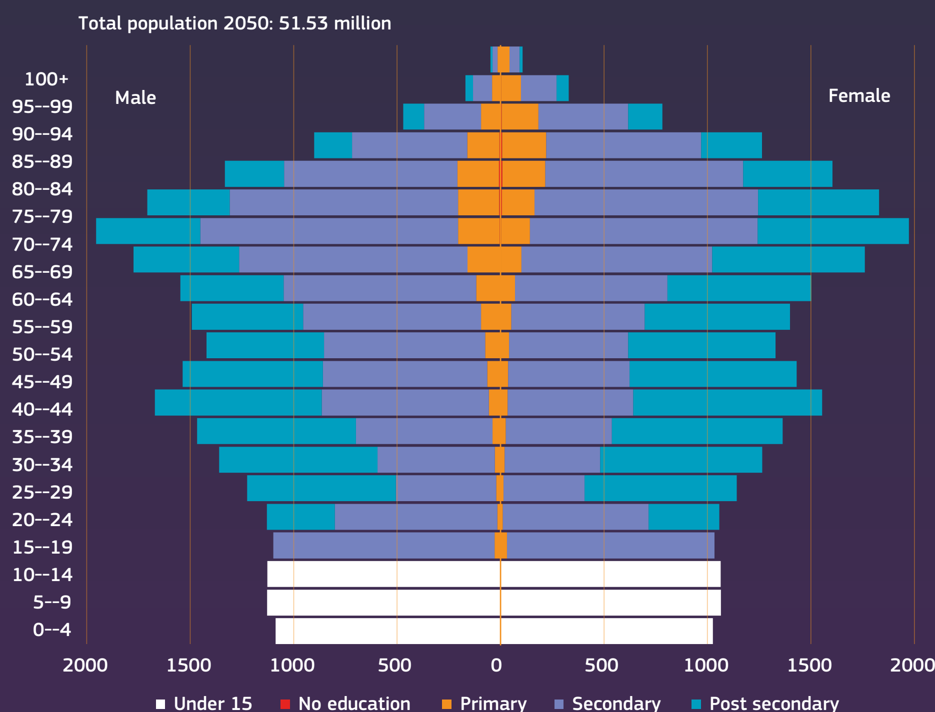
19 Kc, S., Barakat, B., Goujon, A., Skirbekk, V. and Lutz, W. Projection of populations by level of educational attainment, age, and sex for 120 countries for 2005-2050. *Demogr. Res.* 22, 383-472 (2010).



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



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

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[20]. It is important to remember, however, that such 'replacement migration' is unlikely to have any meaningful impact on the macro-demographic circumstances of the continent[21] 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[22]. 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[23].

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 I MF. 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 E uropean 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[24].

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[25]. 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[26]. In 2015, for example, it was claimed that nearly half of all jobs in Japan could be performed by robots[27].

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"25. To summarise, what is needed is not just a strong research an 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.

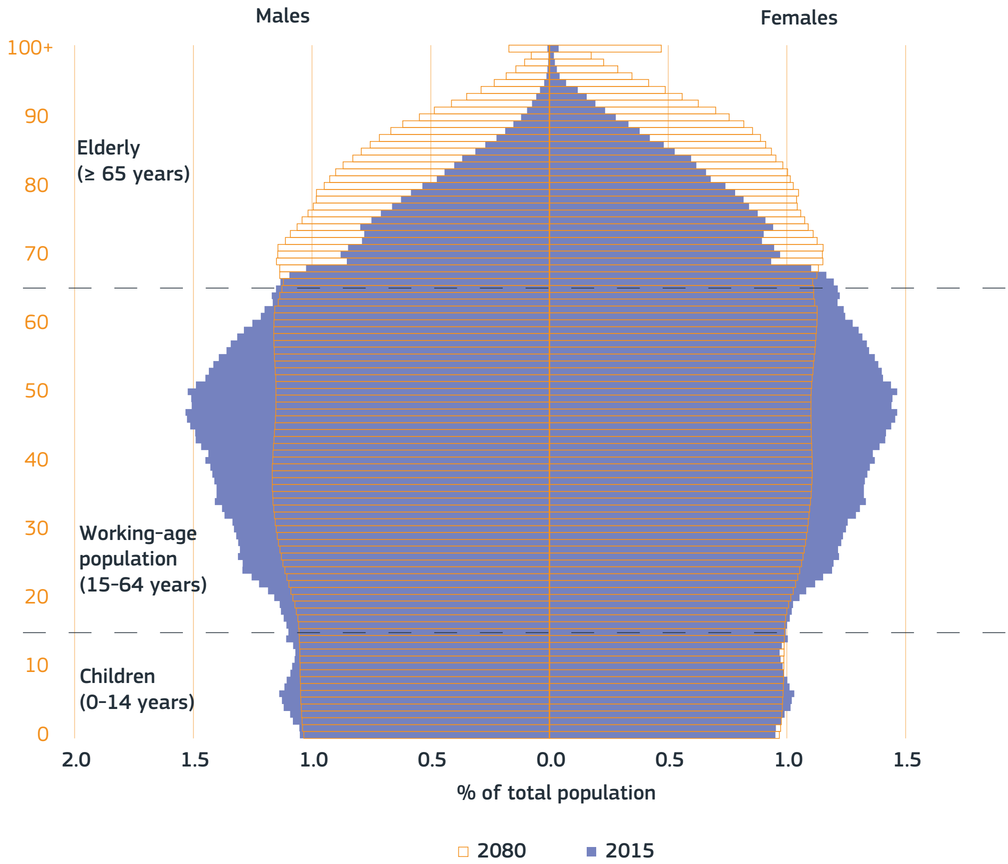
24 Heerink, N. et al. China has reached the Lewis turning point. *China Econ. Rev.* 22, 542-554 (2011).

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

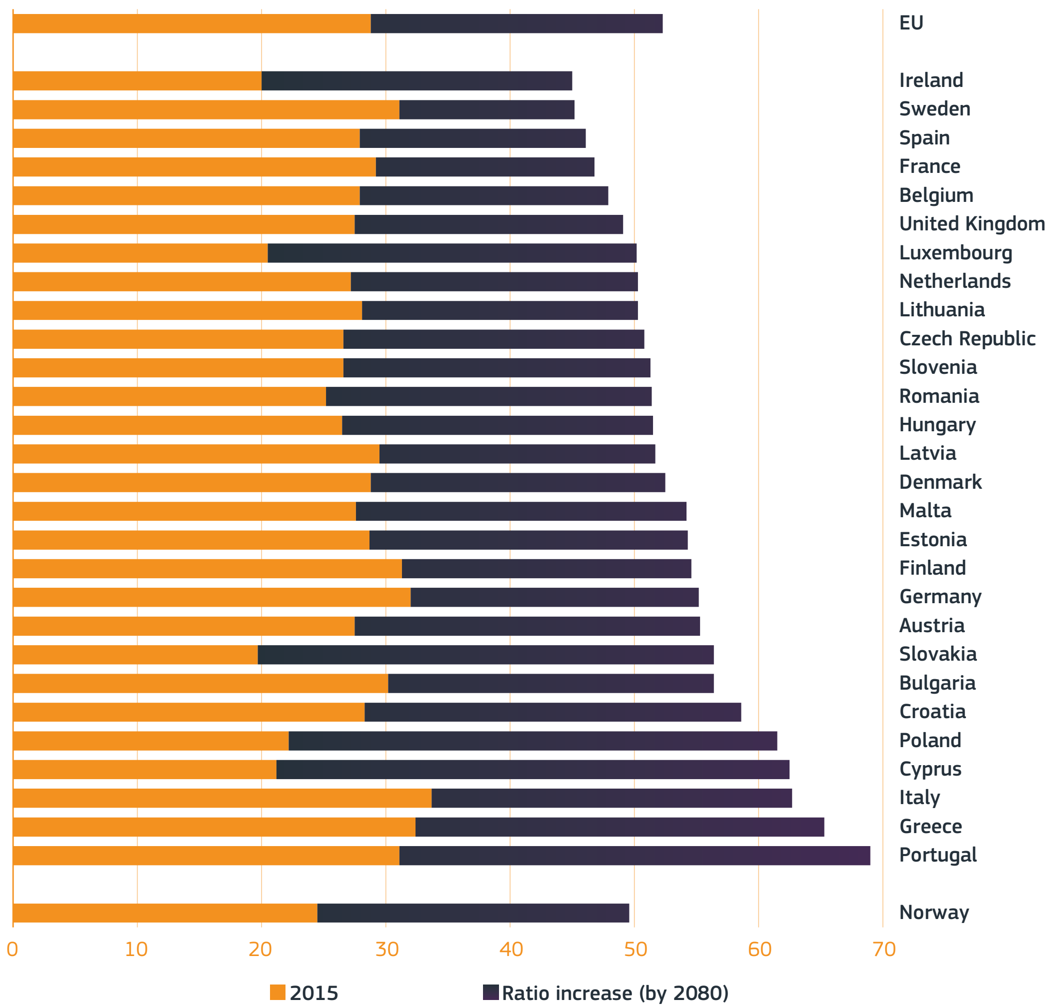
Data: Eurostat

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a1_population_pyramid.xlsx

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[28]. 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

28 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 communication 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

