PART II

CHAPTER 8

A POLICY TOOLKIT TO INCREASE RESEARCH AND INNOVATION IN THE EUROPEAN UNION

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Summary

What R&I policies should the EU adopt? The world faces a challenge to rebuild after the pandemic, but also faces the same structural slowdown of productivity growth that occurred in the decades before the COVID-19 crisis. The EU needs a plan around innovation policy to address the challenge. We show that Europe is less innovative on many dimensions compared to other advanced regions, such as the USA and parts of Asia. We review the econometric evidence on R&I policies and argue that there is good evidence for the efficacy of many of them. A mix of R&D subsidies, reinvigorated competition and a big push on expanding the quantity and quality of human capital is needed. These could be bound together around the need for green innovation to achieve the mission to radically reduce carbon emissions.

1. Introduction

Rebuilding our societies after the COVID-19 pandemic is a huge task, reminiscent of the challenges facing Europe after the Second World War. The fall of output in 2020 due to the pandemic and the necessary policy response of lockdowns was substantial – of the order of 13 % across the EU as a whole[1]. This was more than twice the GDP loss in the depths of the global financial crisis in 2008-09. To tackle the crisis, we need a serious plan for growth using the best innovation policies. This will be no easy task, of course. Not only was the crisis deep – and continues at the time of writing – but economic performance was poor in the decades even prior to COVID-19.

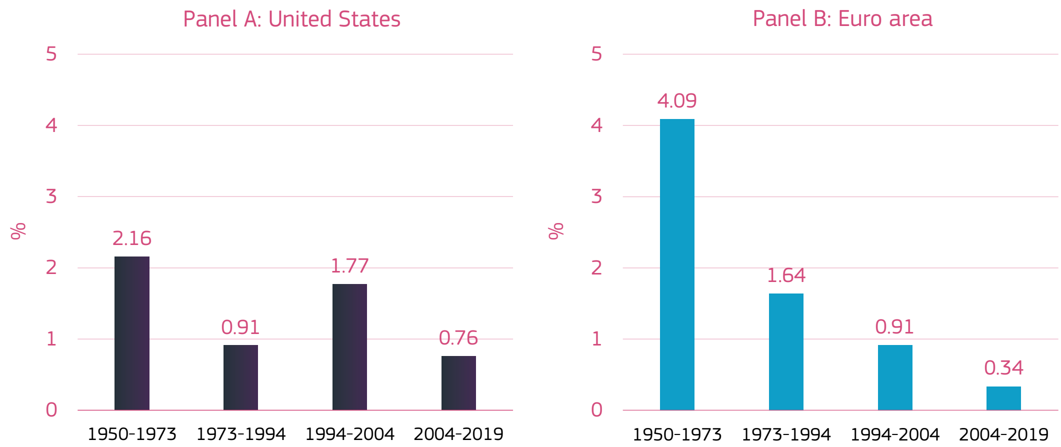
Figure 1 shows the growth in total factor productivity (TFP) since 1950 for the USA (Panel A) and the euro area[2] (Panel B). TFP is a proxy for technical change – the improvement in the efficiency with which an economy uses production inputs such as labour and capital. The picture is grim. TFP growth has been on a declining path over the last 70 years.

Productivity growth was strongest during the post-war reconstruction period (1950-73); in fact, even stronger in Europe than the USA (4 % per annum vs 2 %) as the damage was greater in war-torn Europe. After the OPEC oil shocks of the 1970s, productivity growth more than halved from 1973 to 1994, but still remained higher in Europe (1.6 %) than in the USA (0.91 %). Although Europe continued on a downward path after the mid-1990s, the USA experienced a brief 'productivity miracle' between 1994 and 2004 based around the rapid fall in quality-adjusted prices of information and communication technologies (ICT) enhanced by the growth of the internet (see Draca, Sadun and Van Reenen, 2007; Bloom, Sadun and Van Reenen, 2012). Nevertheless, over 2004-19, TFP growth has been only 0.76 % a year in the USA and 0.34 % in Europe. Although this dismal performance is influenced by the global financial crisis and its aftermath, such as the euro crisis, the fact that the productivity slowdown began well before Lehman's collapse implies that there are more structural forces at play.

1 Eurostat: https://ec.europa.eu/eurostat/documents/2995521/11563211/2-30072021-BP-EN.pdf/0567c280-b56c-2734-2a4b-e4af85a55bf5?t=1627630313030 (last accessed on 30 July 2021).

2 We define the euro area (or 'Europe' for short) in this chapter as DE, FR, IT, ES, NL and FI, using data updated from Bergeaud, Cette and Lecat (2016). These countries made up 82 % of the euro area's GDP in 2012.

Figure 8-1: Average annual TFP growth in the United States and the Euro area in different time periods



Source: Data updated from Bergeaud, Cette, and Lecat (2016). Data publicly available at http://www.longtermproductivity.com/
Note: The average annual TFP growth in the US (panel A) and Euro area (panel B) is shown. There is insufficient data for the whole EU, so we use Germany, France, Italy, Spain, the Netherlands and Finland to represent the euro area.
Stats.: link

Productivity growth matters because it determines wage growth in the long-run. It expands the economic pie, which enables a society to pursue its goals, whether this be greater consumption or spending on public goods such as the environment, health, education or defence. Without productivity growth, the effective economic pie is fixed in size, so some groups have to be made strictly worse off if we want to redistribute resources to others, which is no politically easy task.

TFP growth can be driven by several proximate causes. One is **frontier innovation**, defined as commercially applicable new ideas that are new to the world (not just to a country, industry or firm) that push forward the production possibility frontier. Frontier innovation is the most important factor for advanced economies such as Europe and the USA. A second factor driving aggregate TFP growth is **diffusion**, the spread of these frontier technologies across people, firms, industries and countries. A third factor is **reallocation**, the degree to which an economy allocates more output to high-productivity firms and away from low-productivity firms. Diffusion and misallocation are very important in rich countries and are the overwhelmingly dominant force in poorer nations. In this chapter, we focus on frontier R&I policies in order to keep the discussion within manageable limits[3].

Technological innovation is vital for growth, but it is also crucial in order to address the major challenges we face in many other dimensions.

3 For a discussion of diffusion policies, particularly around management practices see Scur et al. (2021). Note that the policies interact: higher R&D might enable faster catch up to the frontier as well as frontier innovations (see Griffith, Redding and Van Reenen, 2004, for evidence on these 'two faces' of R&D).

Above all, combating the existential threat of climate change will require green innovation. Taxes and regulation by themselves will not be enough. Importantly, there are many targets for innovation – for example the environment more broadly (e.g. plastics in the ocean), health (e.g. future pandemics) and inclusion (as inequality has risen within many countries over the last few decades).

In this chapter, we argue for a new plan around innovation policy to foster economic growth. This would have to be based on good evidence, and an important aim of this chapter is to provide the theoretical and empirical evidence upon which such a plan could be based. The EU has already made some progress in this regard. In particular, the Horizon 2020 programme (launched in 2014) had a reinforced focus on innovation in addition to supporting frontier research and collaborative research projects – making funding available to researchers and innovators in the form of grants, prizes and procurement[4]. Horizon Europe is the next phase of this initiative, covering the 2021-2027 period with a budget of EUR 95.49 billion[5]. Compared to Horizon 2020, this amounts to a 30% increase in spending[6]. Based on the evidence we provide in this chapter, this substantial increase is clearly a step in the right direction. However, we think that theory and evidence support an even higher increase in resources. And obviously, not only is the **amount** of money spent important; it is **how** it is to be spent.

The budget should not solely be used as a short-term demand boost, but rather be designed to induce structural changes in the EU economy that will lead to long-lasting productivity increases[7]. We will lay out evidence for a mix of such policies in this chapter.

Horizon Europe is mainly aimed to help researchers, inventors and research institutions through grants. For example, one policy is the Marie Sklodowska-Curie Actions (MSCA), which include postdoctoral fellowships for researchers who recently obtained their PhD. Another is support from the European Research Council for promising early-career and experienced researchers. Additionally, researchers can generally apply for funding of collaborative projects in pre-specified areas (or 'clusters'), with particular emphasis being put in terms of budget on climate, energy, mobility and digital areas, industry and space[8]. Horizon Europe is only a small part of the EU's overall EUR 2.02 trillion budget[9]. Part of this larger budget is the Recovery and Resilience Facility worth a substantial EUR 723.8 billion (47% in grants and 53% in loans) to help Member States to recover from the pandemic. The allocation of the money to individual areas is generally delegated to individual Member States, although particular quotas have to be met (e.g. at least 20% of the total Rescue and Resilience Facility is to be spent on digital transformation) and the plans have to be formally signed off by the Commission.

4 The Horizon 2020 budget was EUR 80 billion over 2014-2020 https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en (last accessed 02 September 2021)

5 The majority of this (EUR 86.1 billion) is from the main budget, with EUR 5.41 billion from the NextGenerationEU instrument and smaller amounts from elsewhere.

