R&D policies for better post-pandemic futures: new approaches and tools

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R&D intensity as a policy target: main takeaways from 11 international case studies

Executive summary

R&D intensity – the Gross Domestic Expenditure on Research and Development [GERD] as a percentage of GDP – has become a widely used indicator and policy target across OECD countries over the past decades. As of December 2020, 27 of 37 OECD countries had R&D intensity targets at national level. These differ significantly, from 1.2% of GDP (Slovak Republic) to 4% of GDP (Finland, Sweden, Japan and Iceland). Some countries have also set such targets at regional level (e.g. Germany, Greece, Poland, and Hungary). Countries that currently do not have R&D intensity targets include Australia, Canada, Israel, Korea, Mexico, Switzerland and the United States.

The rationale for setting R&D intensity targets is threefold:

- **A proxy for innovation performance**. There is a wide consensus around the positive relationship between R&D investments and innovation performance.
- **A quantifiable goal for STI policy**. R&D intensity targets are considered a powerful tool to steer public and private investments towards knowledge-based, growth-enhancing activities. They also increase the visibility of STI policy.
- **Easy to measure, analyse and communicate.** Data on R&D expenditures are systematically collected by statistical offices across countries, and long-time series are publicly available, making it possible to explore trends over time and make international comparisons. Such targets are also easy to understand and communicate.

Key characteristics of the R&D intensity indicator

R&D expenditure is an input in the innovation process, jointly with others such as training and capital investments. The R&D intensity indicator thus **measures only one type of innovation input**, but does not provide any indication of results or innovation outputs. While high levels of R&D expenditure are generally associated with high levels of innovation and economic output, the relationship is not linear. There is no evidence on the optimal level of R&D investment.

Since the indicator is a ratio [GERD over GDP], trends are **determined by the evolution of both R&D expenditure and GDP**. In addition, GERD is the sum of expenditures in four sectors: business (BERD), higher education (HERD), government (GOVERD) and non-profit (PNP). Governments thus have a limited capacity to control the evolution of the R&D intensity indicator.

Countries' R&D intensity levels are highly **contingent on a range of structural factors** that need to be taken into account when conducting cross-country analysis and benchmarking exercises, including:

- **Industry structure**: Countries specialised in R&D-intensive sectors (e.g. pharmaceuticals, engineering, biotech) tend towards higher levels of R&D intensity at the national level than those specialised in low-R&D intensive sectors (e.g. finance, tourism, transportation, etc.). Korea, Japan and Germany are examples of countries ranking among the top countries in terms of R&D intensity with a strong

manufacturing sector that performs most R&D investments. Services sectors tend to invest less in traditional R&D activities than manufacturing industries, but this does not necessarily reflect the innovation performance of those sectors. For instance, the Netherlands and the United Kingdom register relatively low R&D intensity levels but rank as highly innovative when using other metrics, due to the importance of highly-innovative services sectors in their total value added. Within-sector differences in R&D investment patterns can also explain part of the observed variation in aggregate R&D intensity levels across countries. In many countries, ambitious industrial and technology policies have been implemented to strengthen industrial R&D and consequently affect aggregate business R&D intensity.

- **Firm sizes and the role of multinationals**: Large firms (including MNEs) tend to perform higher levels of R&D compared to SMEs. Some studies find that size plays a key role in explaining the R&D intensity gap between the EU and the US, independently of sectoral composition. Particularly in small countries, total BERD levels can even be driven by a small number of large firms. For instance, in 2009 Nokia (once the world's largest mobile phone maker) accounted for around 40% of total BERD in Finland. The company's downsizing had a significant impact on total GERD, which declined from 3.73% in 2009 to 2.72% in 2017.

There are a range of **critical aspects that aggregate R&D indicators do not capture**: the quality of R&D performed; its economic and social impact; the extent of disparities in R&D performance at the firm level (i.e. between leading firms and the rest) and territorial level (i.e. between urban and rural areas, between top cities and the rest); a range of innovation activities that are becoming increasingly prominent in the digital age, such as business model innovation; the benefits obtained from R&D performed abroad and, in many cases, the contribution of innovative start-ups to R&D performance. These aspects should be considered when using the R&D intensity indicator as a policy tool.

Some takeaways from international policy practices

Some of the takeaways from the 11 case studies explored in this document include the following:

- **R&D intensity targets should not be used in isolation.** Many countries include a range of complementary targets in their science and innovation strategies, which jointly allow for more rigorous assessments of the evolution of innovation systems' performance. Scoreboards produced at EU level follow the same principle.
- **Funding targets should be accompanied with a strategic vision.** Clear objectives and direction should be set for R&D investments to create scientific, societal, environmental and/or economic impacts, based on a sound identification of current and future needs through consultation and co-creation exercises, strategic foresight, evaluation and impact assessments. The increasing popularity of mission-oriented research and innovation policies (MOIP) over the past years reflects a shift towards more strategic innovation policies, which may be reinforced by the COVID-19 crisis. Political stability and long-term, predictable public investments in R&D is a precondition for trust building and for increasing private investments in R&D.
- **R&D strategies need to be tailored to specific R&I ecosystems.** The framework conditions should be factored in when designing R&D strategies to ensure the full effectiveness of R&D investments. In less technologically advanced countries, the priority should be to enhance absorptive capacity levels of firms and other actors in the ecosystem, and to support R&D and innovation efforts to address internal

economic and social needs by adapting existing technologies, rather than developing new-to-the-world technologies.

- **Policy mixes in support of business R&D are shifting towards tax incentives in many countries.** The amount of tax support to BERD across OECD countries has increased over time, and in many countries it represents the lion’s share of total public support to BERD. Recent OECD analysis finds that R&D tax incentives are effective in boosting business R&D but their effectiveness differs sharply across firms of different sizes and across countries. Tax incentives are also better suited for supporting R&D projects closer to the market, while direct government funding – such as through grants and R&D procurement – is more conducive to research that may not immediately result in new goods or services.
- **Participatory governance models and political commitment are essential for systemic changes.** The ability of STI policy to shape changes in STI policy frameworks highly depends on the level of political commitment and the mandate of the institutions in charge of implementing reforms. The engagement of stakeholders in STI policy design through participatory governance models is also found to be critical to enhance adoption and alignment of efforts across actors. For instance, in Australia, incorporating stakeholder feedback in policy programme design has improved their efficiency and leveraged more investment by industry into research.

1. Introduction

R&D intensity – the Gross Domestic Expenditure on Research and Development [GERD] as a percentage of GDP – has become a widely used indicator and policy target across OECD countries over the past decades. Its use expanded across OECD countries in the 1960s, reaching a peak in the mid-1970s. The target gained popularity again at the turn of the century, as the Lisbon European Council in 2000 committed to the goal for the EU "to become the most competitive and dynamic knowledge-based economy in the world" by 2010, among others by "making research and development (R&D) a top priority". In 2002, the Barcelona European Council set two specific targets: reaching an R&D investment of 3% of EU GDP by 2010, and having two-thirds of this investment funded by the business sector (European Commission, 2003[1]). Since then, countries in the EU and beyond have set R&D intensity targets to stimulate investments in R&D as a means to achieve higher levels of innovation and economic growth.

This document presents the key lessons learned from countries' policy experiences in using (or not using) the R&D intensity targets over the past decades, building on insights from the 11 case studies produced in the context of the project on R&D intensity (2019-20) conducted by the OECD Working Party on Innovation and Technology Policy (TIP). The 11 case studies were contributed by Australia, Finland, France, Germany, Greece, Hungary, Ireland, Korea, the Netherlands, Poland and the European Union (Table 1). An overview of the contents of the case studies is provided in the Annex, and all the case studies will be publicly available in this dedicated project website: http://oe.cd/tiprd. A voluntary peer exchange process was organised in May 2020 among case study authors, providing a platform to exchange about common challenges, provide feedback to the authors and learn about different countries' policy experiences (Table 1). R&D intensity levels and policy experiences differ significantly across those countries, making cross-country analysis particularly insightful.