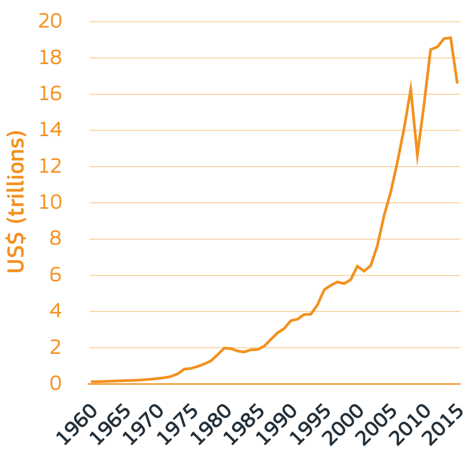
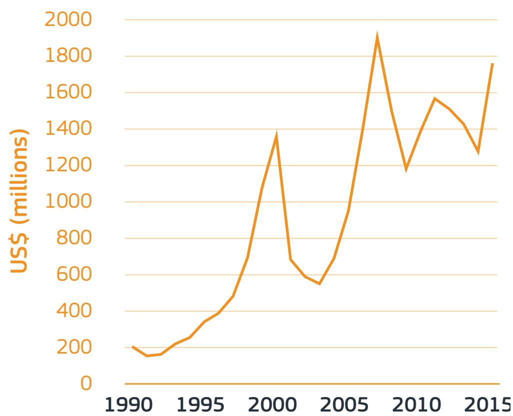


Figure I.2-A.4 World inflows of foreign direct investment (FDI) in millions of current US dollars, 1990-2015



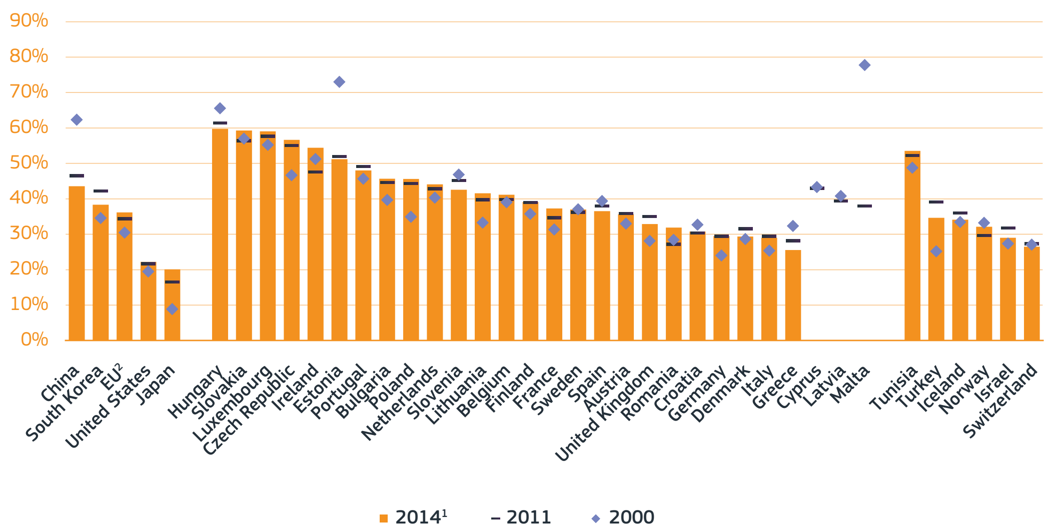
Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: World Bank - World Development Indicators, UNCTAD (World Investment Report 2016)
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a3_and_fi2a4_exports_and_fdi.xlsx

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[29], 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



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: [1]The nowcast approach was used for 2014. [2]EU for 2014 was estimated from the available data and does not include CY, LV and MT.

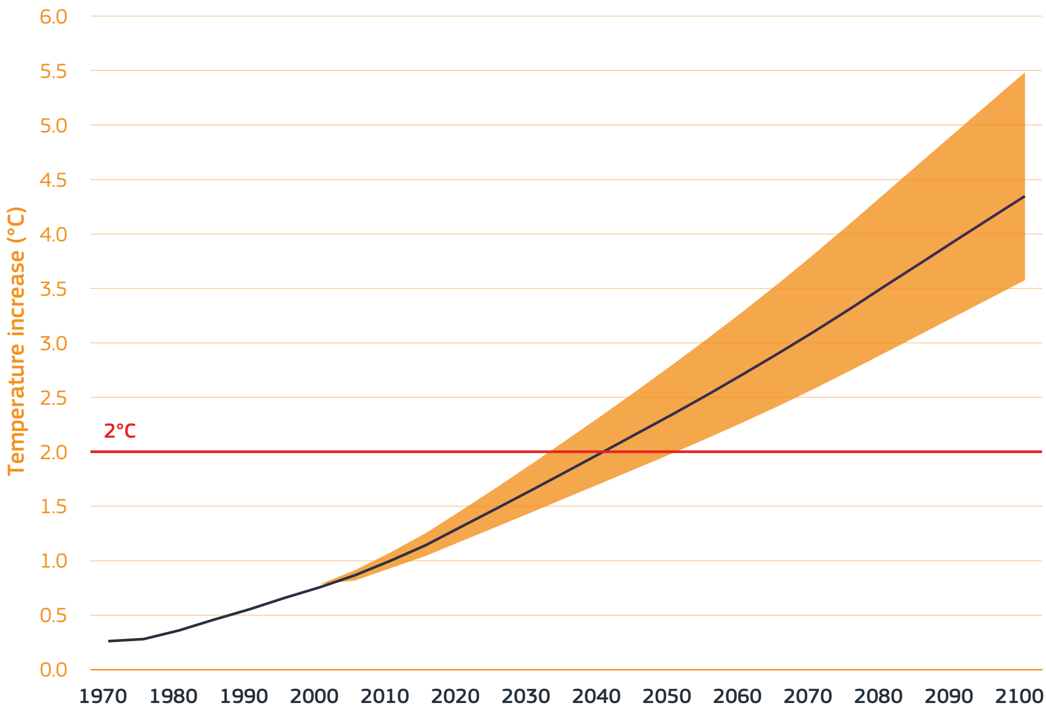
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a5_foreign_va_ht_mht.xlsx

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).

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

As the European Commission underlines[30], 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



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

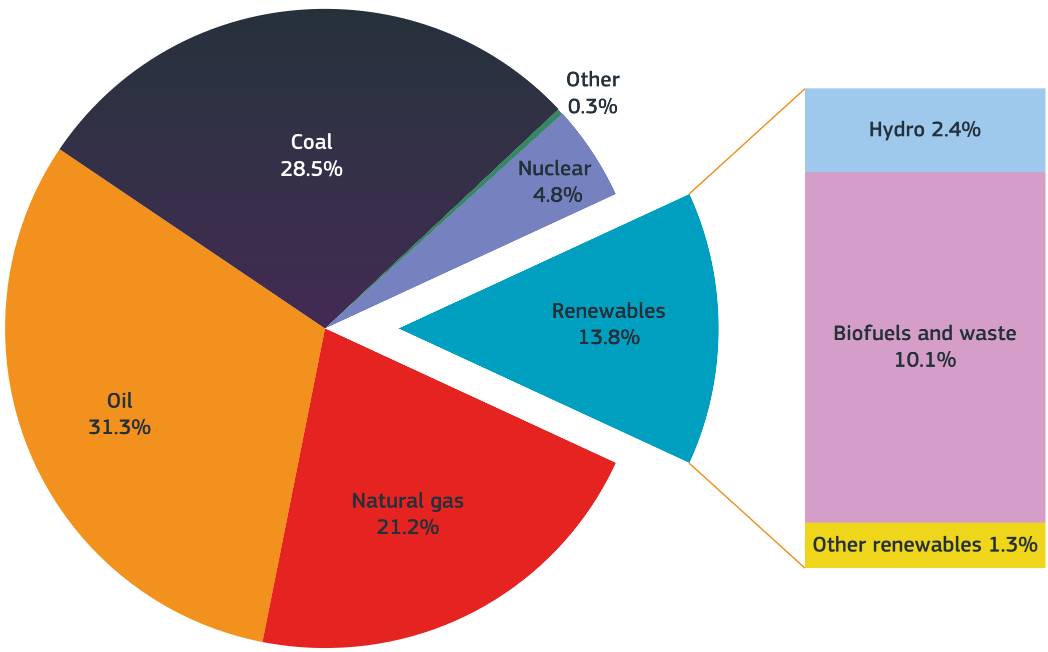
30 https://ec.europa.eu/jrc/en/research-topic/climate-change

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

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 extent, 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 manufacturer 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[31] 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[32] 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

Source: Bloomberg and PwC analysis

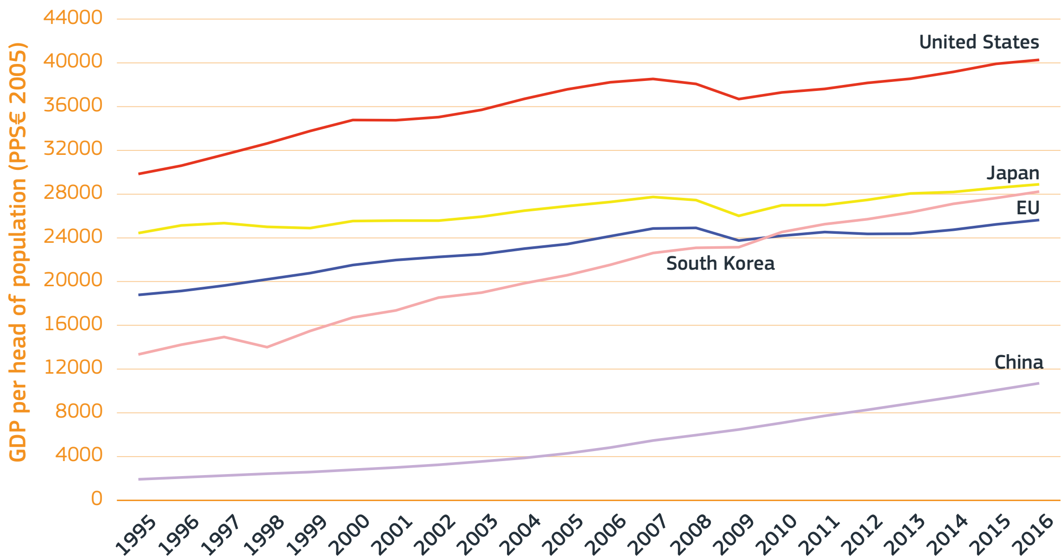
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-a_figures/fi2a8_top_100_companies.xlsx

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[33], will require a boost to Europe's productivity.