6 This excludes data on the UK beneficiaries from the previous programme so that the numbers are on a consistent basis pre- and post-Brexit. The increase is measured in real terms. https://op.europa.eu/en/publication-detail/-/publication/1f107d76-acbe-11eb-9767-01aa75ed71a1 (last accessed 03 September 2021)

7 For example, see the intervention by Luis Garicano at the LSE event on 'Europe's Recovery Programmes': https://www.lse.ac.uk/Events/2021/11/202111181830/europe

8 https://op.europa.eu/en/publication-detail/-/publication/1f107d76-acbe-11eb-9767-01aa75ed71a1 (last accessed 03 September 2021)

9 This covers 2021-2027 (passed in 2020) and is composed of the long-term budget (EUR 1.210 trillion) and NextGenerationEU (EUR 806.9 billion).

Some of the country-specific plans clearly seem to involve spending on innovation. For example, Italy explicitly states 'innovation in the production system' as one policy area[10], and Germany plans to support disadvantaged students[11]. Although the latter is not a classical innovation policy, we will argue below that this kind of human capital support can be a successful supply-side innovation policy (Aghion et al., 2017; Bell et al., 2019a; Van Reenen, 2021).

The structure of the chapter is as follows. We provide some background innovation statistics in section 2. In section 3, we discuss the rationale for state intervention in innovation and present a review of evidence on these policies in section 4, before offering concluding comments in section 5. Further analysis is available in the Online Appendix.

10 For more detailed information on the Italian recovery plan, see https://www.mef.gov.it/en/focus/The-National-Recovery-and-Resilience-Plan-NRRP/ (last accessed 3 September 2021).

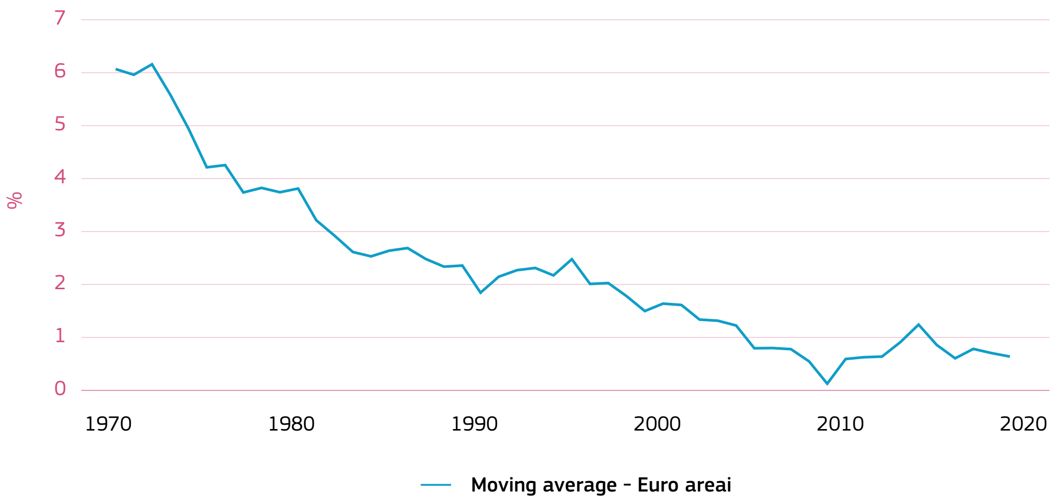
11 This and additional information on the German recovery plan can be found here: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3133 (last accessed 03 September 2021).

2. Background: R&I facts

Productivity trends

As we documented in the previous section, TFP growth has slowed down in the USA and Europe since the mid-1970s. Figure 1 presented this for TFP and Figure 2 does the same for labour productivity (GDP per hour) in the 'euro area'. Growth rates of labour productivity have been falling relatively consistently between 1970 and the financial crisis and have stagnated on a relatively low level since the crisis (growth of less than 1 % in most years).

Figure 8-2: Annual growth of labour productivity in a subset of EU countries (1970-2019)



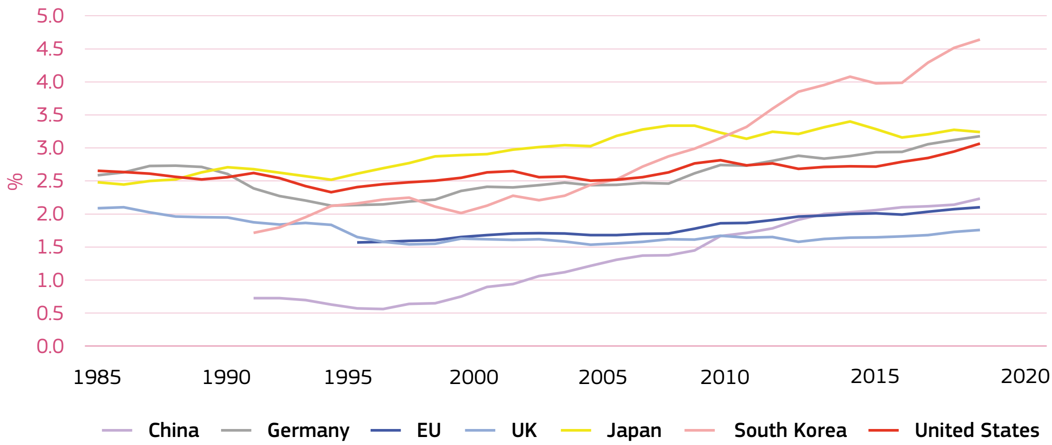
Source: Data updated from Bergeaud, Cette, and Lecat (2016). Data publicly available at: http://www.longtermproductivity.com/
Note: The line shows annual growth of real GDP per hour in a subset of EU countries (Germany, France, Italy, Spain, Netherlands, and Finland). Data are shown as 5-year moving averages (i.e. 1970 includes the 1970 change and the previous four yearly changes).
Stats.: link

R&I statistics

As innovation is vital to restore productivity growth, we now turn to different innovation statistics. There are many different indicators of innovation, and we present only some of them here. We give an overview of the time-series patterns of innovation in the EU compared to other major industrialised economies.

In 2019, total R&D spending in the EU-27 amounted to EUR 308 billion[12]. This is about 60% of the value in the USA (which spends more money on R&D than any other country), and more than twice the value of Japan. In part, these differences are related to the size of the different economies, so we consider R&D intensity (R&D spending as a fraction of GDP) in Figure 3 for selected countries. This shows that R&D intensity has generally increased over time in the EU (from 1.6% in 1995 to 2.1% in 2019, with most of this increase occurring since 2007). This fraction lies well below the EU's own target of 3%, which was supposed to be reached by 2020[13]. Compared to other OECD countries, the EU's R&D intensity is relatively low. The USA, Germany and Japan all have R&D intensities closer to 3% or more – a whole percentage point higher. South Korea's R&D intensity is more than double that of the EU (about 4.5%). China

Figure 8-3: R&D spending as a share of GDP in selected countries (1985-2019)



Science, Research and Innovation Performance of the EU 2022

Source: OECD. https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm
Note: The respective lines show R&D spending as a share of GDP in different countries. R&D spending from abroad is included, but domestic funds for R&D that are not used within the domestic economy are excluded. EU-27 refers to the EU Member States as of 2020 (i.e. not the UK). The EU-27, China and South Korea series start later due to limited data availability.
Stats.: link

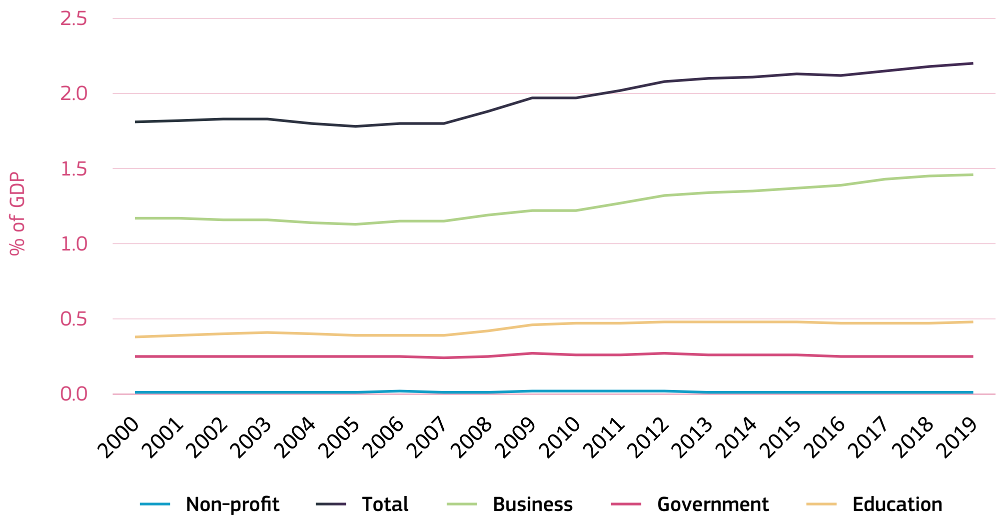
12 Eurostat Science, Technology and Innovation data base: https://ec.europa.eu/eurostat/databrowser/view/RD_E_GERDSC__custom_1392084/default/table?lang=en (last accessed on 11 October 2021).