This document is structured as follows. Section 2 provides an overview of the main takeaways from international experiences in setting R&D intensity targets. Section 3 provides a preliminary overview of lessons regarding the policies implemented to enhance R&D and innovation performance. Section 4 concludes.

Table 1. Case studies on R&D intensity: authors and peer reviewers

Country case study	Authors	Peer reviewers
Australia	Wayne CALDER, Clarissa LAI, Lyndall MILWARD-BASON, Lauren CHA and Nicholas MORTIMER	Job TEURLINX (Netherlands)
Finland	Matthias DESCHRYVERE, Kai HUSSO and Arho SUOMINEN	Agni SPILIOTI, Vasileios GONGOLIDIS and Antonios GYPAKIS (Greece)
France	Esther GOREICHY, Faÿçal HAFIED, Guillaume ROULLEAU	-
Germany	Susan SCHULZ	Kai HUSSO (Finland), Hyuk HAN and Yoonbeen LEE (Korea)
Greece	Agni SPILIOTI, Vasileios GONGOLIDIS, Antonios GYPAKIS and Georgia MAZIOTI	Arho SUOMINEN (Finland)
Hungary	Krisztina SÓVÁGÓ	Jaroslaw SARUL (Poland)
Ireland	Ian HUGHES	Susan SCHULZ (Germany), Wayne CALDER (Australia) and Matthias DESCHRYVERE (Finland)
Korea	Hyuk HAN and Yoonbeen LEE	Arho SUOMINEN (Finland), Susan SCHULZ (Germany)
Netherlands	Job TEURLINX and Piet DONSELAAR	Ian HUGHES (Ireland), Jaroslaw SARUL (Poland) and Wayne CALDER (Australia)
Poland	Jaroslaw SARUL	Kai HUSSO (Finland)
European Union	Coordinated by Ruzica RAKIC and Ana CORREIA under the guidance of Román ARJONA and Jessica LARSSON. Co-drafted by the team of the "R&I Strategy and Foresight" Unit of DG Research and Innovation (European Commission).	Ian HUGHES (Ireland) and Kai HUSSO (Finland)

Note: All case studies are available at: http://oe.cd/tiprd

2. Setting R&D intensity targets: main takeaways from international experiences

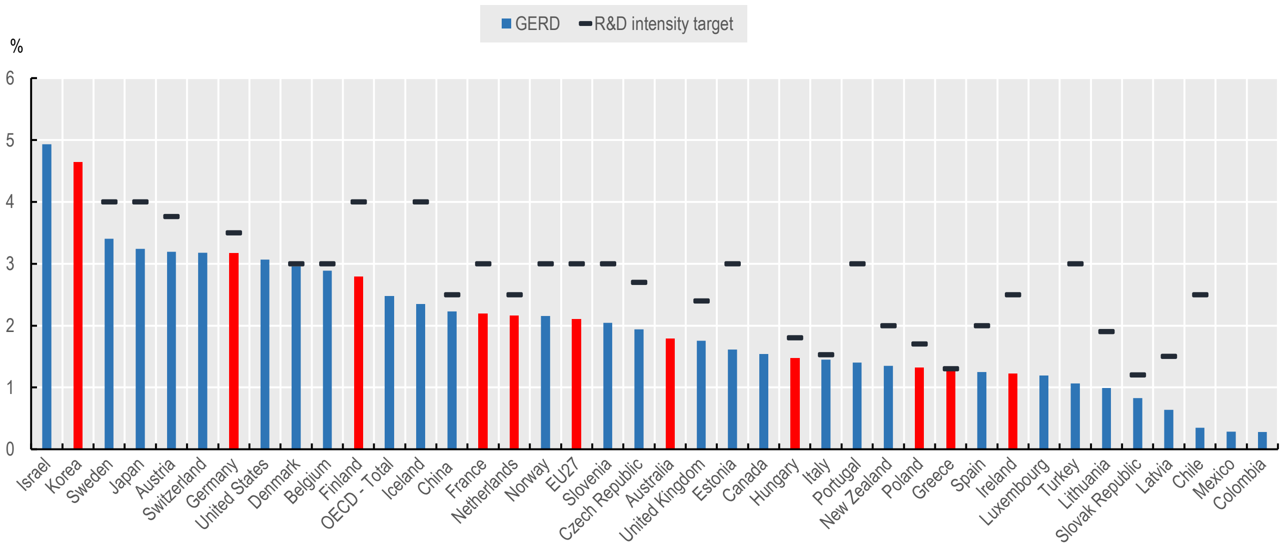
Following the 2002 European Council in Barcelona, all EU countries were urged to set their own R&D intensity targets to be reached by 2010, a goal that was extended to 2020 by the Europe 2020 strategy for smart, sustainable and inclusive growth (European Commission, 2010[2]; Rakic et al., 2021[3]). Specific national targets that reflect these goals were adopted by all EU member countries via their respective National Reform Programmes (NRP), and in many countries were also included in their STI strategies. A number of non-EU countries also set their own targets, including Chile, Japan and New Zealand. Over the years most countries have revised their targets or extended their deadlines.

As of December 2020, 27 of 37 OECD countries had R&D intensity targets at the national level (Figure 1). These differ significantly, from 1.2% of GDP (Slovak Republic) to 4% of GDP (Finland, Sweden, Japan, and Iceland). Countries that currently do not have such targets include Australia, Canada, Israel, Korea, Mexico, Switzerland and the United States. Table 2 presents the current R&D intensity targets in case study countries, and provides references to the documents setting them.

Some countries have also set R&D intensity targets at regional level. This is the case of Germany, Greece, Poland, and Hungary (Table 3). For instance, in Germany the regional distribution of innovation is an important issue due to large disparities in terms of innovation performance (Schulz, 2021[4]).

Figure 1. R&D intensity and targets in selected economies, 2019 or latest available

As percentage of GDP



Note: The graph illustrates the Gross domestic expenditure on R&D (GERD) as a percentage of GDP. Ten countries and the European Union, that contributed case studies to the TIP R&D project, are highlighted in red. The graph also illustrates the current R&D intensity targets across countries. For most countries, targets are for 2020, except for Chile (2021), Turkey (2023), Germany (2025), United Kingdom (2027), and Finland, Norway and Portugal (2030).
Source: OECD (2021), "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database), https://doi.org/10.1787/data-00182-en (accessed on 01 April 2021).

Table 2. R&D intensity targets in case study countries

	R&D intensity target	Target year	Document setting the target
Australia	No target	-	-
Finland	4	2030	Inclusive and competent Finland – a socially, economically and ecologically sustainable society
France	3	2020	National Reform Programme 2011- France
Germany	3.5	2025	The High-Tech Strategy 2025
Greece	1.3	2020	Greece- National Reform Programme 2019
Hungary	1.8	2020	National Reform Programme 2011 – Hungary
Ireland	2.5	2020	Innovation 2020 - Ireland's strategy for research and development, science and technology
Korea	No target	-	-
Netherlands	2.5	2020	National Reform Programme 2011 – The Netherlands
Poland	1.7 / 2.5	2020 / 2030	Strategy for Sustainable Development
European Union (28 countries)	3	2020	Europe 2020: A strategy for smart, sustainable and inclusive growth (2010)

Source: Country case study contributions to the TIP R&D intensity project – Calder et al. (2021[5]), Deschryvere, Husso and Suominen (2021[6]), Goreichy, Hafied and Roulleau (2021[7]), Schulz (2021[4]), Spilioti et al. (2021[8]), Sóvágó (2021[9]), Hughes (2021[10]), Han and Lee (2021[11]), Teurlinx and Donselaar (2021[12]), Sarul (2021[13]) and Rakic et al. (2021[3]).