Figure I.2-B.1 Evolution of real GDP per head of population[1], 1995-2016



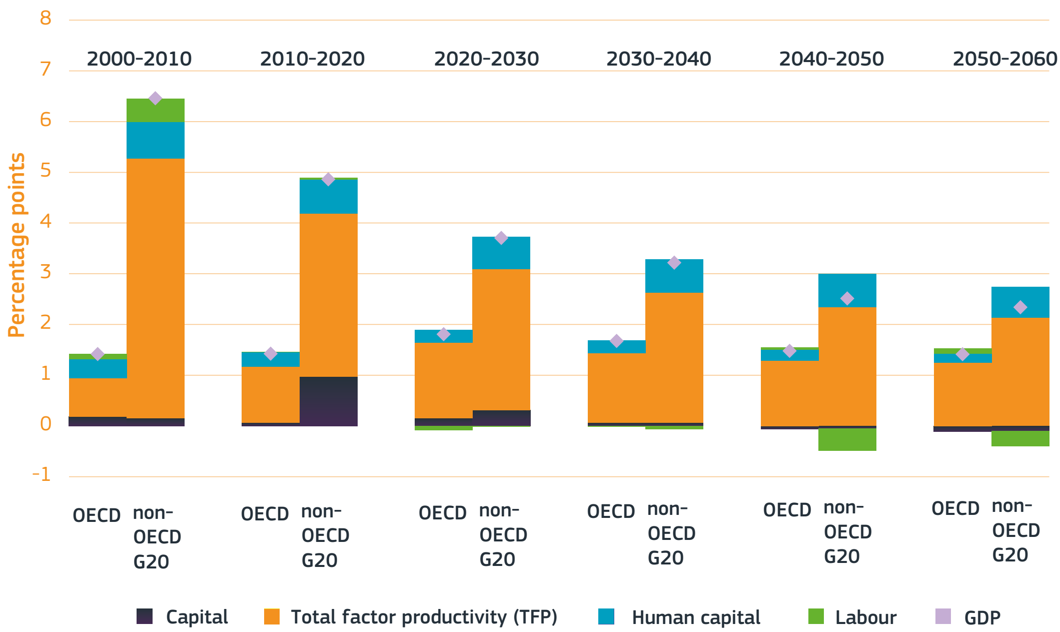
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, DG Economic and Financial Affairs
Note: [1]GDP per head of population in PPS€ at 2005 prices and exchange rates.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_1.xlsx

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)



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

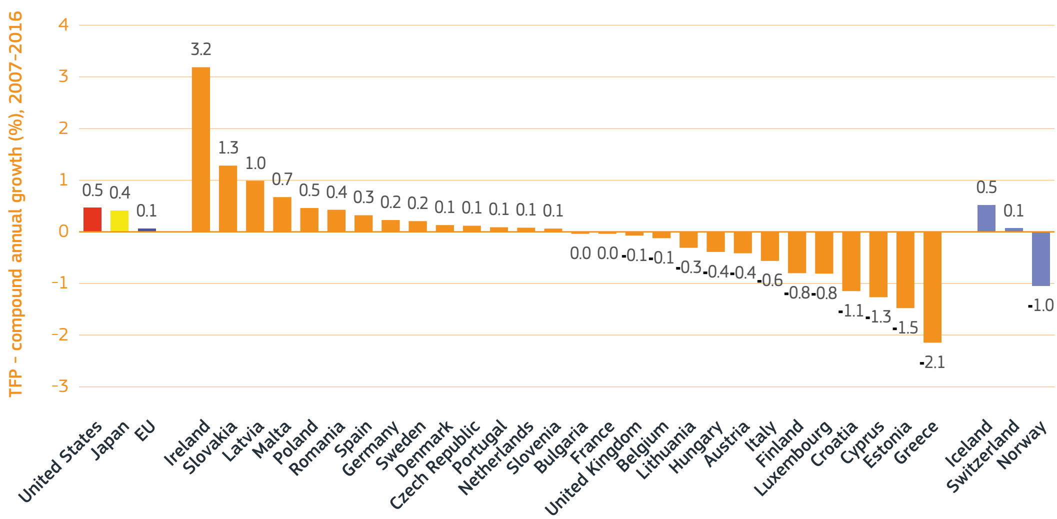
Note: The non-OECD G20 countries are Argentina, Brazil, China, India, Indonesia, Russian Federation, Saudi Arabia and South Africa.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_2.xlsx

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[34], 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

34 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.

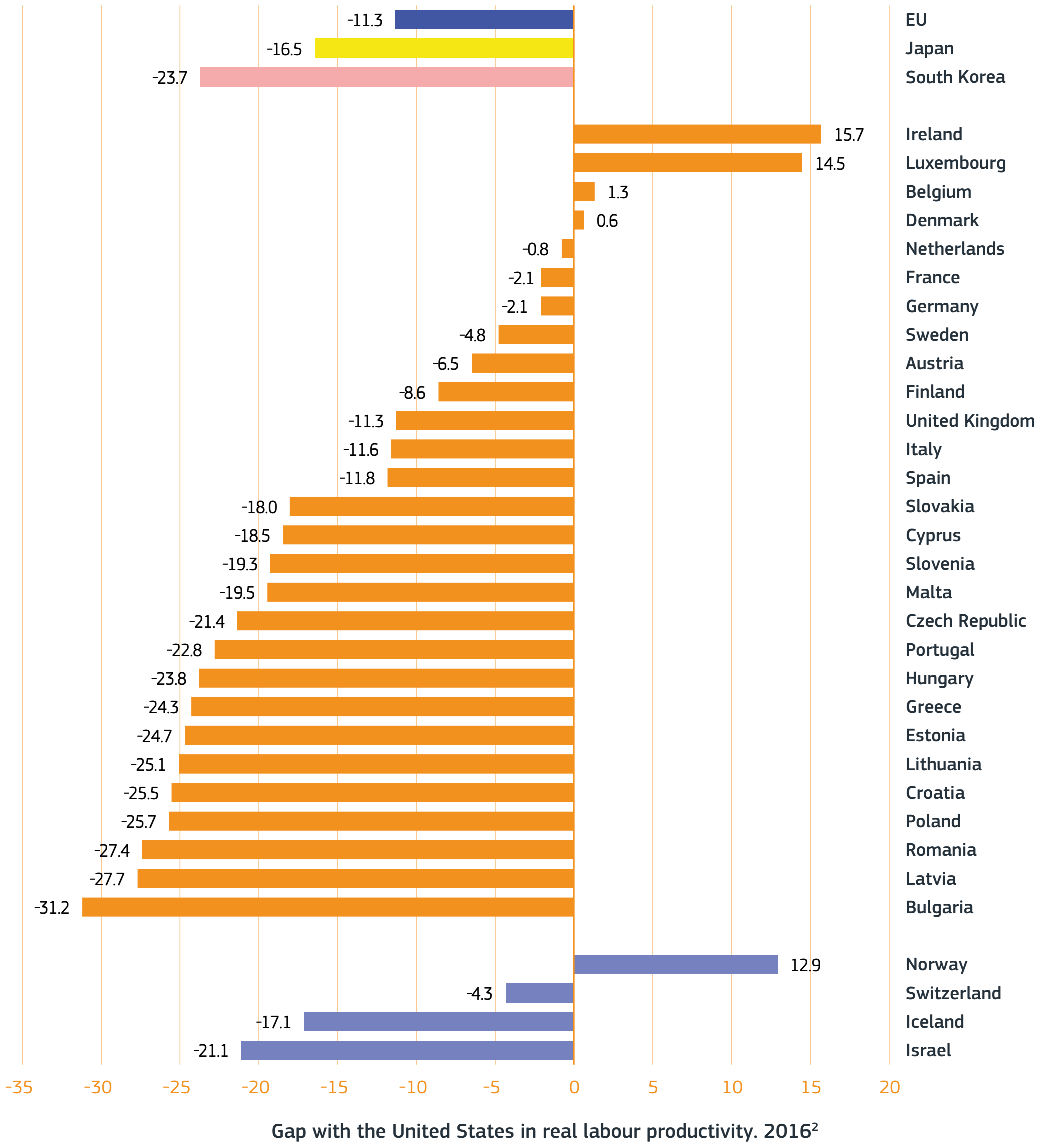
Labour productivity growth measures the amount of value added produced per work hour and is very often considered a good measure of the overall efficiency of the economy. It is often used as a proxy of society's level of prosperity[35]. Labour productivity growth depends notably on three main factors: capital investment, employed labour[36], 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 difference 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.