13 This target was part of the EU's 2020 strategy. For more information, see https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Europe_2020_indicators_-_R%26D_and_innovation&oldid=383721 (last accessed on 02 September 2021).

has seen massive increases in its R&D intensity since the mid-1990s, and it is now slightly higher than that of the EU. The EU average conceals huge heterogeneity among Member States. Whereas countries such as Germany, Austria and Sweden had R&D intensities of more than 3% in 2019, other Member States spent less than 1% (e.g. late joiners such as Latvia, Romania and Slovakia.

Figure 4 shows how R&D expenditure of the EU-27 breaks down into the broad sectors that conduct the R&D. Two-thirds of R&D is conducted by businesses. This is followed by universities (about 22%), then by governments (about 11%). The increase in the EU's R&D spending seems to be almost totally driven by the business sector (making up about three-quarters of the increase), with a smaller increase from higher education (about one quarter). This is consistent with the trends in the USA, where there has also been a switch away from government and towards the business sector in R&D (Bloom, Williams and Van Reenen, 2019)[14]. Today, US federal funding of R&D as a fraction of GDP is only a third of its level in the mid-1960s. The move towards business R&D and away from government R&D may matter. If the government often supports more basic and higher-risk research than the private sector, this public R&D will tend to produce higher value innovations[15].

Figure 8-4: R&D expenditure in the EU by sector of performance (2000-2019)



Source: Eurostat (2021). https://ec.europa.eu/eurostat/databrowser/view/tsc00001/default/table?lang=en
Note: All series are shown as share of GDP. 'Total' is all R&D expenditure, 'Business' refers to R&D expenditure conducted by business enterprises, 'Education' is the higher education sector, 'Non-profit' is the private non-profit sector and 'Government' is conducted by the state.
Stats.: link

14 The corresponding graph for the USA can be found in Appendix A.

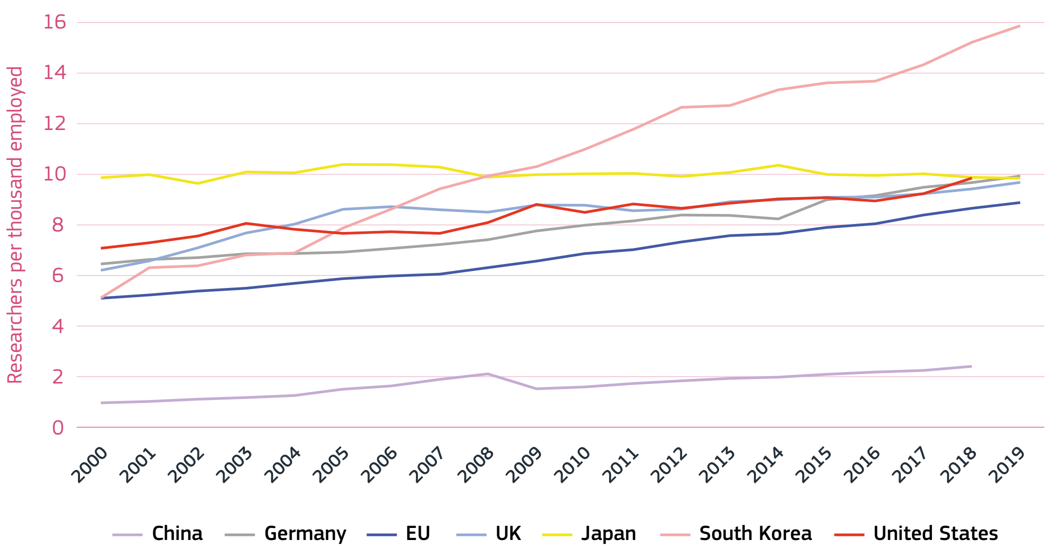
15 There is also some evidence that even within business R&D, the fraction of basic research has declined relative to applied research (e.g. Arora, Belenzon and Patacconi, 2018). Indeed, the decline in basic research in both public- and private-sector R&D spending may be one reason why the productivity of US R&D appears to have fallen over time, as documented by Bloom et al. (2020).

Although R&D is an attractive measure as it can be measured in a reasonably consistent way across time and countries, it does have well-known issues as a measure of innovation. R&D is an input and not an output of the innovation process: a lot of money could be spent too little avail. R&D also tends to be focused on formal activity in laboratories and misses out on much innovative effort in services, homes and garages. Productivity in Figures 1 and 2 are innovation output measures, but these are rather indirect and (as discussed above) could grow for many reasons such as diffusion or reductions in misallocation. Thus, TFP is inevitably coarse as a measure of technological progress and innovation.

An alternative measure is the relative size of the scientific workforce. This indicator has some attractive features as it abstracts away from the problem that R&D expenditure might be high only because the cost (rather than the volume) of R&D is high. On the other hand, R&D spending includes spending on capital (e.g. labs and equipment) as well as materials, whereas the scientific workers measure only includes labour.

Figure 5 shows that the number of researchers (per thousand employees) in the EU-27 has increased more or less continuously since 2000 (from 5.1% to 8.9%). The 2019 level in the EU is similar to that of the USA, UK and Japan. Consistent with the R&D spending numbers shown in Figure 3, South Korea has seen the biggest increase in the number of researchers per thousand employed over the period. China's levels are strikingly low compared with the other countries, although it has still experienced a doubling in their numbers from less than 1% to 2.4%. The general consistency between trends in R&D spending and number of researchers is unsurprising, as most R&D spending is on people, such as scientists.

Figure 8-5: Researchers per thousand employed in different countries (2000-2019)



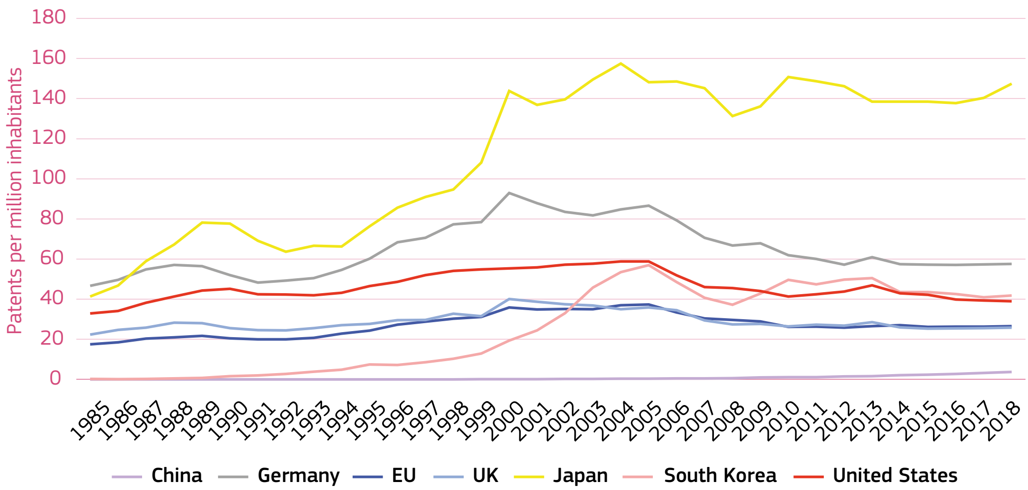
Science, Research and Innovation Performance of the EU 2022

Source: OECD. https://data.oecd.org/rd/researchers.htm
Note: Data are shown per thousand employed. The line of China ends in 2018 due to limited data availability.
Stats.: link

A more direct measure of innovation is based on patents. With patent data, there are the well-known issues that some innovations may not be patented and thus will be missed in the statistics as well as the difference in patent definitions by different patent offices. In particular, a concern is that patents are of hugely heterogeneous values, with many duds and a few bonanzas. As a result, we focus on 'triadic' patents. These are patents that have been registered in at least three different patent offices: in the EU, in Japan and in the USA. These should be the relatively high-value patents.

Figure 6 shows patent registrations per million inhabitants since 1985. Over this period, patents per million inhabitants in the EU increased by about 41% (from 18.1% to 25.6%). The trend looks similar to those in the UK and the USA. The Asian countries show very different trends: Japan and South Korea have both seen massive increases in patents per million inhabitants (Japan's number has more than tripled, and South Korea's has increased from almost no patents per million inhabitants to more than 40). This occurred especially at the end of the 1990s and the beginning of the 2000s, mostly coinciding with increases in R&D spending, as shown in Figure 3.