Table 3. R&D intensity targets at the regional level in case study countries

	Target	Document
Germany	Regional targets are set in the 16 Länder of Germany.	Regional strategies presented in the OECD Case study 2020 [in German]
Greece	BERD by 2023 for 5 types of regions: Less developed (0.24), in transition (0.12), developed (0.6), Sterea Ellada (0.51), and South Agean (0.01)	2014 Operational Programme "Competitiveness, Entrepreneurship and Innovation-EPANEK"
Hungary	BERD by 2023 for 2 types of regions: Less developed (0.71) and the Central Hungary Region (2.08)	EU Operational Programme
Poland	11 of 16 regional strategies include R&D targets at the regional level (as relation to regional GDP, per capita or as an amount)	Regional strategies presented in the OECD Case study 2020

Source: Country case study contributions to the TIP R&D intensity project - Schulz (2021[4]), Spilioti et al. (2021[8]), Sóvágó (2021[9]), Sarul (2021[13]).

This section explores the main characteristics of the R&D intensity indicator, as well as its main advantages and limitations when using it as a policy target.

2.1. Key characteristics of the R&D intensity indicator

An indicator of innovation input

R&D expenditure is an input in the innovation process, jointly with others such as training and capital investments. The R&D intensity indicator thus measures only one type of innovation input, but does not provide any indication of results or innovation outputs (e.g. inventions, patents and publications, introduction of new products to the market, adoption of new processes or organisational changes).

While high levels of R&D expenditures are generally associated with high levels of innovation and economic output, the relation is not linear. There is no evidence on the optimal level of R&D investments, and the impacts of R&D activities are critically shaped by factors such as the quality of the R&D performed, the efficiency and effectiveness of the R&D investments, the objective of the R&D conducted (e.g. R&D for military vs. sustainability purposes), and the framework conditions affecting innovation ecosystems (e.g. the effectiveness of linkages between public research and industry, the ease of bringing new products to the market, the conditions for accessing financial resources by innovators and the capacity to enforce intellectual property regulations).

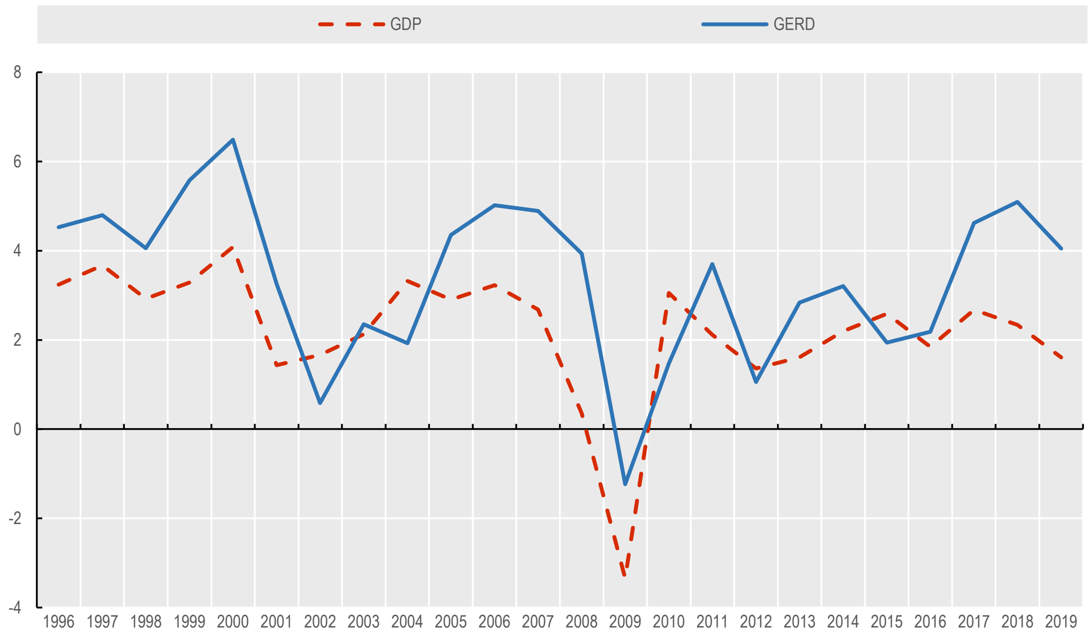
Translating R&D investments into innovation outputs with positive socioeconomic impacts has been a challenge in some countries. For instance, Korea has the highest R&D intensity in the world, devoting 4.5% of GDP to R&D in 2017 – well above the OECD average of 2.3% of GDP. Yet a range of systemic challenges, including low levels of entrepreneurship, have challenged the efficient translation of value from the R&D stage to the commercialisation of innovations. As discussed in the Korean case study, "while R&D investment goals presented in the 3rd Science and Technology Basic Plan (2013-2017) were achieved and investment-related plans were easily implemented, performance-related goals such as ranking in the top 1% scientific papers, technological competitiveness of small businesses, and industrial value-added per capita were not achieved. This fact indicates that it is difficult to secure a process from investment to performance and that policies such as establishing R&D ecosystems and capacity building have not performed well" (Han and Lee, 2021[11]). Another example is the so-called 'Swedish paradox', where high R&D intensity coexists with low levels of production of high-tech products (Bitard et al., 2018[14]; OECD, 2016[15]). Therefore, while relevant as an innovation input indicator, reaching a specific R&D intensity level should not be considered a policy goal in isolation.

A relative and moving indicator

The R&D intensity indicator is a ratio [GERD over GDP]. It is therefore **determined by the evolution of both R&D expenditure and GDP**. For example, in cases where R&D and GDP both increase, the ratio could remain relatively stable or even decrease. Where GDP decreases and R&D remains stable, the ratio would increase. R&D intensity is thus a moving target, making it challenging for governments to control its evolution. For instance, Ireland's GERD has increased substantially in recent years (by 14.4% between 2014 and 2017, with an increase in BERD of 31.5%), but GNP has increased at an even faster rate (43.3%). As a result, Ireland's R&D intensity rate expressed as a percentage of GNP[1] declined from 1.81% of GNP in 2014 to 1.46% in 2017 (Hughes, 2021[10]).

Figure 2. GERD expenditure over the business cycle, OECD countries

Annual growth rate



Source: OECD (2021), "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database), https://doi.org/10.1787/data-00182-en and OECD (2020)"National Accounts at a Glance", OECD National Accounts Statistics (database), https://doi.org/10.1787/data-00369-en (accessed on 1 April 2021).

Data for OECD countries show that the evolution of R&D expenditure and GDP are closely related (Figure 2). During periods of economic expansion, corporate profits and firm creation increase, and consequently amounts available to invest in R&D also tend to increase. In periods of economic recession, on the contrary, budgetary allocations to R&D and firm creation tend to decline (Sheehan and Wyckoff, 2003[16]). Yet as seen in the figure,