35 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.

36 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[1]) 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

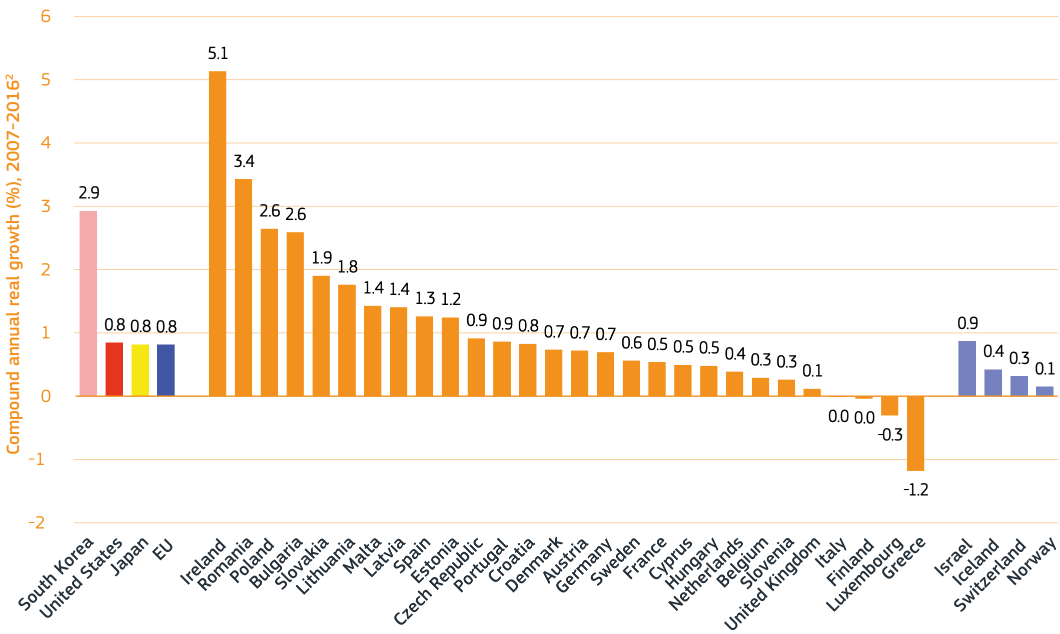
Notes: [1]GDP per hour worked in PPS€ at 2010 prices and exchange rates. [2]IS, CH, JP, KR: 2015.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_4_updated.xlsx

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[37].

Figure I.2-B.5 Labour productivity (GDP per hour worked[1]) - compound annual real growth, 2007-2016



Science, Research and Innovation performance of the EU 2018

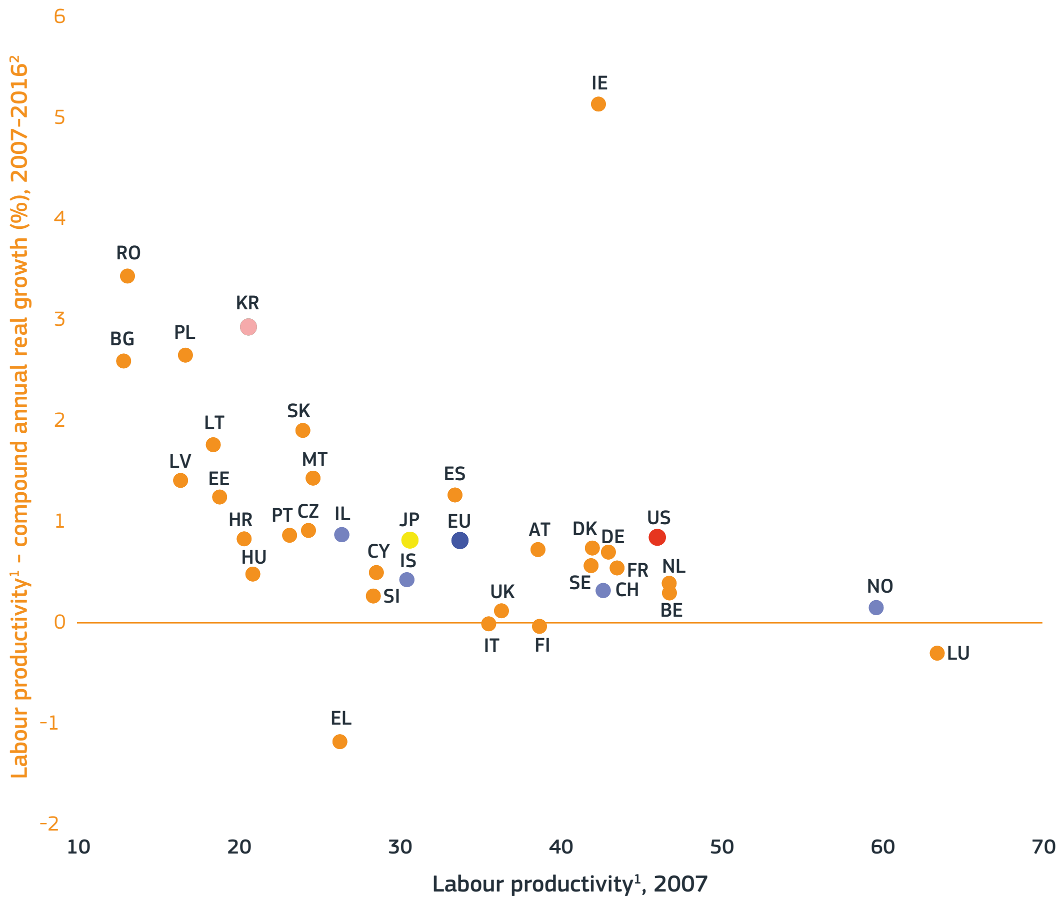
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, DG Economic and Financial Affairs, OECD
Notes: [1]GDP per hour worked in PPS€ at 2010 prices and exchange rates. [2]IS, CH, JP, KR: 2007-2015.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_5_updated.xlsx

37 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[1]), 2007 and 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: [1]GDP per hour worked in current PPS€; real growth was calculated from values at 2010 prices and exchange rates.
[2]IS, CH, JP, KR: 2007-2015.

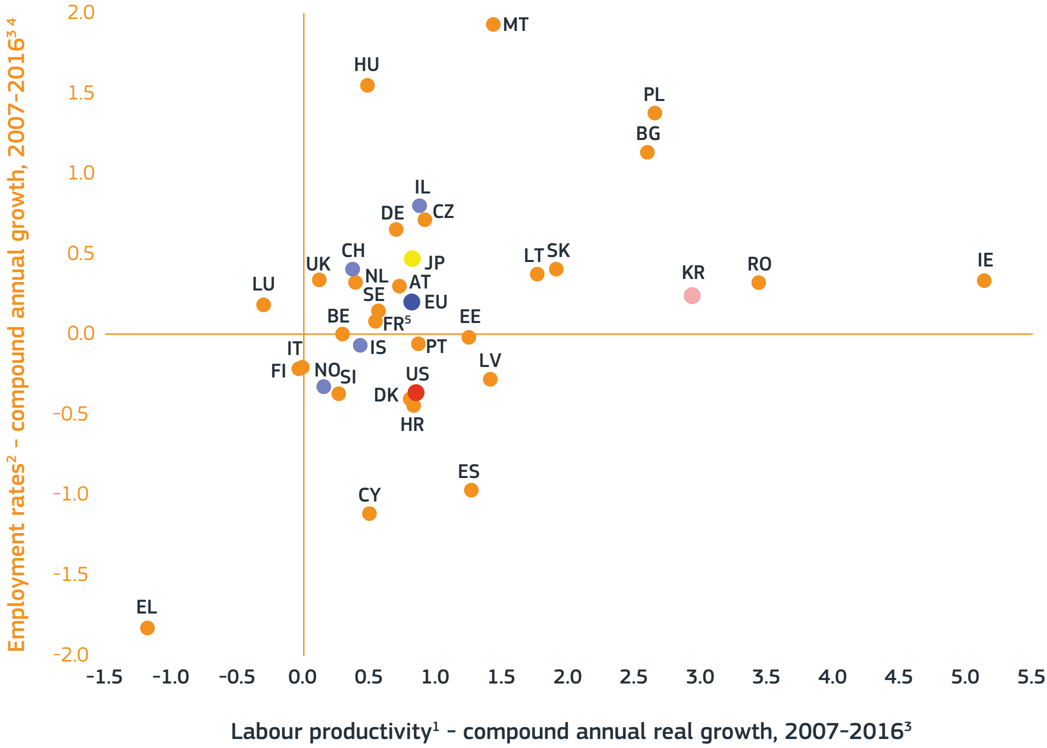
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_6_updated.xlsx

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[38].