Figure 8-6: Patents per million inhabitants in different countries (1985-2018)



Science, Research and Innovation Performance of the EU 2022

Source: OECD. Patent data: https://data.oecd.org/rd/triadic-patent-families.htm#indicator-chart, Population data: https://data.oecd.org/pop/population.htm

Note: Patents per million inhabitants are obtained by dividing total annual registered patents by million inhabitants in a country. We only consider triadic patents, which are registered at the European Patent Office (EPO), Japan Patent Office (JPO) and the United States Patent and Trademark Office (UPSTO). A patent's country of origin is determined by the residence of the inventor. The EU series ends in 2017 as patent data is not available for 2018.

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Summary

In summary, the EU is lagging behind the USA in most innovation statistics that we have considered. In terms of changes over time, advanced Asian economies, especially South Korea but also partly Japan and China have seen much more growth in their innovation metrics than the EU. It is important to note that there is large heterogeneity among EU Member States – whereas countries like Germany or Sweden show relatively strong R&D investment and patent numbers, others have relatively low spending and patent numbers.

3. What is the rationale for public intervention in innovation?

Are low innovation rates a problem? And if so, should governments intervene? We tackle this question in this section, broadly answering in the affirmative. The subsequent section then investigates whether governments can intervene successfully. Jones and Summers (2020) examine the arguments on why governments should support R&D in detail, so we only briefly summarise the arguments here (also see Mazzucato and Semieniuk, 2017; Bloom, Williams and Van Reenen, 2019; Bryan and Williams, 2021 for more detail)[16]. The bottom line is that both theory and (more importantly) evidence imply that there is under-provision of government support for innovation.

3.1 Rationale for public support of innovation: theory

The primary argument for public support of innovation is that there are large positive externalities from R&D. This is because there are benefits of the technological innovation created by the research that spill over to other agents who did not conduct the research. For example, although firms who invest in R&D expect to see some return – even if this is highly uncertain and a long way off – the profits obtained by the individual firm do not fully reflect the social benefits of the R&D. Spillover beneficiaries include other firms who might copy the innovation and/or build on the knowledge created by the inventor's R&D. Moreover, domestic and foreign consumers will get the innovation benefits potentially at a tiny fraction of the (full) costs. Flaubert's (1911) definition of inventors is often cited: 'All die in the poor house. Someone else profits from their discoveries; it is not fair.'

The externalities of research imply that there is a gap between the social and private benefits of R&D. The larger this gap, the bigger is the necessary government subsidy to promote innovation and reduce the difference between social and private returns.

Although knowledge spillovers are the main justification for government action, there are additional arguments. In particular, Arrow (1962) pointed to financial-market failures in innovation due to high risk, uncertainty, absence of collateral and asymmetric information (e.g. Hall and Lerner, 2010). A potential innovator must convince an external funder of the value of the innovation, especially if the investor is expected to take an equity stake, reflecting the uncertainty of the return. But revealing this information means that the funder might steal the idea from the inventor. All these financial frictions can lead to many good ideas being unrealised. In general, many other market frictions can lead to under-provision. For example, if labour unions are strong, they may demand higher wages if the firm innovates, and this 'hold-up tax' may discourage firms from investing in R&D in the first place (Grout, 1984; Menezes-Filho, Ulph and Van Reenen, 1998).

On the other hand, there may be other factors that lead to **too much** R&D. The most well-discussed mechanism is through the 'business stealing' effect of innovation due to product market rivalry. When a firm innovates, it not only expands the overall size of the market (or indeed creates new markets); it also takes some market share from rival firms due to higher quality and/or lower cost of products.

16 See also European Commission (2017) for an EU perspective on why public R&I support is important.

Although this creates a private incentive for the firm to innovate if there is only a small improvement in cost/quality, but a big shift in market share, this means that there will only be small social benefits. For example, 'me-too' drugs of minor therapeutic improvement can lead to large shifts in market share as doctors and patients want the best drug. In this case, the private returns may be larger than the social returns and there is somewhat of an R&D 'arms race'. We see such effects in Schumpeter's notion of creative destruction and in many industrial organisation models (Griffith and Van Reenen, 2021).

The fact that a decentralised market economy will not deliver the optimal amount of investment in innovation is well recognised. Indeed, there is a wide panoply of policies and institutions (see our discussion below on the evidence) that are designed to deal with this problem. Many of these policies are not always effective, and indeed they can themselves create more problems than they solve (i.e. the 'cure' can be worse than the 'disease'). A much-discussed example is the system of intellectual property (IP) rights. IP rights such as patents are designed to deal with the knowledge spillover problem by granting a temporary monopoly to an inventor of an original and commercially practical innovation. In return for making the knowledge public, a private incentive for R&D is restored to the inventor; when the patent runs out, all are free to use the invention. This seems in principle attractive, as there is no need for the government to directly intervene and 'pick winners', and the trade-off between dynamic innovation incentives (the monopoly period to incentivise investment) and static inefficiencies (the distortions from the high monopoly price) is embodied within the institution of IP rights.

Alas, in practice, the way the IP system works is far from its ideal. Many patents can be 'designed around' and may offer little effective protection. In many industries, innovation cannot be formally protected as it is often tacit, hard to codify and incremental. This suggests the under-investment problem will still occur in many if not all industries. Even more worryingly, in recent decades, especially in the USA, there is ample evidence that the patent system has been abused with (predominantly large) firms creating 'patent thickets' to block entry by rivals. This is characterised by trivial patents receiving protection (with massive legal expenditure being used to defend them) and much useful knowledge hidden in patent documents rather than being revealed (see Jaffe and Lerner, 2007, for a survey; Williams, 2017, for a more recent general discussion; Ouellette and Williams, 2020, for some specific ideas for reform; and Boldrin and Levine, 2013, for a call to fully abolish current patent systems).

3.2 Rationale for public support of innovation: evidence

We now turn to the evidence on whether the social benefits of R&D exceed the private returns. There is a wealth of evidence from case studies recording both dramatic failures of government subsidies for innovation (for example, the Anglo-French supersonic aircraft, Concorde; or see the more systematic review in Lerner, 2005) as well as successes (e.g. nuclear power, jet engines, GPS, radar and the internet, e.g. Janeway, 2012; Mazzucato, 2013). Such qualitative evidence is useful but by their nature, case studies are small, highly selective and hard to quantify. There is a literature of statistical studies, beginning with Griliches' (1958) hybrid corn analysis. Griliches (1958) found social returns to government investment to be many multiples of private returns but cautioned against generalisation.

The more modern econometric literature examines a wider range of firms, sectors and technologies. A popular approach here is to use patent citations. A patent application is legally required to cite the prior art and even if an applicant does not do this, the patent examiner will frequently add citations. Past citations are an explicit (or implicit) way in which previous ideas spill over to future ones. This dynamic pattern of ideas can be used to estimate the speed at which knowledge diffuses and decays. Many authors have shown how citations are geographically clustered (both by country and also within a country), with inventors more likely to cite original inventors they live geographically close to, even after controlling for the technological field (e.g. Trajtenberg 1990; Jaffe, Trajtenberg and Henderson 1993; Griffith, Lee and Van Reenen 2011).

A problem with patent citations as a measure of spillovers is that they are hard to translate into a numeraire to calculate out a euro value for the social vs private returns. To address this, another approach is to analyse the impact of R&D expenditures of firm A on the productivity of firms B and C ('neighbours'). This is a kind of 'peer effect' that is of great interest in economics and other social sciences. It is nevertheless very difficult to identify these effects econometrically (see Manski, 1993). An immediate issue is that there are a very large number of firms who might get R&D spillovers. For example, consider the productivity of Microsoft. Clearly, the company might draw on the past R&D efforts of other firms in the software industry in America. But how much does Oracle's R&D benefit Microsoft relative to say IBM's R&D? Do we simply add them up, even if their R&D investments are in different technological fields? And of course, there may be spillovers to Microsoft from non-software firms, say in hardware or telecommunications. Additionally, the R&D of European firms may also benefit Microsoft. In principle one could allow the productivity of Microsoft to depend on a separate variable for the R&D of every firm, but in practice there are not enough data and we suffer from 'the curse of dimensionality'.

One way to address this issue draws on the seminal paper by Jaffe (1986). The idea is that some firms are technologically closer to each other than others. The R&D of a firm that is closer will be more likely to have an impact on productivity than one that is more distant. There are many ways to define proximity, but a useful one has proven to be based on looking at the technology classes a firm is active in as revealed by its past patenting behaviour. A firm that has patented mainly in software will be very close to another that is solely in software. However, if this firm has 50% of its patents in software and 50% in pharmaceuticals, it will also benefit from firms that patent a lot in pharmaceuticals. Armed with such a distance metric between every pair of firms, the R&D of neighbours can be weighted to generate an 'R&D spillover pool', which is one variable instead of potentially thousands.