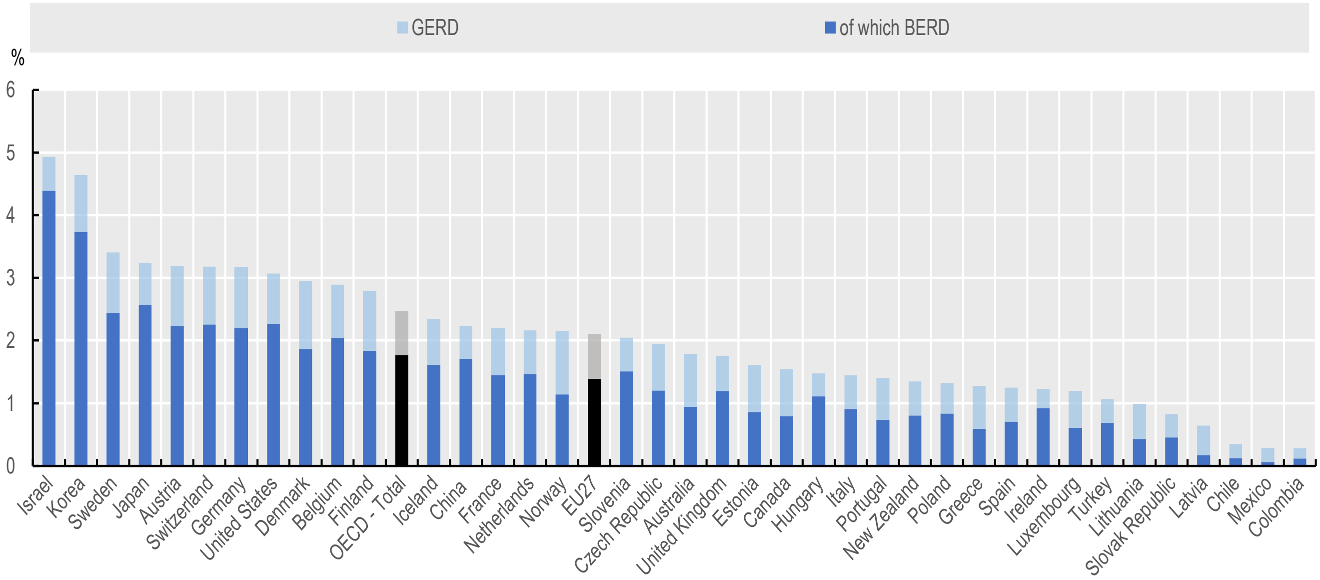
[1] GNP and GDP both reflect the national output and income of an economy. The main difference is that GNP (Gross National Product) takes into account net income receipts from abroad, and excludes income earnt by multinationals when profits are sent back to other countries. Ireland's National R&D Action Plan stated that GNP is a more appropriate measure of national output for Ireland than GDP due to the transfers within multinational organisations located in Ireland.

there are certain time lags between the changes in economic cycles and its effects on GERD, which can also lead to significant changes in R&D intensity levels.

Another important factor to consider is that **GERD is the sum of expenditures in four sectors**: business (BERD), higher education (HERD), government (GOVERD) and non-profit (PNP). Governments thus have a limited capacity to control the evolution of R&D spending – and in particular to influence BERD, which accounts for the bulk of R&D investments in most OECD countries (Figure 3, Figure 4), even if governments can stimulate business investments in R&D through a range of measures (e.g. R&D tax incentives, R&D loans and grants).

Figure 3. Total R&D expenditures (of which business expenditures) in selected economies, 2019

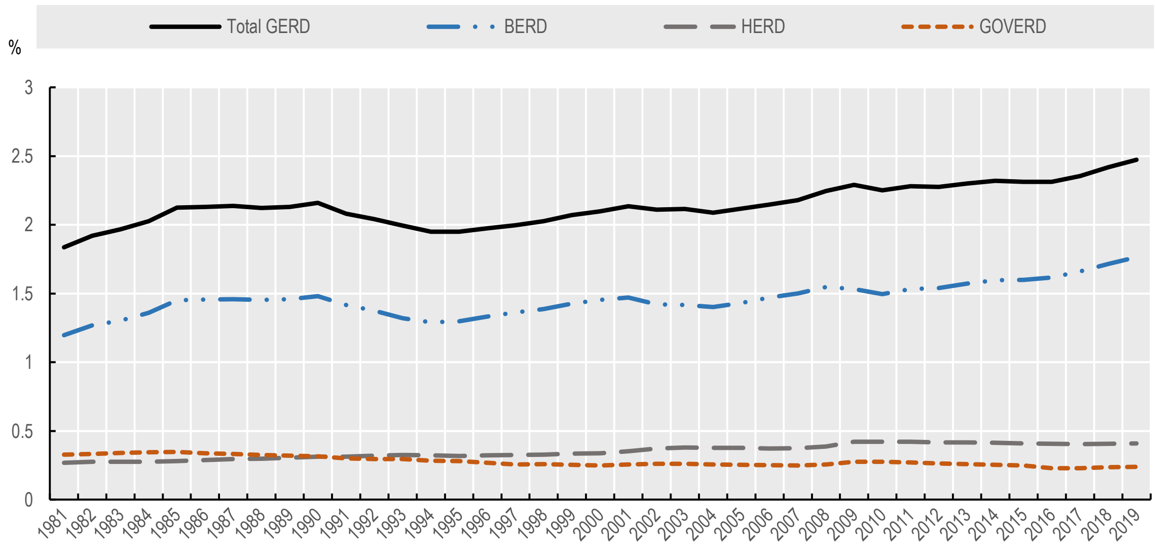
As percentage of GDP



Note: 2019 or latest year available. The graph illustrates the Gross domestic expenditure on R&D (GERD) and the Business expenditure on R&D (BERD) as a percentage of GDP.
Source: OECD (2021), "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database), https://doi.org/10.1787/data-00182-en (accessed on 01 April 2021).

Figure 4. R&D intensity by performing sector, OECD countries

As percentage of GDP



Source: OECD (2021), "Main Science and Technology Indicators", OECD Science, Technology and R&D Statistics (database), https://doi.org/10.1787/data-00182-en, April 2021.

An aggregate indicator conditioned by systemic factors

Countries' R&D intensity levels are highly dependent on a range of structural factors that need to be considered when integrating R&D intensity targets in science and innovation strategies, and when conducting cross-country analysis and benchmarking exercises. Such systemic factors, presented below, include 1) industrial structures, 2) firm sizes, and 3) the weight of multinational enterprises. These are explored in detail in the different case studies.

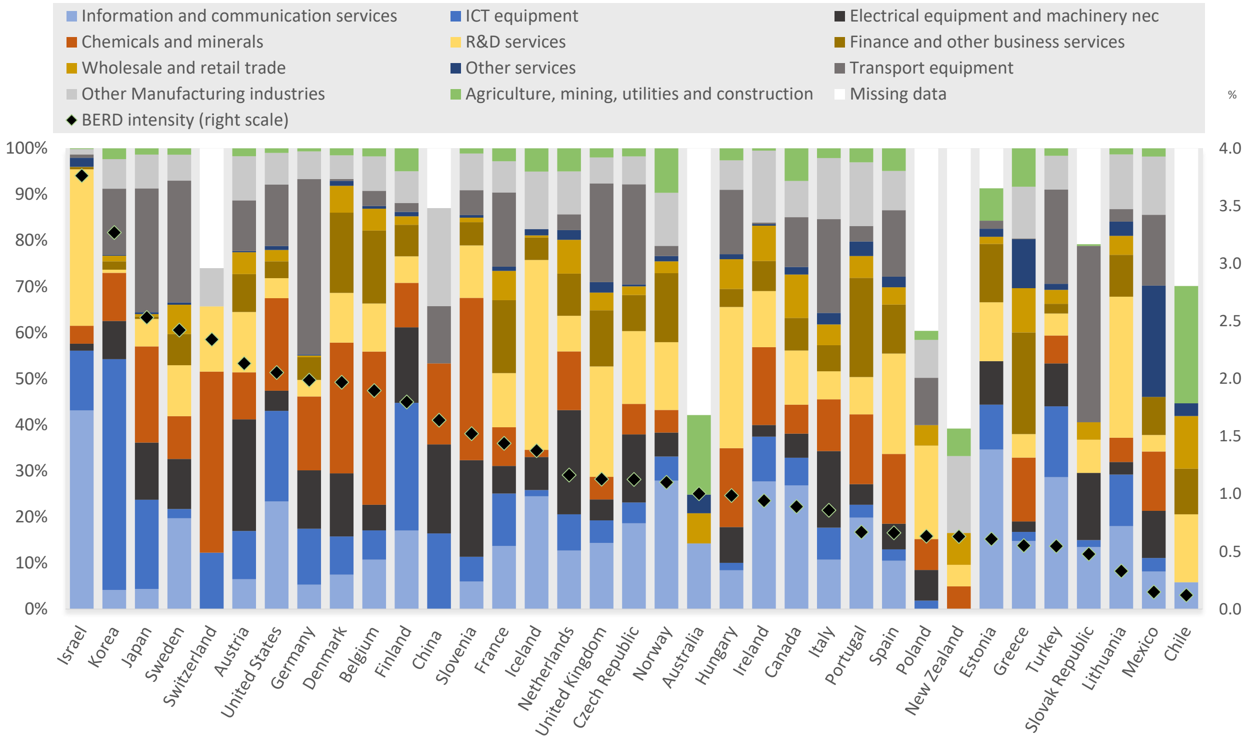
Other well-known factors critically influence the dynamism of innovation ecosystems in a country, including the availability of human capital and know-how to conduct R&D activities, conditions for market access (including conditions for start-ups and SMEs to access finance for innovation), access to infrastructure and testing facilities, data access conditions, the level and efficiency of interactions among business and research organisations for innovation purposes, and the regulatory environment.