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[1] and employment rates[2] - compound annual growth, 2007-2016



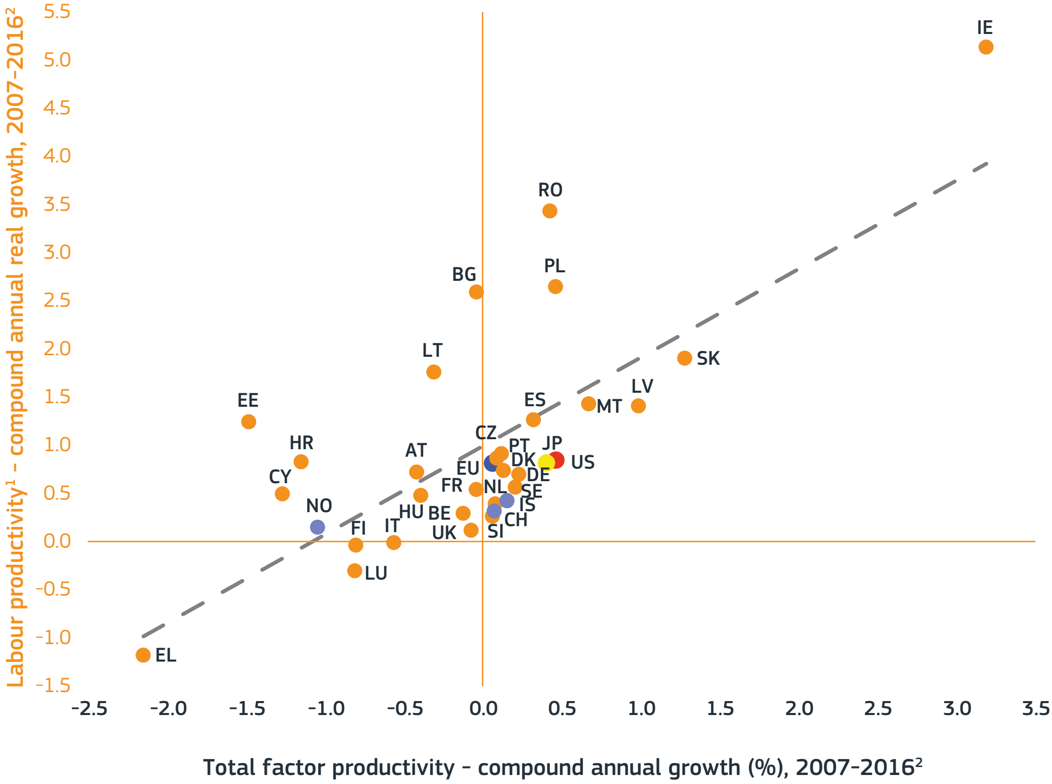
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, DG Economic and Financial Affairs, OECD
Notes: [1]GDP per hour worked in PPS€ at 2010 prices and exchange rates. [2]Employment rates refer to the age group 20-64. [3]DK, IS, JP, KR: 2007-2015; CH: 2010-2015. [4]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. [5]FR: Employment rates refer to Metropolitan France.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_7_updated.xlsx

38 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[1] - 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: [1]GDP per hour worked in PPS€ at 2010 prices and exchange rates. [2]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

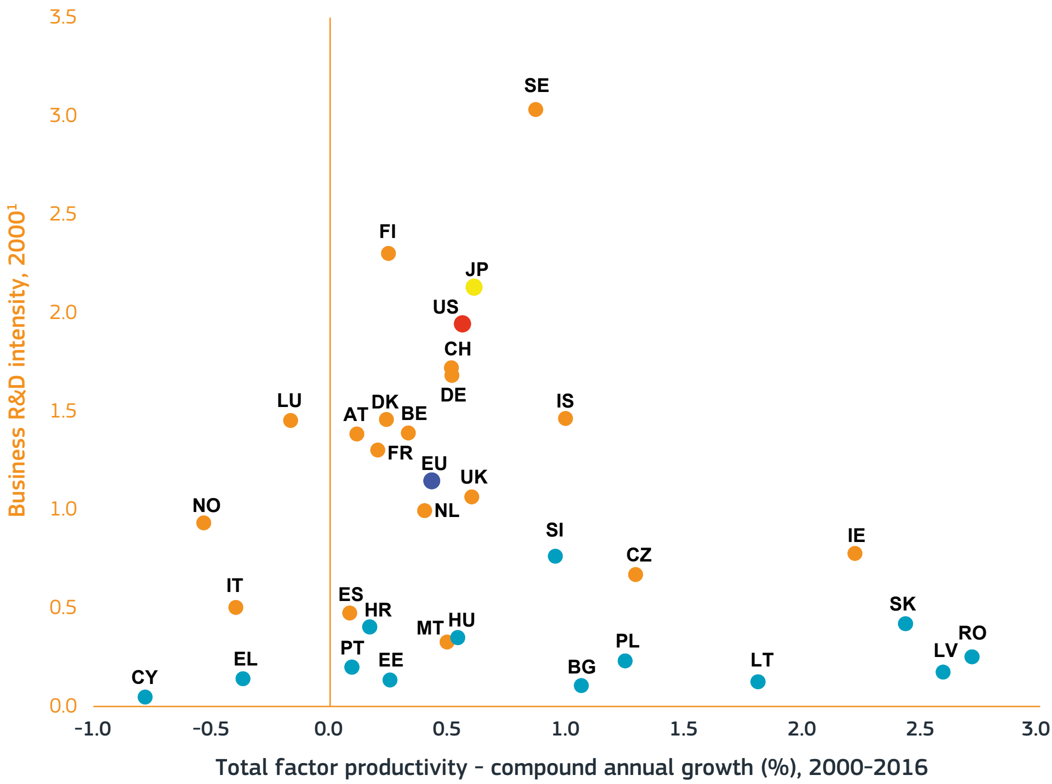
TFP is driven by many factors, from capital investment to well-functioning institutions and markets. For advanced economies, however, R&I investments and investments in other intangible assets are essential to drive up TFP.

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 Easter 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

Countries in blue had a GDP per head of population of less than 25 000 PPS€ (current) in 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: [1]SE, NO: 2001; HR, AT: 2002; MT: 2004. [2]US: Business expenditure on R&D (BERD) does not include most or all capital expenditure.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-b_figures/figure_i_2-b_9_updated.xlsx

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[39] 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 mismeasurement 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.

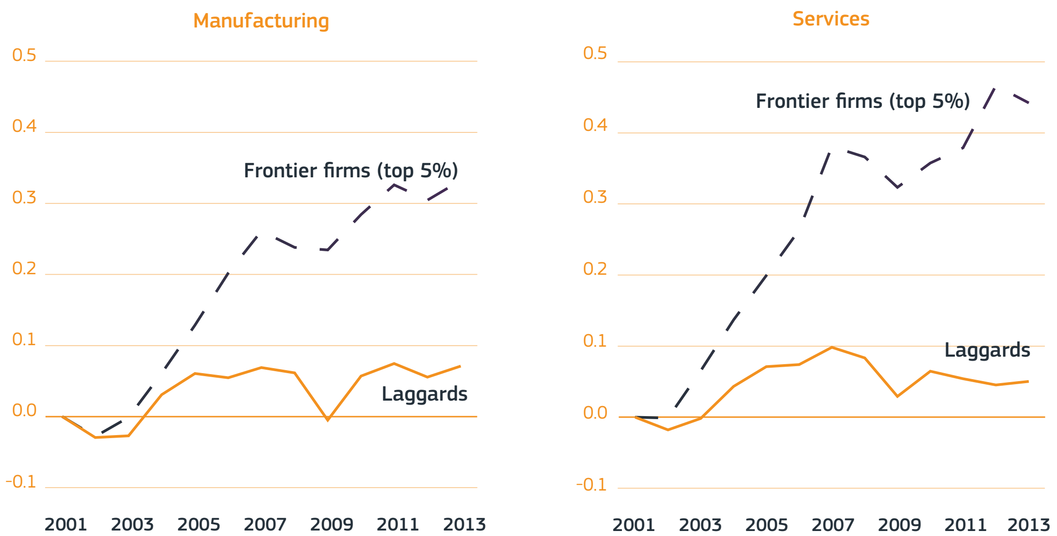
This gap in productivity performance between highly productive firms at the frontier and the remaining companies seems to occur across all sectors of the economy and is putting a brake on innovation diffusion (ECB 2016, OECD 2015).

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[1], 2001-2013



Source: Andrews et al. 2016(8)

Note: [1]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/parti/i_2-b_figures/figure_i_2-b_10.xlsx

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)[40], 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.

40 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.