Bloom, Schankerman and Van Reenen (2013) generalise the Jaffe (1986) approach to consider a number of distant metrics in technology space, product market space, geography, etc. (see also Lychagin et al., 2016). Defining firms that are close in product market space enables them to identify the rivalry effect of business-stealing separately from the knowledge-spillover effect. For example, more R&D by a firm that is a close product market rival (but distant in technology) will **reduce** the market value of a firm via potential business stealing. By contrast, more R&D by a company that draws on similar technologies but operates in entirely different product markets will tend to **boost** market value and productivity. The paper also addresses the endogeneity issue. A strong and positive association between changes in a firm's productivity and growth in the R&D spillover pool may not be causal. A demand shock, for example, could drive up both the firm's own productivity and its neighbours' R&D. The authors exploit the differential exposure of firms to changes in R&D tax credits at the state and federal levels. These R&I policy changes increased R&D incentives differently across firms (see next section) and are unlikely to be related to changes in a firm's demand. Thus, the differential impact of the structure of the tax across firms generates instrumental variables for the spillover terms enabling the authors to identify the causal effects of R&D spillovers.

There is good evidence for substantial knowledge spillovers using the distance metric approach. For example, Bloom, Schankerman and Van Reenen (2013) and Lucking, Bloom, and Van Reenen (2020) use panel data on publicly listed firms in the USA and find evidence for both R&D knowledge spillovers and business stealing. Quantitatively, the knowledge spillover effect dominates, and they calculate that social returns are over three times as large as private returns. This implies that even with the current set of extensive innovation supporting policies, there is underinvestment in R&D subsidies in the USA.

4. R&I policies

There are a wide range of policies to boost innovation. We give a brief summary of the econometric evidence here, but interested readers are referred to Bloom et al. (2019) and Van Reenen (2021) for more details. We focus on studies that are relatively well-identified as aiming at causal effects, rather than more correlation-based studies. We do not focus on all policies. For example, there is literature on how regulation can have negative or positive effects on innovation. Some emphasise negative effects due to red tape whereas others argue for positive effects from, say environmental innovation (see Aghion, Bergeaud and Van Reenen, 2021, for a discussion). Moreover, there is literature on how policies can affect the direction of technical change, such as how carbon pricing may induce more clean, green innovation relative to dirty innovation (e.g. Aghion et al., 2016). These are important issues, but they are beyond the scope of this chapter.

4.1 Supporting innovation through the tax system

4.1.1 R&D tax credits

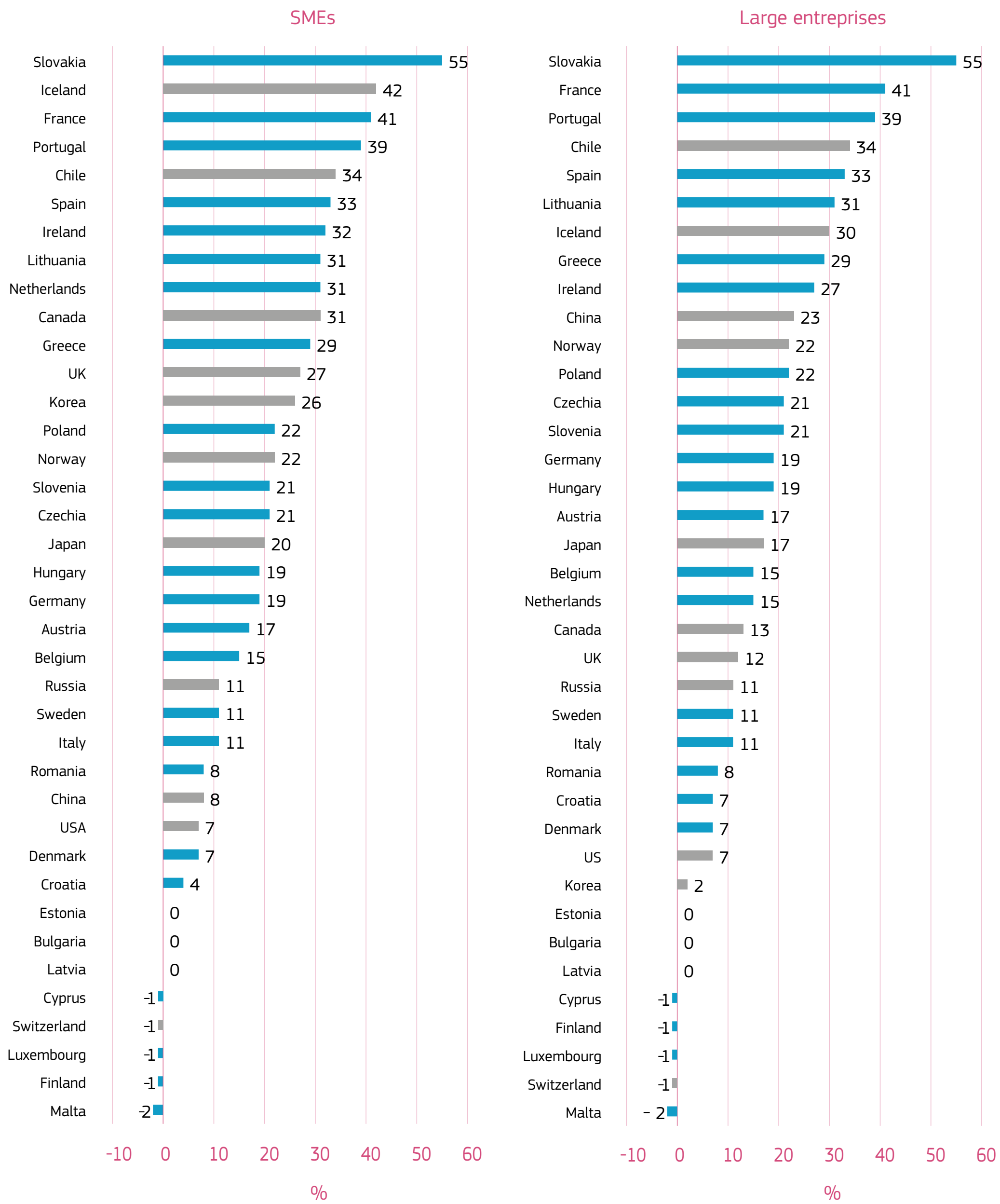
Given the gap between social and private returns on R&D documented in the previous section, the natural approach is to subsidise R&D through the tax code. Most R&D can be classified as current expenses (mainly people such as scientists, but also materials), although the returns on R&D are spread out over time (it is a form of intangible capital). As a result, the tax code implicitly treats it more generously than standard capital.

This is because R&D can be written off immediately against corporate tax bills ('100% deductibility'), whereas other investments in land or equipment can only be offset gradually over time. However, most countries offer additional incentives over and above this implicit incentive. These are generically called 'R&D tax credits' in the literature, although there are a variety of different ways the tax code is changed. A common strategy is to allow 'super-deductibility', where more than 100% can be written off (e.g. 175% for smaller firms in the UK after 2008).

Figure 7 shows the impact of the tax code on the effective subsidy rate for R&D in many OECD and some non-OECD countries. Panel A shows implied tax subsidy rates for SMEs and Panel B for large companies. The generosity varies a lot across the EU (the bars of EU Member States are coloured blue), from Slovakia, which has implied subsidies of over 50% (followed by France and Portugal on around 40%), to some with negative implied tax credits (e.g. Finland, Luxembourg and Malta). Several things stand out. First, fiscal incentives are generally more generous for SMEs than for large companies. Second, EU countries have more generous tax incentives than the USA, which is firmly in the bottom third of the table[17]. Third, tax credits seem to have increased in generosity since the mid-2000s. (e.g. Slovakia, Germany and Sweden were near zero in 2007; a corresponding graph can be found in the Appendix).

17 This is mainly because the tax credit is based on the incremental increase in a firm's R&D over a historically defined base level, rather than a subsidy based on the total amount of R&D spending.

Figure 8-7: Implied tax subsidy rates on R&D expenditure in different countries in 2020



Source: OECD R&D Tax Incentives Database. https://stats.oecd.org/Index.aspx?DataSetCode=RDSUB

Note: Implied tax subsidy rates for SMEs (Panel A) and large enterprises (Panel B) in different countries in 2020 are shown. The bars for EU countries are blue; those for non-EU countries are grey. This is the 'profitable scenario'. For a detailed methodology behind calculations, see https://stats.oecd.org/Index.aspx?DataSetCode=RDSUB#. Countries with no notable bar (i.e. Latvia, Estonia and Bulgaria) have an implied tax subsidy rate of 0 %. Countries are ordered by level of tax subsidy rate (descending order). A corresponding graph showing the values for both firm types in 2007 as a comparison can be found in the Appendix.