(1) Industrial structures

The role of R&D varies significantly across sectors. It is critical for competitiveness for some (e.g. high-tech industries) while less central for others (e.g. a wide range of services) (Galindo-Rueda and Verger, 2016[17]). Countries specialised in R&D-intensive sectors (e.g. pharmaceuticals, engineering, biotech) tend to be more R&D-intensive at the national level than those specialised in low-R&D-intensive sectors (e.g. finance, tourism, transportation). Germany, for instance, which ranks among the top countries in terms of R&D intensity, has a strong manufacturing sector (accounting for 22.3% of value added in 2018, above the EU average of 17%) that invests intensively in R&D: in 2018, the automotive sector accounted for 38% of business R&D investment (BERD), followed by mechanical engineering (10%), manufacturers of data processing equipment, electronic and optical products (11%), and finally the pharmaceutical (7%) and chemical industries (6%) (Schulz, 2021[4]). Korea and Japan are other examples of top countries in terms of R&D intensity with a strong manufacturing sector that performs most R&D investments (Figure 5).

Figure 5. BERD distribution by industry, 2017

Industry shares (left scale) and total BERD as percentage of GDP (right scale)



Note: 2017 or latest year available. ISIC Rev.4 divisions are as follows: Agriculture, mining, utilities and construction: 01-03, 05-09, 35-39 and 41-43; Chemicals and minerals: 19-23; Electrical equipment and machinery nec: 27-28; Finance and other business services: 64-66 and 69-82 excluding 72; ICT equipment: 26; Information and communication services: 58-63; Other Manufacturing industries: 10-12, 13-15, 16-18, 24-25 and 31-33; Other services: 49-53, 55-56 and 84-99; R&D services: 72; Transport equipment: 29-30; and Wholesale and retail trade: 45-47.
Source: OECD ANBERD database, http://oe.cd/anberd, November 2019, and OECD, Main Science and Technology Indicators Database, http://oe.cd/msti, July 2019.

While services sectors tend to invest less in traditional R&D activities than manufacturing industries, this does not necessarily reflect the innovation performance of those sectors and affects aggregate national statistics. The United Kingdom is a case in point: a range of highly-innovative services sectors (e.g. creative industries, the financial sector), which account for a high share of national value added, perform relatively low levels of traditional R&D activities. This, however, is not to say that these sectors are not engaged in innovation activities. The sectoral composition of the UK economy, however, has contributed to an aggregate level of R&D intensity that is relatively low. The level has remained at around 1.6% of GDP over the past decade, despite policy efforts to increase it (Harrison and Griffith, 2003[18]; Rae, Phipps and Bakhshi, 2017[19]). The Netherlands is another example: the weight of high-tech and medium-high-tech sectors is relatively low (5.4% of GDP in 2017), compared to other countries and the EU average (7.9% of GDP in 2018), while services account for the bulk of the Dutch business sector (78% of value added in 2020). Some of these service sectors (including financial and mobility sectors) invest intensively in intangibles, which are not fully captured in R&D statistics (OECD, 2015[20];

OECD/Eurostat, 2018[21]). These investments, however, are critical inputs for innovation in the digital age, such as business model innovations which are gaining key competitive relevance and disrupting traditional services sectors (such as e-learning or e-health). As a result of successful performance here, the country scores high in international benchmarking exercises such as the European Innovation Scoreboard (4th position among EU countries in the 2020 edition) (Teurlinx and Donselaar, 2021[12]).

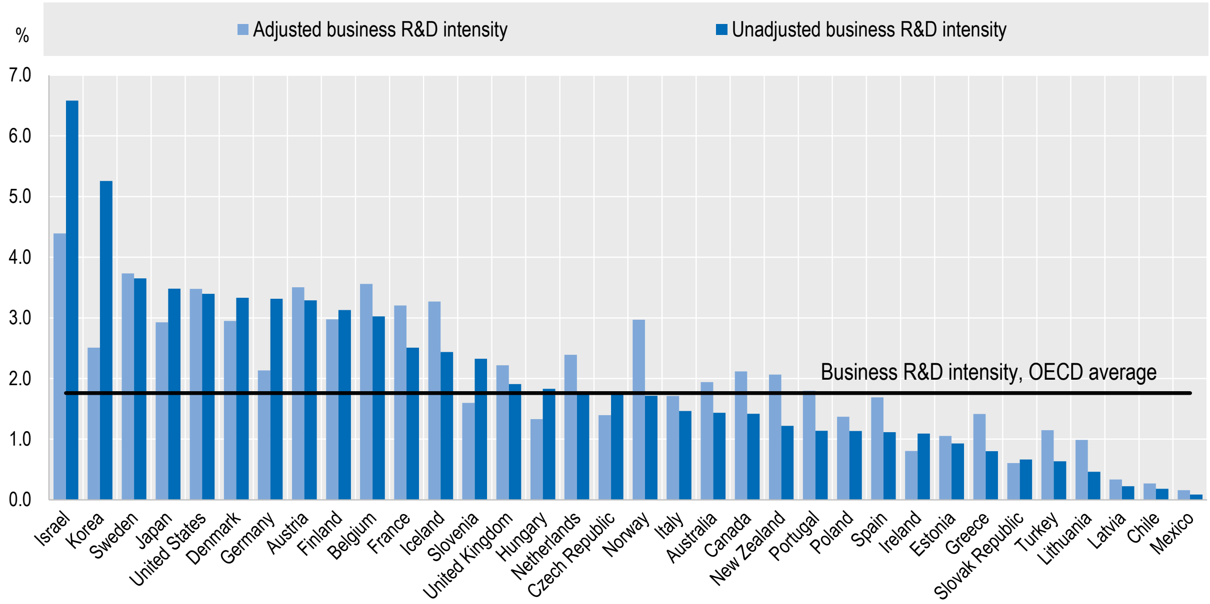
However, it is not the case that high service intensity necessarily results in low aggregate R&D intensities, as is demonstrated by Israel. This country has the highest business R&D intensity in the world (accounting for 3.7% of GDP in 2017) with R&D investments being performed chiefly by services sectors, like information and communication services and R&D services (Figure 5). Iceland and Norway are similar examples, yet their levels of business R&D intensity are lower. It is not only services sectors that account for lower R&D investment. In Australia, low R&D intensity levels are due to the country's strong reliance on the mining sector (which accounted for 10.4% of GDP in 2019-20, and has experienced a decrease in R&D investments since major investments were undertaken in 2008-09), in addition to the increasing weight of services sectors over time (Calder et al., 2021[5]).