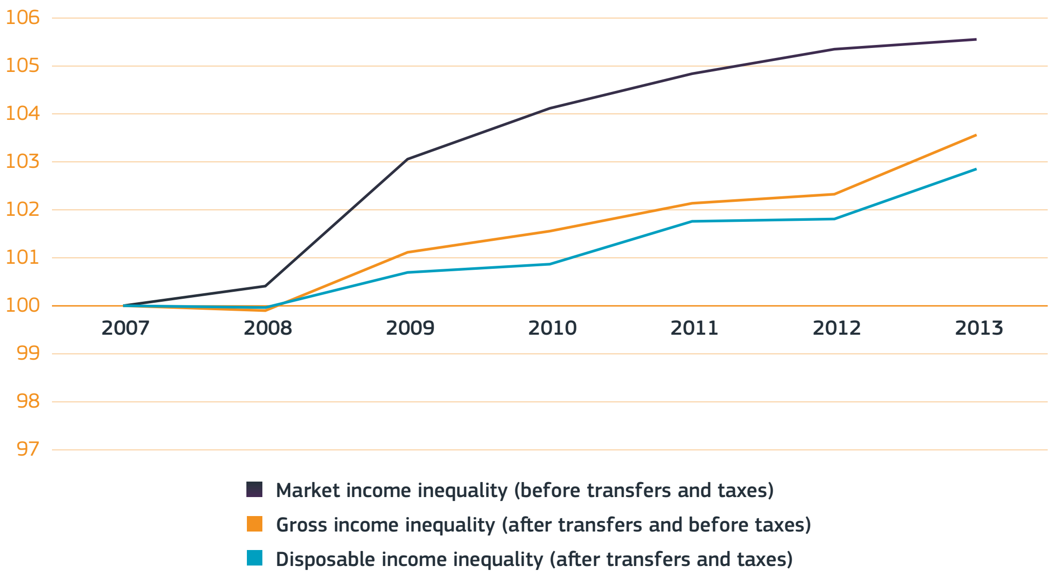
Overall market income inequality[41] in the EU is rising, although it is difficult to disentangle its main drivers, e.g. the economic and financial crisis or technological change and innovation.

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[1] inequality of the working-age population (2007 = 100) in the EU[2], 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

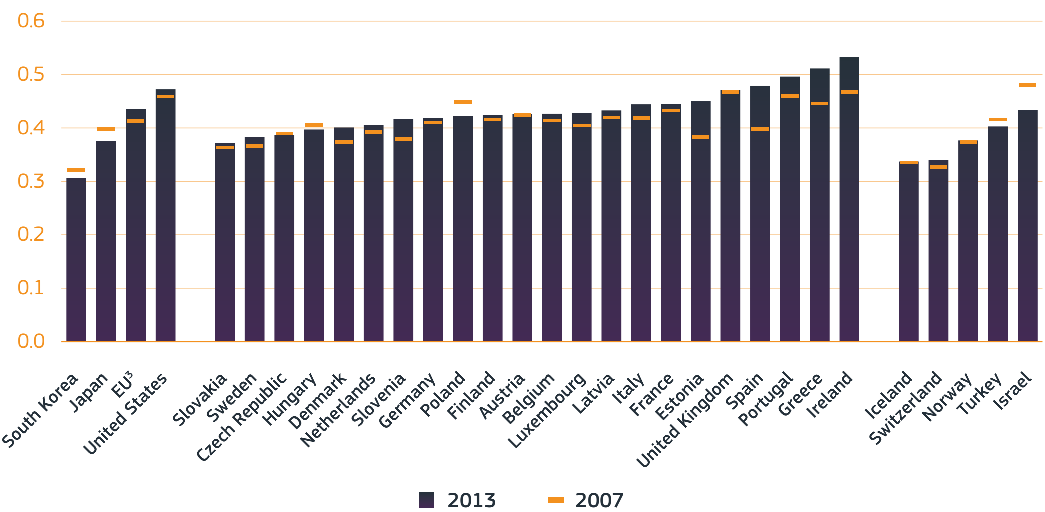
Notes: [1]Labour and capital incomes plus private transfers. [2]EU is the unweighted average of the values of the Member States for which data are available.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_1.xlsx

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[42]. 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[43]. 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[1] inequality (Gini coefficient)[2], 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: [1]Labour and capital incomes plus private transfers. [2]0 = perfect equality; 1 = perfect inequality. [3]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_2.xlsx

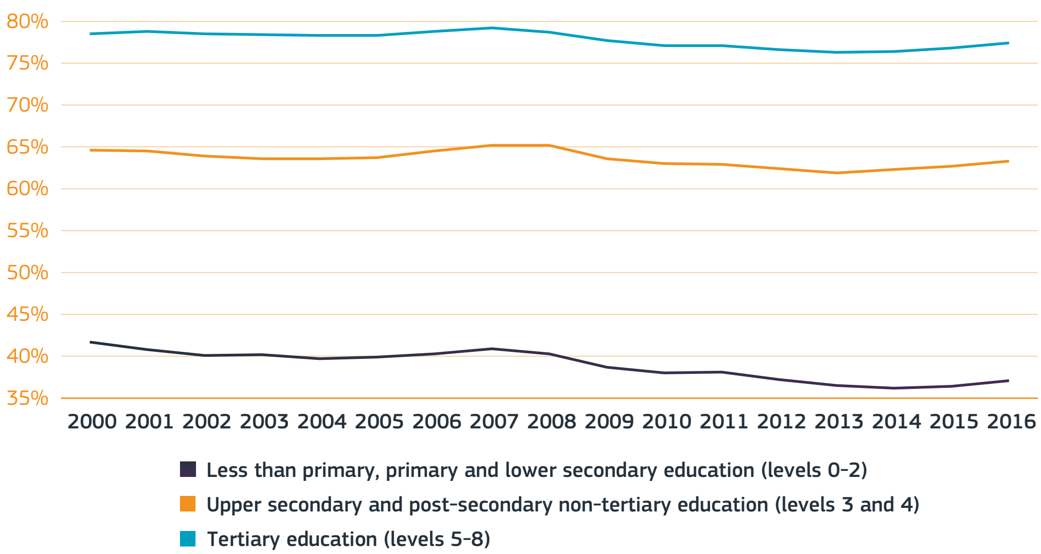
42 Source: https://data.oecd.org/inequality/income-inequality.htm

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[1] in the EU[2] by level of educational attainment (ISCED 2011), 2000-2016



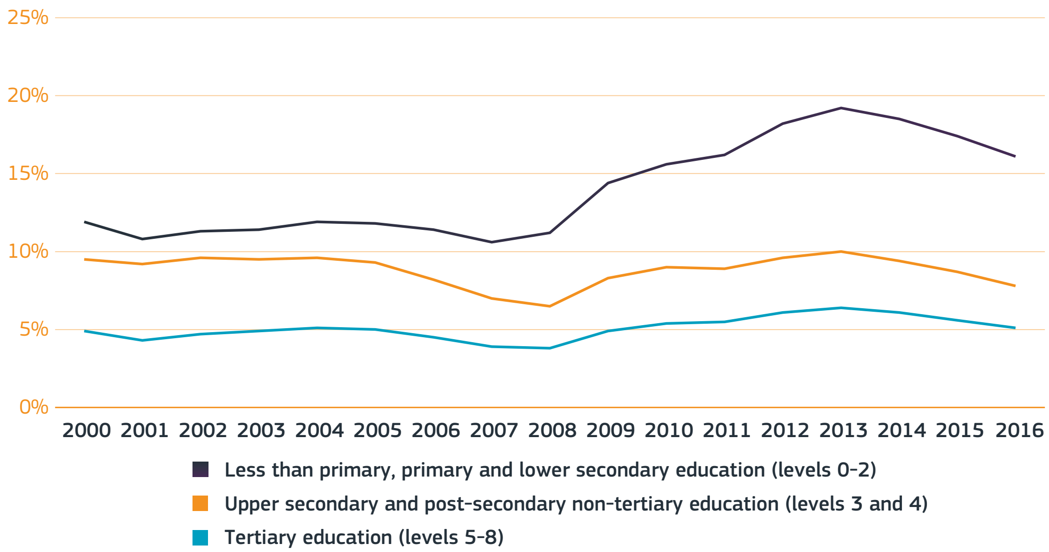
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat (Labour Force Survey)
Notes: [1]Age group 15-74. [2]EU: Croatia is not included for 2000 and 2001.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_3.xlsx

Unemployment rates have traditionally been higher in those lower-skilled segments that have been disproportionally 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[44]. 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[1] in the EU[2] 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: [1]Age group 15-74. [2]EU: Croatia is not included for 2000 and 2001.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_4.xlsx

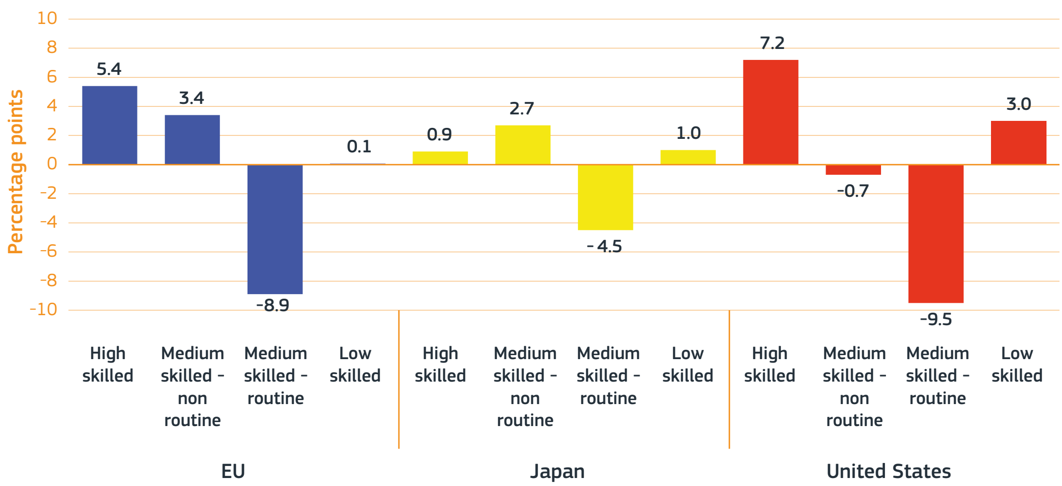
44 According to the Employment and Social Developments in Europe Annual Review, qualifications and skills are becoming more and more important for employment as a result of globalisation and technological change.