Stats.: link

There is substantial literature examining the impact of R&D tax credits on R&D expenditure (for a survey, see Becker, 2015). Earlier studies tended to use data aggregated to the country level (e.g. Bloom, Griffith and Van Reenen, 2002, construct a cross-country panel dataset) or aggregated to the state level within countries (e.g. Wilson, 2009, uses a panel of US states). These studies relate changes in R&D spending to changes in the tax-price of R&D (i.e. filtering the tax rules through the Hall-Jorgenson tax-adjusted user cost formula in a similar way to that in Figure 7). The more recent literature exploits differential effects of tax rules across firms using firm-level panel data (see Hall, 1993, for a pioneering example). For example, Figure 7 showed that SMEs typically obtain more generous R&D tax treatment. Dechezlepretre et al. (2016) compare firms just below and just above the threshold before and after a surprise policy change in the UK using a regression discontinuity design to show large increases in R&D and patenting in response to the change in tax generosity. They also document substantial R&D spillovers using the same causal design.

Looking at the studies on R&D tax incentives as a whole, we believe that a reasonable conclusion is that the tax-price elasticity of R&D is at least unity and probably greater. In other words, a 1 % fall in the tax-price of R&D causes at least a 1 % increase in the volume of R&D in the long run. A concern about this conclusion is that firms may relabel existing expenditure as 'research and development' to take advantage of the more generous tax breaks. For example, there appeared to be substantial relabelling following a change in Chinese corporate tax rules according to Chen et al. (2021). To address this, some papers have looked directly at how non-R&D outcomes such as patenting, productivity or jobs respond to changes in tax credits. These more direct measures also seem to increase (with a lag) following tax changes, suggesting that relabelling is not driving the results (see Akcigit et al., 2018; Dechezlepretre et al., 2016; Bøler, Moxnes and Ulltveit-Moe, 2015).

4.2.1 Other tax policies

R&D tax credits are directly targeted at R&D. Other tax policies may have an impact even if they are not directly targeted. One popular alternative is 'patent boxes'. These are special tax regimes that apply a lower tax rate to revenues linked to patents relative to other commercial revenues. By the end of 2015, patent boxes (or similarly structured IP tax incentives) were used in 16 OECD countries (Guenther, 2017). These are indirect and encourage shifting about of patent revenue with no obvious direct incentive to do more R&D. Indeed, in practice their effect is mainly to encourage firms to shift their royalties into different tax jurisdictions (Griffith, Miller and O'Connell, 2011). This is particularly easy for multinationals, which are able to extensively manipulate where they book their taxable income from IP. Patent boxes do not have much effect on the real location or the quantity of R&D (see Gaessler, Hall and Harhoff, 2018), and appear to be simply a harmful form of tax competition.

General falls in corporate tax rates could have positive effects on innovation, especially if firms are credit-constrained. Atanassov and Liu (2020) present evidence in favour of this from UK publicly listed firms. Akcigit et al. (2018) use a variety of empirical strategies, including event studies and border designs, to argue that falls in effective individual tax rates and corporate rates have stimulated more patenting in the USA.

4.2 Government research grants

As discussed in the previous subsection, trying to incentivise R&D through the tax system is complex and may lead to a change in reporting rather than actual innovative activity. An alternative approach is to directly subsidise R&D

through grants. In principle, this is more efficient as the grants can be targeted directly towards the R&D that has the greatest knowledge spillovers (e.g. basic R&D such as that performed in universities rather than more applied R&D) and the least business stealing. Another advantage of grants is that they can be targeted directly towards the issues with high priority in the EU (e.g. climate change, health or digital transformation). A variety of government programmes seek to encourage innovation by providing grant funding to academic researchers and to private firms, for instance at the European level through Horizon Europe. These include the European Research Council and the Recovery and Resilience Facility support for Member States to implement reforms and investments that are in line with the EU's priorities.

There are also many potential disadvantages of direct government grants compared to a tax-based approach. First, the government agency has to select the high social-value programmes, and this is difficult given the great uncertainties and informational asymmetries around innovation. These exist in the private sector as well, of course, but it is likely that the R&D-performing firms have better information than the public funding body. Second, even for a well-informed agency, there is the risk of being politically captured and the public money flowing to well-connected firms, rather than the firms the benign planner would like to distribute resources to. Finally, there is the administrative costs of maintaining the bureaucracy to allocate and monitor the grants.

From an empirical perspective, identifying the causal impact of grant funding raises particular challenges. While the tax rules are usually widely applicable, a grant is specifically given for a reason and may target the most promising projects. A simple correlation between future success (e.g. R&D spending, patents or productivity) and R&D grant receipt will be biased upwards as the project would have enjoyed a good return even in the absence of the grant. On the other hand, the opposite might also be true, and the agency might give more money to firms and sectors who are performing poorly, generating a downward bias. The general problem is constructing a counterfactual for what would otherwise have happened in the absence of public R&D funds. A particular concern is that if EUR 1 of public R&D simply crowds out EUR 1 of private R&D that would otherwise have been invested in the same project, then public R&D could have no real effect on overall R&D allocations (or innovative outcomes). However, it is also possible that crowd-out is less than 100%, or even that public R&D 'crowds in' and attracts additional private R&D spending. For example, public R&D might complement private spending through intra-firm synergies, shared fixed costs (e.g. of R&D labs) and/or relieving financial constraints.

Although less extensive than the R&D tax literature, there is a growing body of work in this area. In terms of public grants to private firms, there are several papers that examine the Small Business Innovation Research (SBIR) scheme. SBIR is a US federal programme that is the largest SME innovation programme in the world. Howell (2017) examines outcomes for grant applicants from the Department of Energy (DOE), comparing marginal winners and losers. She estimates that early-stage SBIR grants roughly double the probability that a firm receives subsequent venture capital funding, and that receipt of an SBIR grant has positive impacts on firm revenue and patenting. Howell et al. (2021) also look at SBIR grants in the US Air Force using a regression discontinuity design. The authors show large causal effects of winning an SBIR grant on patenting, venture capital funding and the development of new military technologies[18]. Staying in the

18 Interestingly, they find that there are only positive impacts when the SBIR competitions are 'open': where the applicants can suggest new technologies. For the conventional SBIR competition where the Air Force tightly stipulates what technology it wants, the causal impacts of the programme are zero.

military context, Moretti, Steinwender and Van Reenen (2019) use shocks to defence spending (which are largely driven by geo-political events such as 9/11) as an instrument for public R&D spending. They also find crowd-in of private R&D and positive effects on TFP growth. Using a regression discontinuity design to analyse an Italian R&D grant programme, Bronzini and Iachini (2014) find that the programme's impact varies across firm size. Whereas they do not find a positive impact of subsidies (received by firms through grants) on investments for large firms, their results indicate that small firms increased R&D investments after receiving public support. They link this to higher financial frictions, which smaller firms tend to face.

There are also some studies focusing on the impact of academic grants[19]. Jacob and Lefgren (2011) show that National Institutes of Health (NIH) grants produce positive but small effects on research output, leading to about a 7% increase in academic publications over 5 years. Azoulay et al. (2019) use changes in NIH budgets across research areas as an exogenous shock to look at the effect of academic research on commercialisable innovations. They find that NIH funding increases of USD 10 million lead to corporations filing just under three additional patents.

In summary, there seems an increasing corpus of work suggesting that R&D grants can stimulate more innovative activity, even if the empirical literature is still modest.

4.3 Universities

How important is higher education for innovation? Europe had the world's first modern secular university (Bologna), but in recent decades, the continent has fallen behind in research rankings compared to the USA. Currently, the EU has only seven universities in the Shanghai Rankings top 50, the list being dominated by the USA[20]. Areas with strong science-based universities such as Silicon Valley also seem to have substantial clusters of innovation. Valero and Van Reenen (2019) analyse 50 years of data from over a hundred countries, and document that the founding of a university increases local output per-capita and patenting in future years[21].

There are many ways in which universities could stimulate innovation. First, their founding and expansion increases the supply of individuals' science, technology, engineering and mathematics (STEM) qualifications. These STEM workers are likely to increase innovation. Second, the research efforts by academics create new ideas and these may be translated into commercial innovations through scientist entrepreneurial start-ups, university-corporate partnerships or informal links. In the previous subsection, we discussed the evidence that academic grants can stimulate innovation by academics and private firms in the life-sciences sector. Here, we look at graduate supply and academic incentives.

19 See also Jaffe (1989), Belenzon and Schankerman (2013) and Hausman (2018).

20 https://www.shanghairanking.com/rankings/arwu/2021 (last accessed on 03 September 2021).

21 See also Jaffe (1989), Acs, Audretsch and Feldman (1992), Belenzon and Schankerman (2013), Hausman (2018), Andrews (2020), Zucker, Brewer and Darby (1998) and Furman and MacGarvie (2007).

4.1.3 Graduate supply

Perhaps the best and most direct test of the role of universities in increasing STEM supply and innovation is the paper by Bianchi and Giorcelli (2019) on Italy. They exploit the fact that enrolment requirements for STEM majors changed in a particular year, which substantially boosted graduate numbers. Later, innovation increased, especially in medicine, chemistry and information technology, which are key STEM-related subjects. Another strong study is from Finland, where Toivanen and Väänänen (2016) find that individuals growing up near a technical university (which rapidly expanded in the 1960s and 1970s) had a significantly higher probability of becoming engineers. Norway also had a rapid increase in college start-ups in the 1970s. Carneiro, Liu and Salvanes (2018) compare areas where there was a particularly large increase in STEM-focused courses compared to non-STEM areas (synthetic cohorts). This seemed to lead to more R&D and a focus on STEM-related technological progress about 10 years after the colleges were founded[22].