A country's R&D intensity is thus largely a reflection of its industrial structure (Sheehan and Wyckoff, 2003[16]). Figure 6 illustrates this by comparing the R&D intensity values that each OECD country would have if they all had the same industrial structure (i.e. the current OECD average composition) with current levels based on each country's actual sectoral composition. Countries such as Korea, Israel, Japan and Germany would have lower aggregate levels of R&D intensity if their sectoral composition was that of the average OECD countries, while the opposite would be true for countries such as France, the United Kingdom, the Netherlands, Norway and Australia. Accounting for national industrial structures would thus change country rankings and possibly reduce the dispersion of R&D intensity performances, as some econometric studies suggest (Mathieu and Van Pottelsberghe de la Potterie, 2010[22]).

While sectoral composition is a key factor explaining variances observed across countries in aggregate R&D intensity levels, within-sector differences are also relevant, as not all firms within each sector are equally R&D-intensive. Such within-sector differences can be due to a range of factors including firm-/industry-specific economic and financial factors (e.g. access to finance, market opportunities, relations with customers and providers, etc.), product market competition, access to public support, firm location and human capital as well as the presence of foreign R&D investing companies. Moncada-Paternò-Castello (2016[23]) provide a review of the empirical literature on these questions.

Figure 6. Business R&D intensity adjusted for industrial structure, 2019

As percentage of value added in industry



Note: 2019 or latest year available. R&D intensity adjusted for industry structure is a weighted average of the R&D intensities of a country's industrial sectors, using the OECD industrial structure's sector value added shares as weights instead of the actual shares used in the unadjusted measure of R&D intensity. The unadjusted measure of BERD intensity is by definition an average based on each country's actual sector shares. The methodology used to adjust R&D intensity for industrial structure is sensitive to the industrial classification used. Other impacting factors are the level of aggregation at which the sectoral weights are calculated and the countries included in the benchmark. Countries where the disaggregation level for R&D is too low and where there are no comparable SNA data on Value Added by industry have been excluded. Calculations are based on the ISIC Rev.4 classification. This indicator is expressed as a percentage of Gross Value Added (GVA) in industry, estimated as the value added in all activities except: Real estate activities (ISIC Rev.4 68); Public administration and defence; Compulsory social security and education (ISIC Rev.4 84-85); Human health and social work activities (ISIC Rev.4 86-88); and Activities of households as employers (ISIC Rev.4 97-98). R&D performed in these sectors across the OECD is reported to be negligible.

Source: OECD calculations based on the ANBERD Database, http://oe.cd/anberd, and the Structural Analysis (STAN) Database, http://oe.cd/stan, Main Science and Technology Indicators Database, http://oe.cd/msti, and Research and Development Statistics Database, http://oe.cd/rds, April 2021.

Nonetheless, the sectoral composition plays an important role in the "effort" countries need to invest to increase their R&D intensity (Mohnen, 2019[24]). In some, stimulating higher investment among firms in traditionally more R&D-intensive sectors could suffice to improve aggregate performance, while in others more profound transformations leading to changes in sectoral structures are needed. Yet, as illustrated for the cases of the Netherlands and the United Kingdom above, having relatively low levels of R&D intensity is not synonymous with low innovativeness. This is why, as explored in more detail in section 3, the R&D intensity indicator should be complemented by other indicators of innovation capacity and performance.

A number of ambitious industrial and technology policies have been implemented to strengthen industrial R&D and consequently affect aggregate business R&D intensity by changing sectoral structures. An example is France's Investments for the Future Programme (*Programme d'Investissements d'Avenir*, PIA), created in 2010, which co-finances innovative investments in priority sectors to enhance the competitiveness of the

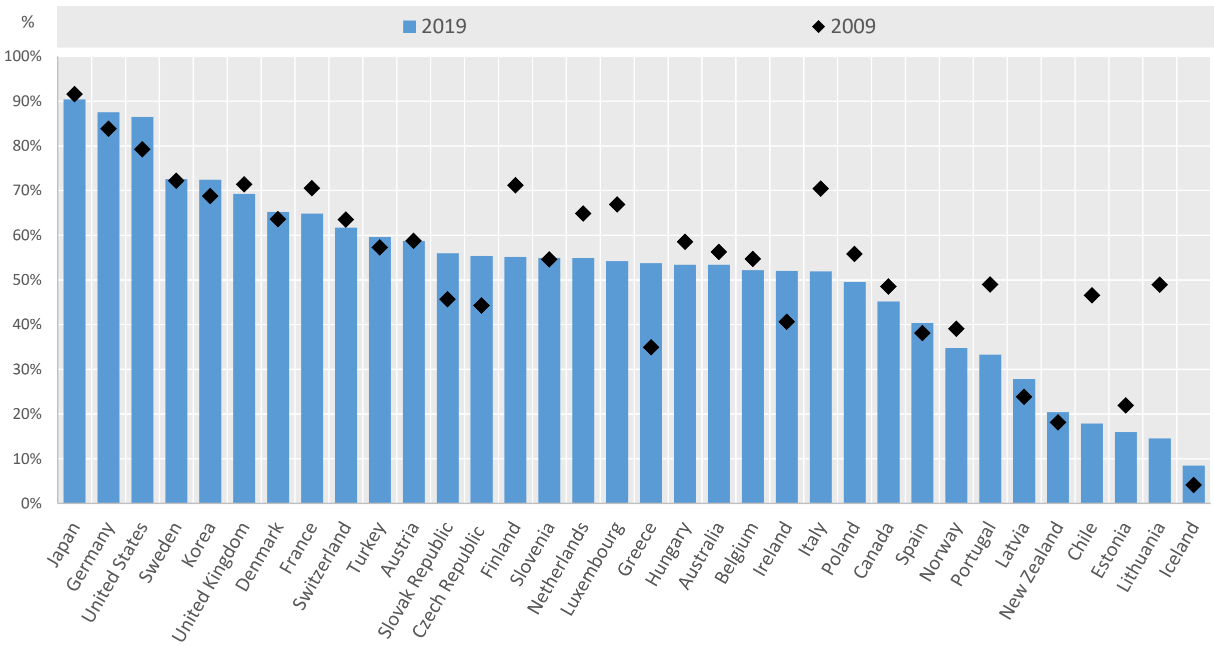
French business and create non-relocatable jobs. The fourth programme (PIA 4) will leverage EUR 11.5 billion between 2020 and 2022 from France's recovery plan to support investments in key technologies of the future (Goreichy, Hafied and Roulleau, 2021[7]). Another example is the Dutch top sector policy established in 2011, which as of 2018 was reformulated into a mission-driven top sector policy (Teurlinx and Donselaar, 2021[12]; OECD, 2020[25]).

(2) Firm sizes

Large firms tend to perform higher levels of R&D compared to SMEs. In Japan, Germany, the United States, Korea and Sweden more than 70% of BERD is conducted in large firms (with 500 employees or more) (Figure 7). R&D investment growth over the past decade (2007-2017) has also been driven mainly by increasing investments by large firms (Figure 8). Some papers explore this evidence using econometric models. Ortega-Argilés and Brandsma (2009[26]), for instance, find that size plays a key role in explaining the R&D intensity gap between the EU and the US, independently of sectoral composition of R&D. In some countries (particularly small ones) and regions, these may even be driven by a small number of large firms. For instance, in 2009 Nokia (once the world's largest mobile phone maker) accounted for around 40% of total BERD in Finland. The company's downsizing had a significant impact on total GERD, which declined from 3.73% in 2009 to 2.72% in 2017 (Deschryvere, Husso and Suominen, 2021[6]).