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 routine 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
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_5.xlsx

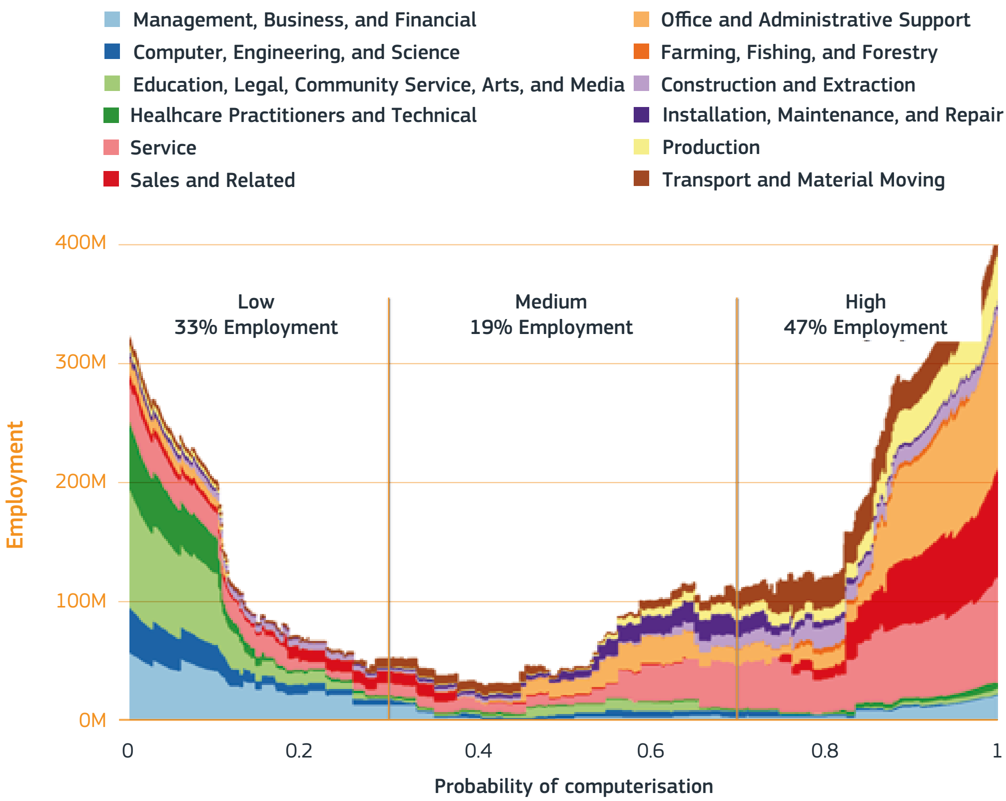
Job polarisation is likely to continue as the risk of automation and computerisation is deeply disrupting or destructing existing jobs: up to 50% of existing jobs are expected to be affected by automation and computerisation in the coming years.

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



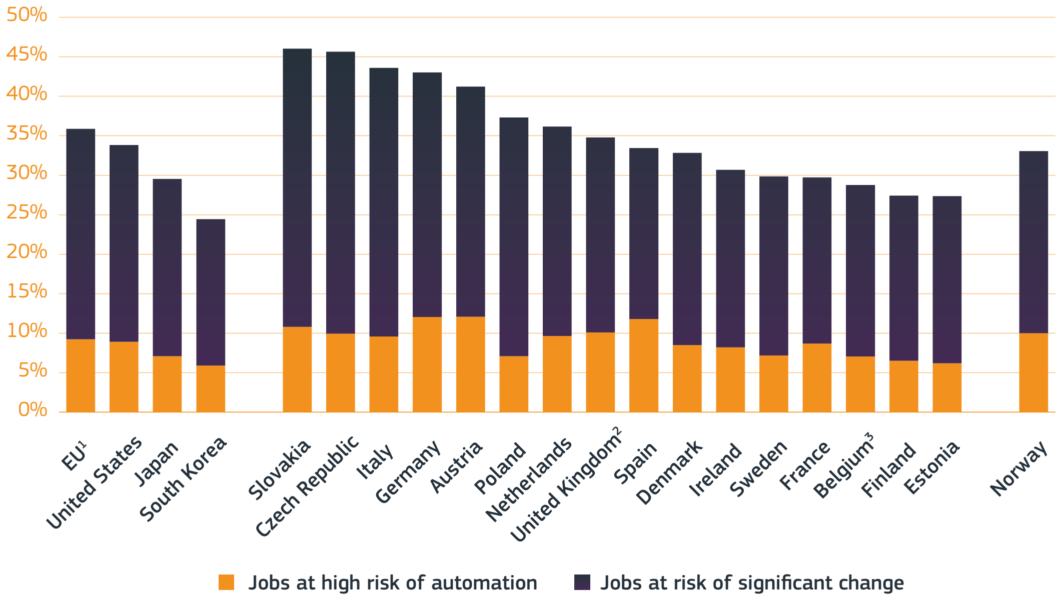
Source: C. Frey, M. Osborne / Technological Forecasting & Social Change 114 (2017) 254-280[45]
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_6.xlsx

45 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



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

Notes: [1]EU is the unweighted average of the values of the Member States for which data are available. [2]UK: England and Northern Ireland only. [3]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

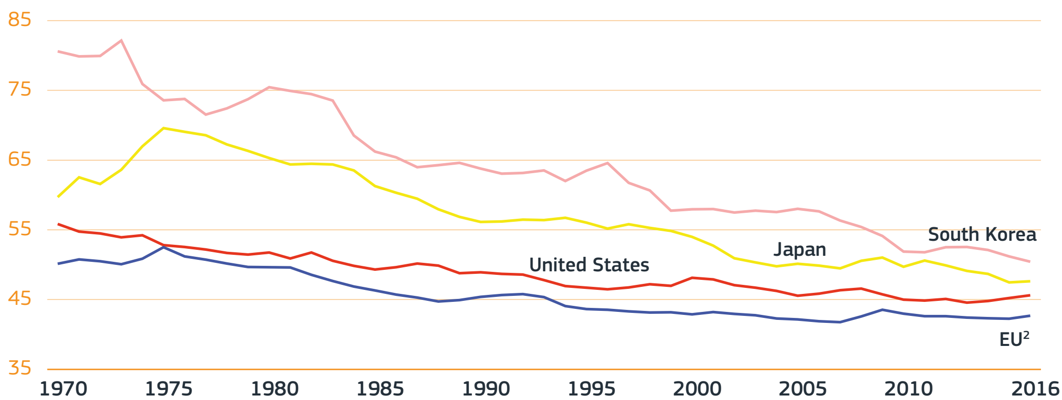
Innovation will also create new jobs, although there is no certainty about the speed and scope of new job creation.

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[1], 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: [1]Share of wages in total GDP adjusted by the ratio of total-to-dependent employment. [2]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.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_8.xlsx

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 economic 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 were 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.

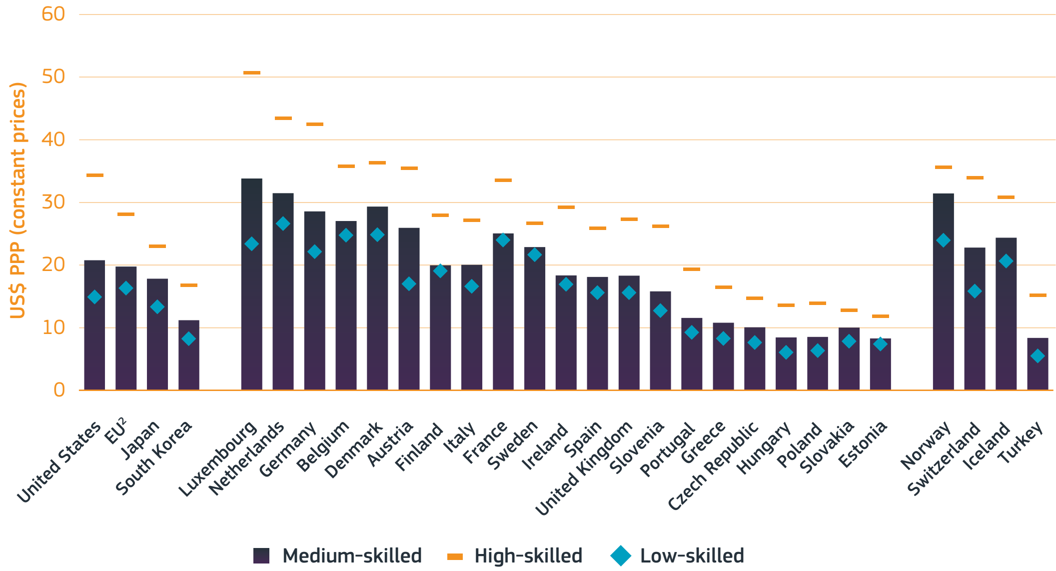
An increase in the demand for skills in conjunction with an increase in observed skills shortages and mismatches across the EU, as well as advances in technologies is fuelling fears of robots and artificial intelligence substituting human labour. Furthermore, there is a growing trend of higher-educated 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[45] 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.