4.2.3 Academic incentives

How can policies be designed that allow university discoveries to be made in commercialisable innovations? After the 1980 Bayh-Dole Act changed the ownership of inventions developed with public R&D (giving universities more ownership of the intellectual property), many US universities created ‘technology transfer offices’ to support this process. Lach and Schankerman (2008) find that larger ownership of patents by scientists generated more innovation.

In the case of Norway, Hvide and Jones (2018) argue that giving professors full innovation rights incentivised them to create more start-ups and file more patents. Financial returns for academics seemed to get more ideas out of universities and turn these into real products.

4.4 Immigration

Immigration is not conventionally thought of as an R&I policy. But it is striking that immigrants are heavily over-represented among inventors and entrepreneurs. For example, in the US immigrants account for 14% of the workforce but 52% of STEM doctorates, a quarter of all patents and a third of all US Nobel Prizes. Kerr and Kerr (2021) survey immigration and innovation in detail. Much research has found that immigrants (especially the more highly skilled) increase innovation. For example, Hunt and Gauthier-Loiselle (2010) report that increasing the share of immigrant college graduates by one percentage point boosts patenting per person by 9-18%. Kerr and Lincoln (2010) find positive effects from changes in policies on H-1B visas. Bernstein et al. (2018) find large spillover effects of immigrants on native innovation from such changes. Moser and San (2019) show how changes in US immigration quotas in the early 1920s discouraged southern and eastern European scientists from migrating and reduced overall innovation (see also Doran and Yoon, 2018). Additionally, Moser, Voena and Waldinger (2014) show that the Nazi expulsions of Jewish scientists in the 1930s boosted innovation in US chemistry when they arrived[23].

22 For evidence of a causal impact of mathematics skills on labour market outcomes, see, for example, Joensen and Nielsen (2009).

23 Not all work finds such positive effects. Doran, Gelber and Isen (2015) use H1(B) lotteries and find smaller effects than Kerr and Lincoln (2010). Borjas and Doran (2012) look at publications by US mathematicians following the fall of the Soviet Union and argue for negative effects. But these findings may reflect special features of academic publishing, where the supply of journals is very slow to respond.

In our view, the weight of the literature suggests that immigration, especially skilled immigration, raises innovation. A liberal immigration policy is particularly attractive because the cost of educating immigrants has been borne by other countries rather than by the European taxpayer. Also, the increase in human capital can occur very quickly, which is different from other human capital supply side policies (such as improving education).

4.5 Increasing the quality of the inventor supply: 'lost Einsteins' and 'lost Marie Curies'

One under-appreciated way to increase the effective quantity of R&D is to reduce the barriers to talented people becoming inventors. Children born in low-income families, women and minorities are much less likely to become successful inventors. US children born into the top 1 % of the income distribution are an order of magnitude more likely to grow up to be inventors than are those born in the bottom half of the distribution (Bell et al., 2019a, b). Innate ability explains relatively little of this compared to the differential exposure rates to inventors in childhood. Bell et al. (2019a, b) argue that improved neighbourhoods, better school quality and greater exposure to inventor role models and mentoring could quadruple the innovation rate. Studies from other countries such as Finland find that discriminatory barriers are lower than in the USA, but they exist and serve to substantially lower innovation rates (Aghion et al., 2017)[24].

What kind of policies could be adopted to find the 'lost Einsteins' and 'lost Marie Curies' –[25]? Card and Giuliano (2016) review the effect of in-school tracking for minorities. They look at one of the largest US school districts, where schools with at least one gifted/high achiever (GHA) fourth (or fifth) grader had to create a separate GHA classroom. They found that students significantly improve their maths, reading and science when assigned to a GHA classroom, but these benefits were overwhelmingly concentrated among black and Hispanic participants. Cohodes (2020) examines the long-term effects of a similar programme in Boston Public Schools' Advanced Work Class (AWC) programme comparing those who scored just above and just below the admissions threshold. The programme increases college enrolment by 15 percentage points overall, again with gains primarily coming from black and Hispanic students. Breda et al. (2021) describe an intervention in French schools that exposed high-school girls to female scientists as role models. They found that this positively affected high-achieving grade 12 girls to choose STEM programmes in college. The most effective role model interventions are those that improved students' perceptions of STEM careers without overemphasising women's underrepresentation in science.

Although in its infancy, this evidence suggests that exposure policies can be effective. They are quite long-term and school-focused: there is a need for evidence whether they can also be effective in adults.

4.6 Competition and trade

It is well-known that the impact of competition on innovation is ambiguous in theory. Very high competition means little (or no) profit; consequently, Schumpeter (1942) argued that competition will discourage innovation. On the other hand, monopolists who benefit from high barriers to entry have little incentive to innovate and replace the stream of profits they already enjoy. Hence Arrow (1962) argued that entrants

24 See also Cook and Kongcharoen (2014) and Cook (2010) on gender and race and Murat (2018) for a general framework.

25 Gabriel, Ollard and Wilkinson (2018) have a useful survey of a wide range of 'innovation exposure' policies focusing on school-age programmes.

will have greater incentives to innovation (this is the 'replacement effect'). In Aghion et al. (2005), the relationship between innovation and competition is an inverted-U: when competition is low, the impact on innovation is at first positive (Arrow), and then becomes negative at higher levels of competition (Schumpeter).

Our reading of the empirical literature is that competition typically increases innovation (see Griffith and Van Reenen, 2021, for a recent survey). Some of the literature focuses on import shocks that increase competition, such as China's integration following its accession to the World Trade Organization. Shu and Steinwender (2018) find that in South America, Asia and Europe, trade competition tends to increase innovation (also see Blundell, Griffith and Van Reenen, 1999 and Bloom, Draca and Van Reenen, 2016). In North America, the evidence is more mixed, with Autor et al. (2020) finding negative effects of Chinese import competition on innovation in US manufacturing, and Xu and Gong (2017) arguing that R&D employees were mainly re-employed in services.

Trade openness can boost innovation by increasing market size, spreading fixed R&D costs over a larger market. Trade also leads to improved inputs and faster knowledge diffusion (e.g. Keller, 2004; Diamond, 1997). Aghion et al. (2018) use shocks to a firm's export markets to demonstrate large positive effects on innovation in French firms[26].

In our view, the literature suggests that greater competition and trade openness typically increase innovation. The financial costs of these policies are relatively low, given that there are additional positive impacts associated with policies that lower prices and increase choice. The downside is that such globalisation shocks may increase inequality between people and places.

26 See Melitz and Redding (2021) for a recent survey on trade and innovation.

5. Conclusions: summarising the evidence

Following Bloom, Van Reenen and Williams (2019), we summarise our judgements in Table 1, an R&I policy toolkit. Column 1 shows the policy; Column 2 summarises the quality of the empirical evidence; Column 3, the conclusiveness of the evidence; Column 4 shows the benefit-cost ratio in terms of a ranking where 3 crosses is the highest ranking (this is meant to represent a composite of the strength of the evidence as well as the magnitude of average effects); Column 5 shows whether the main effects would be short-term, medium term or long-term. Different policymakers (and citizens) will assign different weights to these alternative criteria.

In the short-run, research and development tax credits or direct public funding seem the most effective, whereas increasing the supply of human capital (for example, through expanding university STEM admissions) is more effective in the long-run. Skilled immigration has large effects, even in the short run. Competition and trade policies probably have benefits that are more modest for innovation but are cheap in financial terms and therefore also score highly.

One limitation of Table 1 is that it ignores interactions between policies. Moreover, it may be hard to build a political consensus to push for an ambitious programme of change. A way to tackle these issues is to bind them together in a programme aimed at a mission. The most pressing mission is climate change, and a key part of the battle is the stimulation of more green innovation.

Hence, one could consider how to bundle R&I policies together in such a way as to meet the climate challenge. Similarly, other missions include tackling health, defence and other environmental challenges.

The EU's main innovation programme, Horizon Europe, has a particular focus on policies that Table 1 summarises under 'Direct R&D grants'. Other parts of the budget, obviously, are directed towards other policy tools shown in the table. The broader European Research Area (ERA) for example fits into our 'Opening to Immigration' category[27]. One of the main goals, to create an open labour market for researchers, should make migration of researchers between EU countries easier. A further step would be to extend the ERA to additional non-EU member states, such that the EU could attract researchers and innovators from outside its borders. One relatively easy and quick way to increase incentives to innovate would be increases in tax credits by individual countries. As we showed in Section 4, these vary substantially across EU countries – there is room for increases in many countries. Additionally, there should be a focus on supply side policies such as greater educational support for children who show early promise in maths and science, but who are from low-income families. Moreover, there could be more mentoring and internship programmes that allow young people from under-represented groups to have greater exposure to the possibility of becoming inventors. Erasmus+ traineeships are a possible way to increase interactions between innovators and young people who could innovate in future[28].