Figure 7. Business R&D performed by large firms, 2009 and 2019

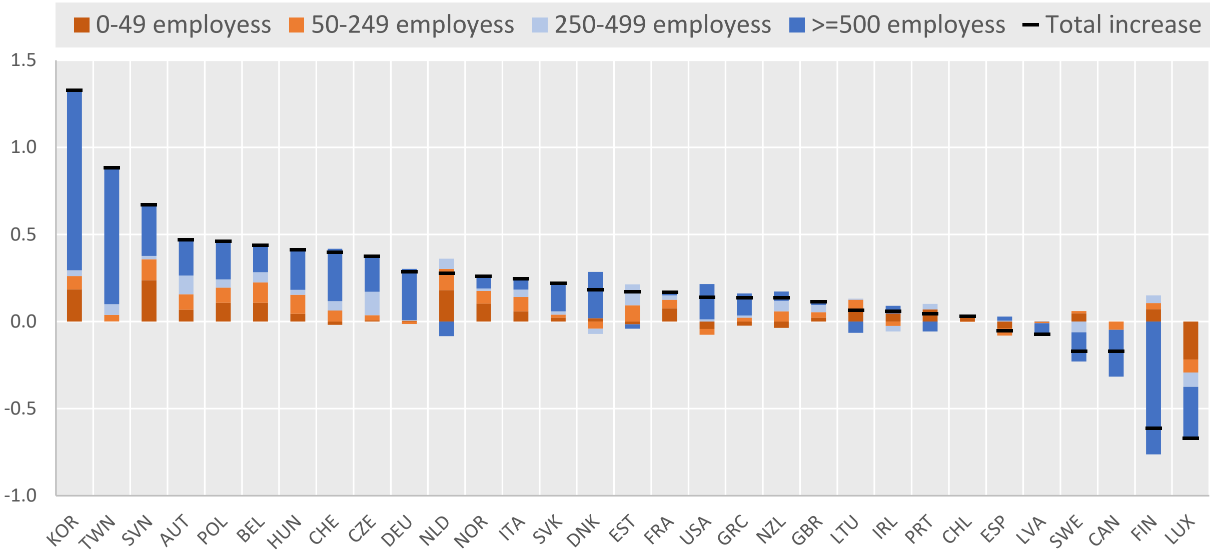
As percentage of total BERD



Note: Based on 2009 and 2019 data, or closest year available. Large firms include those with 500 or more employees
Source: OECD, Research and Development Statistics Database, http://oe.cd/rds, April 2021.

Figure 8. Business R&D growth by business size class, 2007-17

In percentage points



Note: Based on 2007 and 2017 data, or closest year available. Large firms include those with 500 or more employees
Source: OECD, Research and Development Statistics Database, http://oe.cd/rds, September 2019.

(3) Weight of multinational enterprises

Many large R&D performing firms are multinational enterprises (MNEs) with affiliates that operate across borders, which in certain countries (especially small ones) can account for a large share of total BERD. This is for instance the case of Ireland, where 59 companies account for over half (52%) of all R&D expenditure in the country, the majority of which are foreign owned. In Poland and Hungary, an important share of R&D investments are also concentrated in a relatively small number of large foreign firms (Sarul, 2021[13]; Sóvágó, 2021[9]). In the Netherlands, foreign firms with operations in the country often rely on R&D activities conducted in other countries, while a relatively large part of R&D performed by Dutch multinationals is carried out abroad in foreign affiliates (Teurlinx and Donselaar, 2021[12]). Countries interested in boosting R&D intensity might attempt to attract R&D investment by MNEs (Sheehan and Wyckoff, 2003[16]).

2.2. Rationale for setting R&D intensity targets

There is a wide consensus around the positive relation between R&D investments and innovation performance and also between R&D investments and productivity growth (Romer, 1990[27]; Grossman and Helpman, 1991[28]; Aghion and Howitt, 1992[29]; Griliches, 1979[30]; Ugur et al., 2016[31]). In turn, while R&D spending is only one input in the innovation process (as described in section 2.1 above), it represents a share of overall innovation expenditures. This is why it is considered to be a valuable proxy to quantify innovation.

A number of factors contributed to the adoption of R&D intensity as a policy target across countries. Case studies refer to the following advantages of setting a national R&D intensity target:

- **Allows setting a quantifiable goal for STI policy**. Such targets are considered a powerful tool to steer public and private investments towards knowledge-based, growth-enhancing activities, even if often the targets are not reached. The target also increases the visibility and recognition of research and innovation policy.
- **Easy to measure, analyse and communicate.** Data on R&D expenditures is systematically collected by statistical offices across countries, and long time series are publicly available, making it possible to explore trends over time. It is also easy to understand and communicate, making it a powerful tool for R&I policy.
- **Facilitates international comparisons and benchmarking.** Given that it is collected by all countries internationally, it has been widely used as an international benchmarking tool.

2.3. The limitations of the R&D intensity indicator as a policy target

The R&D intensity indicator also has a number of limitations, as explored in detail in the different case studies. In particular, there are a range of critical aspects that aggregate R&D statistics do not capture, but should nevertheless be considered when using them as policy monitoring and target tools:

- ***Quality of R&D performed***: The economic and social impact of R&D activities highly depends on the relevance and quality of the research conducted. Yet the R&D intensity indicator measures the amounts invested, not their impact. The quality of the R&D conducted and the efficiency with which such resources are used can vary widely. Is the research leading to new-to-the-world innovations? Does it involve the use of new techniques? Does it advance knowledge in critical areas? How does it compare to research conducted in the same field in other countries? Some common measures of quality include the number of filed patents or the number of high-impact publications – yet these also have a number of well-known limitations.
- ***Disparities in R&D performance at the firm level:*** the R&D intensity indicator at the national level does not reflect disparities in R&D performance between leading firms and the rest. The growing concentration of R&D performance among leading firms is a concern in many countries. For instance, in Germany between 2010 and 2017 the share of total R&D spending by SMEs went down from 11% to 8% (Schulz, 2021[4]). In Korea, the top 100 companies accounted for 61.7% of national R&D expenditures in 2013, and the ratio increased to 63.7% in 2017 (Han and Lee, 2021[11]). Concentration is also observed when looking at the top 1000 firms in the EU in terms of R&D investment: the top 25 R&D investors account for half of the group's R&D expenditure (Rakic et al., 2021[3]). The case studies provide detailed analyses on how countries' R&D and innovation policies address disparities across firms.
- ***Disparities in R&D performance at the territorial level:*** the aggregate R&D intensity indicator also does not reflect geographical disparities in R&D performance (e.g. between urban and rural areas, core regions and the periphery, top cities and the rest, etc.). In Poland, about 35-40% of the research potential is located in Warsaw (Sarul, 2021[13]). Similar concentration trends are observed at the EU level: the average research intensity of the top 30 EU regions is more than twice the average intensity of the EU as a whole; in turn, more-developed regions represent about 85% of total R&D expenditure. An example is Baden-Württemberg (Germany), which has about 2% of the EU's population but accounts for 8% EU's

business R&D expenditure. The case studies provide more detailed analyses on how countries' R&D and innovation policies address territorial disparities.

- ***Innovation activities in the digital age*:** Some of the innovation activities that are becoming increasingly prominent in the digital context might not be captured in R&D investment statistics (OECD, 2015[20]). These include data and software development innovation activities, innovation in business processes and business model innovation (Paunov and Planes-Satorra, 2019[32]). By definition, they also do not include non-R&D intangible investments, such as investments in ICT (software, data), economic competences (e.g. firm-specific human capital, market research and brand development, investments in organisational capital) and innovative property (e. g. licenses, product design and development) (Corrado, Hulten and Sichel, 2005[33]). The EU case study emphasises the relevance of this limitation (Rakic et al., 2021[3]). The case studies provide more detailed analyses on how countries' R&D and innovation strategies are implemented to respond to the opportunities and challenges of the digital age.