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[1]



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

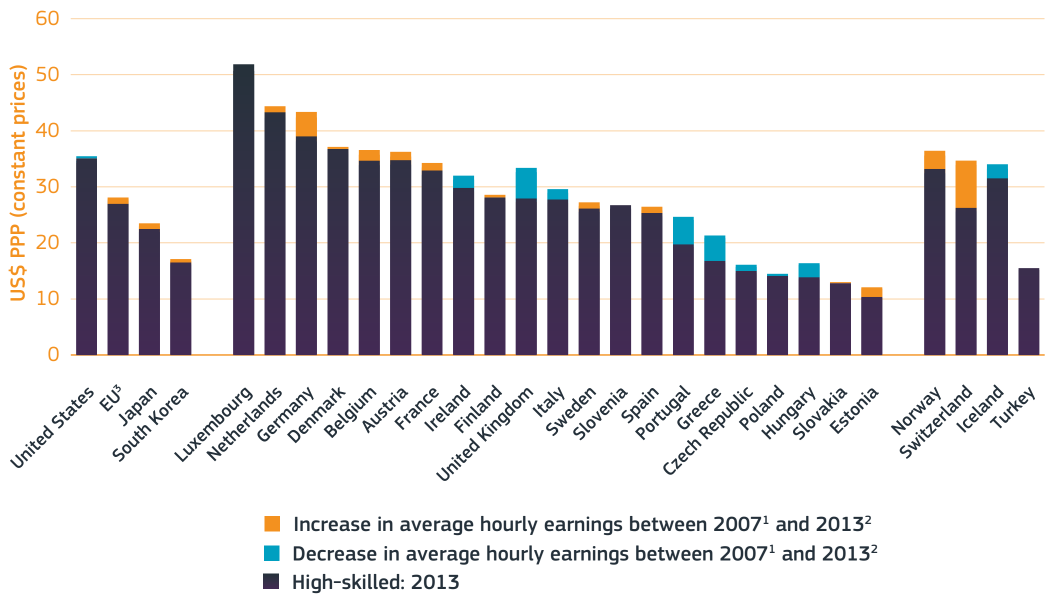
Notes: [1]ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. [2]EU is the unweighted average of the values of the Member States for which data are available.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_2-c_figures/f_i_2-c_9.xlsx

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: [1]EL, NL: 2006; DK, IT: 2008; CH: 2010. [2]ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. [3]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

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.

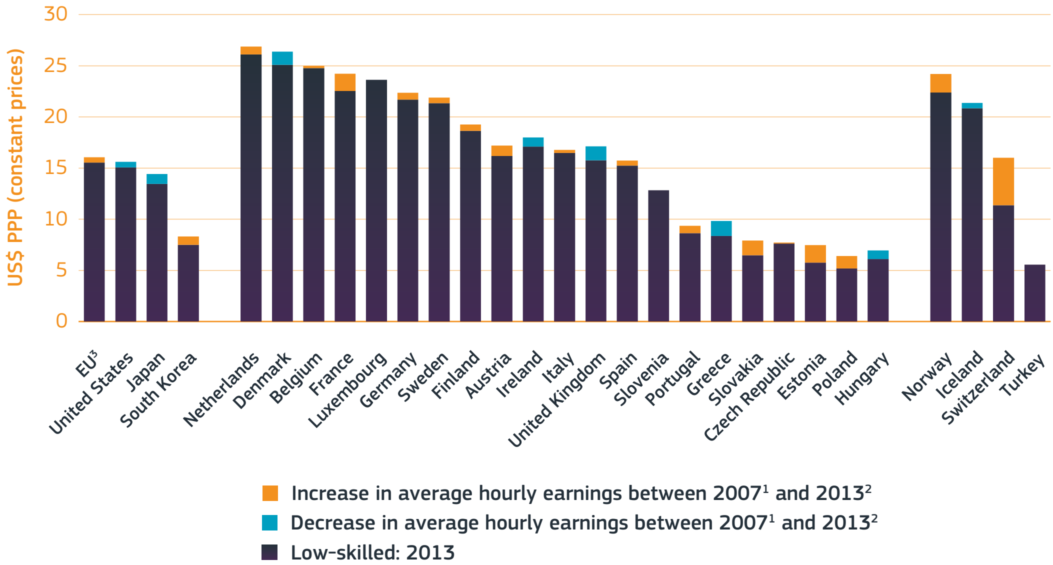
Figure I.2-C.11 Medium-skilled workers - average hourly earnings (US$ PPP constant prices), 2013 compared to 2007

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: [1]EL, NL: 2006; DK, IT: 2008; CH: 2010. [2]ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. [3]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

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



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: [1]EL, NL: 2006; DK, IT: 2008; CH: 2010. [2]ES, FR, IT, PL, SE, CH, KR: 2012; EE, LU, NL, SI, TR: 2010. [3]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

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.

References

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

Andrews, D., Criscuolo, C. and Gal, P.N. (2015). Frontier firms, technology diffusion and public policy: Micro evidence from OECD countries. OECD The Future of Productivity: Main background papers (https://www.oecd.org/eco/growth/OECD-2015-The-future-of-productivity-book.pdf)

Arntz, M., Gregory, T. and Zierahn, U. (2016). The Risk of Automation for Jobs in OECD Countries: a Comparative Analysis, OECD Social Employment and Migration Working Papers, No. 189, OECD Publishing, Paris.

Autor, D. (2015). Why Are There Still So Many Jobs? The History and Future of Workplace automation. *Journal of Economic Perspective* 29(3): 3-30.

Autor, D.H. and Dorn, D. (2013). The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market. *American Economic Review*. 103(5), 1553-97.

Autor D., Dorn D., Katz L.F., Patterson, C. and van Reenen, J. (2017). Concentrating on the Fall of the Labor Share. IZA DP No. 10539.

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

Bijak, J., Kupiszewska, D. and Kupiszewski, M. (2008). 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.

Bruegel (2014). Jobs at Risk. Available at: http://bruegel.org/2014/07/chart-of-the-week-54-of-eu-jobs-at-risk-of-computerisation/

Brynjolfsson, E. and McAfee, A. (2011). Race against the machine: How the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy, Digital Frontier Press.

Brynjolfsson, E. and McAfee, A. (2014). The second machine age: Work, progress, and prosperity in a time of brilliant technologies, W.W. Norton & Company, New York.

CEDEFOP (2015). Skills, qualifications and jobs in the EU: the making of a perfect match?

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

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

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

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

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

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

European Central Bank (2017). Economic Bulletin. Issue 3 (https://www.ecb.europa.eu/pub/pdf/ecbu/eb201703.en.pdf?ea7747ab0ef3b038300a8d51a3a95313)

European Commission (2016). 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).

European Commission (2017A). Globalisation and the EU economy. Available at: (https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/international-economic-relations/globalisation-and-eu-economy_en)

European Commission (2017B). Climate Change. Available at: https://ec.europa.eu/jrc/en/research-topic/climate-change

Frey, C.B. and Osborne, M.A. (2017). The future of employment: How susceptible are jobs to computerisation? Technological Forecasting & Social Change 114, 254-280.

Goldin, C. and Katz, L.F. (2008). The Race Between Education and Technology. Cambridge, MA: Harvard University Press.

Goos, M., Manning, A. and Salomons, A. (2014). Explaining Job Polarization: Routine-Biased Technological Change and Offshoring. *American Economic Review*. 104(8), 2509-2526.

Gordon, R. (2012). Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds, NBER Working Papers, 18315.

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

Graafmans, J.A.M. (2016). The Emerging Field of Gerontechnology Heger, D. & Kolodziej, I. W. K. Changes in morbidity over time: Evidence from Europe. Ruhr Econ. Pap.

Harrison, R., Jaumandreu, J., Mairesse, J. and B. Peters. (2014). Does innovation stimulate employment? a firm-level analysis using comparable micro-data from four European countries. *International Journal of Industrial Organization*. 35, 29-43.

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).

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

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

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

Peek, S.T.M., Wouters, E.J., van Hoof J. and Luijkx, K.G. (2014). Factors influencing acceptance of technology for aging in place: a systematic review. *Int. J. Med. Inform.* 83, 235-248.

United Nations Programme for Development (2015). 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).

Rechel, B., Grundy, E., Robine, J.M., Cylus, J., Mackenbach, J.P., Knai, C. and Mackee, M. (2017). Ageing in the European Union. *Lancet* 381, 1312-1322 (2013).

Schwab, K. (2016). The Fourth Industrial Revolution. World Economic Forum.

Schoar, A. (2010). The Divide between subsistence and transformational entrepreneurship. In Lerner J. and Stern S. NBER book. Innovation policy and the economy, V. 10.

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

Syerson, C. (2016). Challenges to Mismeasurement Explanations for the U.S. Productivity Slowdown. NBER Working Paper No. 21974.

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

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

WIC. Wittgenstein Centre Graphic Explorer (2015).

Zhang, X., Yang, J. and Wang, S. (2011). China has reached the Lewis turning point. *China Econ. Rev.* 22, 542-554.