27 For an overview on ERA, see https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/aae418f1-06b3-11eb-a511-01aa75ed71a1 (last accessed on 11 October 2021).

28 For more information on Erasmus+ traineeships, see https://erasmus-plus.ec.europa.eu/opportunities/individuals/students/traineeship-student (last accessed on 16 November 2021).

Increasing the scope of such programmes and focusing on students from under-represented backgrounds would lead to large long-run benefits.

To rebuild the economy after the COVID-19-crisis, a mix of short-term and long-term as well as demand and supply side policies is needed to stimulate innovation and thus make the European economy more sustainable and productive.

Figure 8-8: **R&I Policy Toolkit**

(1)	(2)	(3)	(4)	(5)
Policy	**Quality of evidence**	**Conclusiveness of evidence**	**Benefit-cost**	**Time frame**
R&D tax credits	High	High	+++	Short-term
Direct R&D grants	Medium	Medium	++	Medium-term
Universities: STEM supply	Medium	Medium	++	Long-term
Universities: incentives	Medium	Low	+	Medium-term
Opening up immigration	High	High	+++	Short-to-medium-term
Increasing inventor quality	Medium	Low	++	Long-term
Greater competition and trade openness	High	Medium	++	Medium-term

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Source: Bloom, Van Reenen and Williams (2019)
Note: This is our highly subjective reading of the evidence. Column (2), 'Quality', is a mixture of the number of studies and the quality of the research design. Column (3) is whether the existing evidence delivers any firm policy conclusions. Column (4) is our assessment of the magnitude of the benefits minus the costs (assuming these are positive). Column (5) is whether the main benefits are likely to be seen (if there are any) in the short term (roughly, the next 3-4 years) or in a longer term.
Stats.: link

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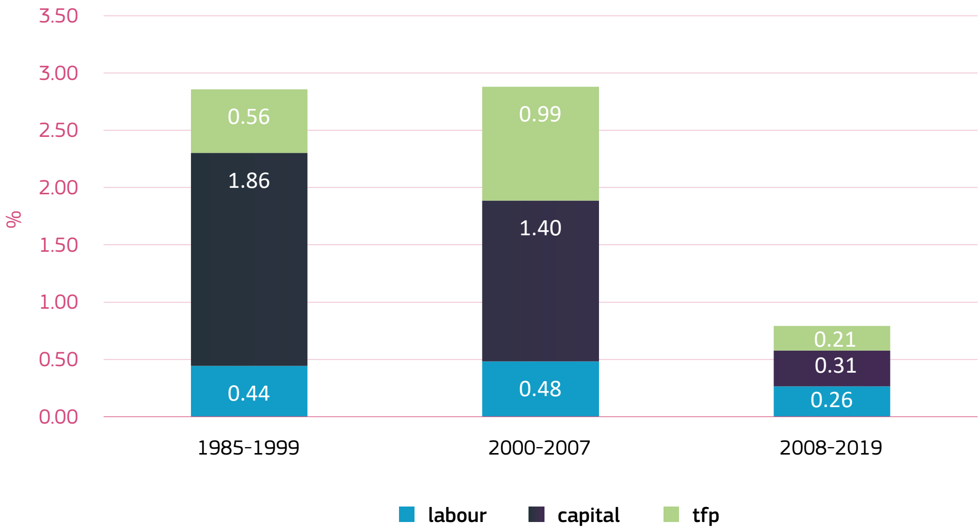
Appendix A

Additional figures

Figure A-1: Contribution of labour, capital and TFP to GDP growth in the EU



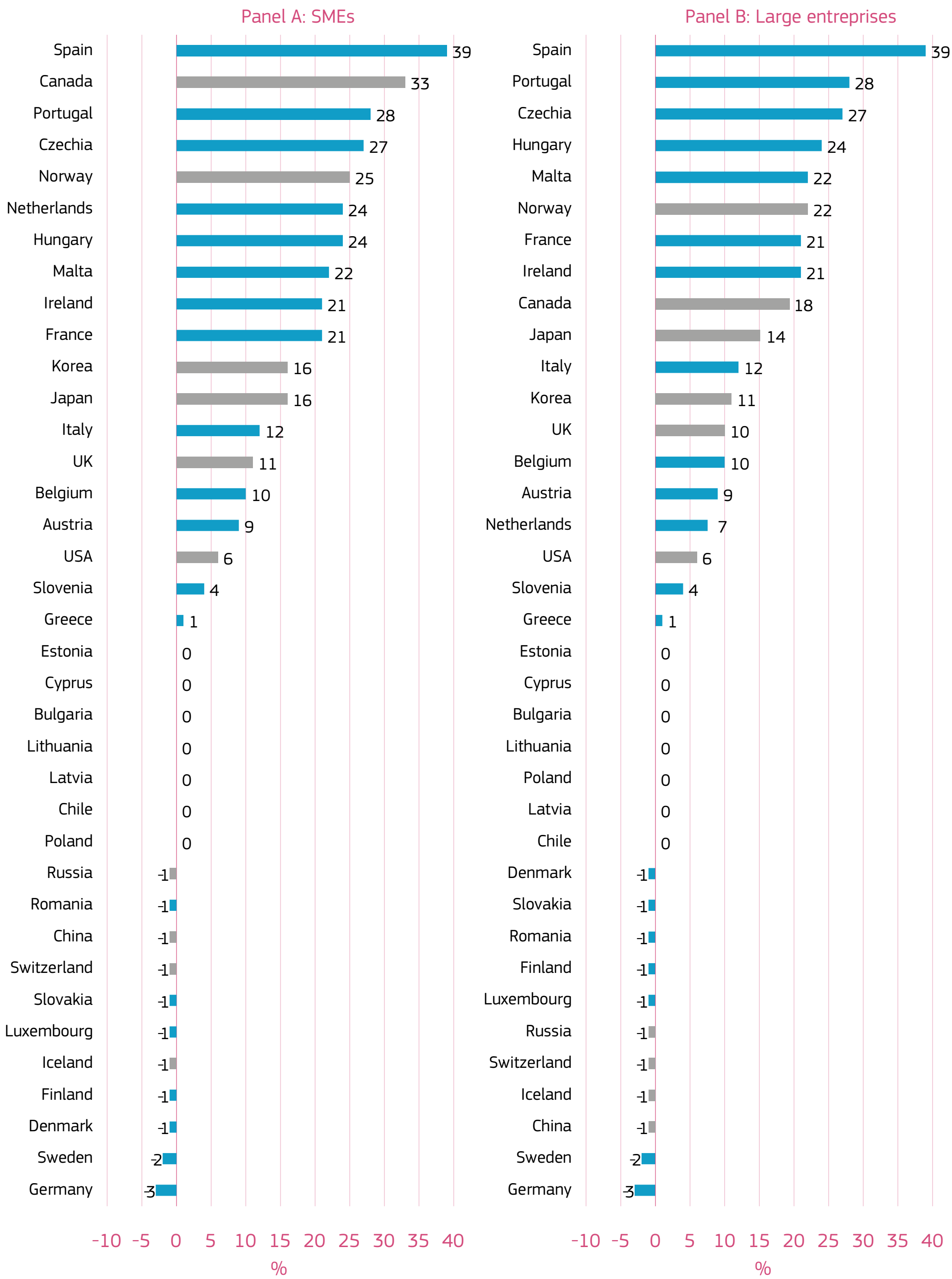
Science, Research and Innovation Performance of the EU 2022

Source: OECD productivity database. https://stats.oecd.org/index.aspx?queryid=66347#

Note: Each stacked bar represents the overall real GDP growth in the given time period as an average for a subset of EU countries (Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Portugal, and Sweden). The single components within a bar show the percentage point contribution of labour (measured as hours worked), capital (ICT and non-ICT capital) and TFP growth towards output growth.

Stats.: link

Figure A-2: Implied tax subsidy rates on R&D expenditure 2007, SMEs and large enterprises



Science, Research and Innovation Performance of the EU 2022

Source: OECD R&D Tax Incentives Database. https://stats.oecd.org/Index.aspx?DataSetCode=RDSUB

Implied tax subsidy rates are shown for SMEs (Panel A) and large enterprises (Panel B) in different countries in 2007. The bars of EU countries are blue, those of non-EU countries grey. This is the ‘profitable scenario’. For a detailed methodology behind calculations, see HYPERLINK “https://stats.oecd.org/Index.aspx?DataSetCode=RDSUB” https://stats.oecd.org/Index.aspx?DataSetCode=RDSUB#. Countries with no notable bar have an implied tax subsidy rate of 0 %. Countries are ordered by level of tax subsidy rate (descending order).

Stats.: link