- ***International R&D spillovers**:* R&D performed abroad can also be a significant source of domestic innovation and technical change. There are several channels through which firms can benefit from R&D activities conducted beyond their borders, such as buying patents and licenses, hiring foreign scientists or interacting with them in international conferences. The final impact of those foreign activities depends on the ability of countries/firms to absorb those foreign technologies (Guellec and Van Pottelsberghe de la Potterie, 2004[34]).

- ***Contribution of innovative start-ups to R&D performance***. Business investments in R&D (BERD) are only categorized by firm size and not by age of companies, making it difficult to measure the contribution of start-ups (Rakic et al., 2021[3]). In Finland, the measure may often not cover firms of less than 10 employees, which could have high levels of R&D intensity as the country experienced a boom of tech-based start-ups over the last decade (Deschryvere, Husso and Suominen, 2021[6]).

- ***Relative R&D policy efforts of a country*:** R&D spending levels do not necessarily reflect the relative R&D commitments or efforts of a country but, as explored in the previous sub-section, are largely a reflection of their industrial structure, company strategies and demographics, and macro-economic dynamics (Moncada-Paternò-Castello et al., 2010[35]). Low levels of R&D intensity could then be due to low levels of R&D intensity across most sectors, or due to a relatively low share of R&D-intensive sectors. International comparisons of R&D intensities should thus be read with caution and take into consideration the economic specialisation of each country. For countries that are far from the technological frontier, learning, absorbing, adopting and adapting new technologies may be more important to enhancing their innovation capacities than their own R&D investments (Mohnen, 2019[24]).

3. Achieving R&D and innovation objectives: main takeaways from international policy practices

R&D intensity targets should not be used in isolation

The characteristics of the R&D intensity indicator and its limitations, explored in section 2, make it a relevant indicator yet not a sufficient one to provide a complete picture of the innovation performance of a country or region. All case studies realised in the context of this project agreed on the need to complement the R&D intensity indicator with a range of additional indicators, which used jointly allow for more rigorous assessments of innovation systems' performance.

For instance, Ireland's National Innovation Strategy 'Innovation 2020' includes a range of targets, in addition to an aggregate R&D intensity target of 2.5% of GDP (Table 4). These include targets related to private R&D funding and the innovation performance of firms (e.g. increase private funding of R&D performed in the higher education sector, increase the number of firms that are actively innovating), human capital (e.g. increase research masters and PhD enrolments, increase the number of research personnel in enterprises), as well as commercialisation targets (e.g. increase the number of commercially relevant technologies, spin-outs, and collaborative research projects between businesses and the public research system). The conclusion reached in the mid-term review of 'Innovation 2020' was that, notwithstanding the decrease in aggregate R&D intensity, Ireland's RDI system continues to perform strongly, having retained the 10th place in the European Innovation Scoreboard in 2019 (Hughes, 2021[10]).

Table 4. Targets included in Ireland's "Innovation 2020" Strategy

	Baseline (2014 unless specified)	**2020 targets**	**Latest data** (December 2018 unless specified)
European Innovation scoreboard performance relative to EU average	+9% (10th place)	+20%	+15.9% (9th place)
Funding secured from Horizon 2020	EUR 620 million under FP7	EUR 1.25 billion	EUR 632.1 million
R&D intensity (GERD as % of GNP)	1.82%	2.5%	1.46% (2017)
Increase private funding of R&D performed in Higher Education sector	EUR 24 million	EUR 48 million	EUR 32 million (2015)
Increase research masters and PhD enrolments	2 235 (2012/13)	+500	2 243 (2017/18)
Increase number of firms that are: a. Innovation active b. Significant R&D performers c. Large R&D performers	 a. 58% b. 1 040 c. 170	 a. 73% b. 1 200 c. 200	 a. 57% (2016) b. 918 (2017) c. 207 (2017)
Research personnel* in enterprise	24 785 (2013)	40 000	27 322 (2017)
Commercialisation targets a. Commercially relevant technologies (licenses, options, assignments) b. Spin-outs c. High potential star-ups from spin-outs d. Collaborative research between enterprises supported by Enterprise Ireland and the public research system	 a. 124 b. 29 c. 11 d. 878	 a. 175 b. 40 c. 16 d. 920	 a. 164 (2017) b. 21 (2017) c. 15 (2017) d. 1078 (2017)

Note: The mid-term review covered the first three years of I2020 (December 2015 to December 2018). Latest data provided is for December 2018, unless specified. *Research personnel includes researchers, technicians and support staff.

Source: Hughes (2021[10])

The scoreboards produced at EU level also highlight the relevance of using a combination of indicators to assess innovation performance and evolution over time. The European Innovation Scoreboard, released annually, is based on scores for 27 indicators on different dimensions of innovation, including access to infrastructure, human resources and employment elements, linkages across actors and IP applications (European Commission, 2020[36]). The EU Industrial R&D Investment Scoreboard also uses a range of indicators to assess the performance of the top 2 500 companies in terms of R&D spending in the world by analysing those companies' R&D and economic indicators (e.g. R&D spending and R&D intensity, net sales, operating profits, number of employees) as well as patent-based analyses, with the objective of benchmarking EU industry innovation performance and helping shape EU policy (Rakic et al., 2021[3]).

Funding targets should be accompanied with a strategic vision and direction

Given that R&D intensity is an input indicator, achieving these targets does not necessarily lead to good research and innovation results. As emphasized by the Korean case study, the process from input to performance results from the interaction of a wide variety of actors and environments. Therefore, plans need to be designed in a way that they improve the research and innovation ecosystem, such as developing researcher-oriented policy by reducing the administrative burden on researchers (Han and Lee, 2021[11]).

The EU case study also underlines that clear objectives and direction should be set for R&I investments to create scientific, societal, environmental and/or economic impacts, based on a sound identification of current and future needs through consultation/co-creation exercises, strategic foresight, evaluations and impact assessments. Moving from a funding and technology push approach to a more use- and demand-oriented approach will eventually reinforce the contribution of such investments to wider political objectives, allow for a greater pool of investments, while ensuring a reinforced uptake of R&I solutions (Rakic et al., 2021[3]).

The increased popularity of mission-oriented research and innovation policies (MOIP) over the past years also reflects a shift towards more strategic innovation policies, which may be reinforced by the COVID-19 crisis (Paunov and Planes-Satorra, 2021[37]). MOIP are defined by a high degree of directionality, i.e. they involve “picking the problem”, while offering flexibility to STI actors to decide on the best technology solutions to address it. Successful MOIP set challenges in such a way that a wide range of actors with different approaches to address the challenge engage. They are also sufficiently concrete and well-defined to provide strong orientation that is “actionable” (i.e. that can be translated into and monitored against precise goals and expected deliverables) (Larrue, 2021[38]). For instance, the Netherlands introduced in 2018 a mission-oriented top sector and innovation policy oriented towards societal challenges (energy transition and sustainability, agriculture, water and food, health and security) (Teurlinx and Donselaar, 2021[12]). Other important targets of countries’ MOIP have been carbon neutrality, the development of cancer therapies and the digitization of manufacturing.

Several case studies also highlight the importance of ensuring long-term and predictable public investments in R&D. This is key to build trust among stakeholders and to provide the necessary framework conditions for private investment (Schulz, 2021[4]; Deschryvere, Husso and Suominen, 2021[6]; Rakic et al., 2021[3]). The Finnish case study also highlights that political stability is a precondition for trust building and for increasing private R&D investments. The case study points to the importance of ensuring an inclusive dialogue (involving policy makers across different policy domains but also a wider range of stakeholders, including business) when planning long-term policy initiatives in order to guarantee their sustainability (Deschryvere, Husso and Suominen, 2021[6]).

R&D strategies need to be tailored to specific R&I ecosystems

The framework conditions beyond R&D funding should be factored in to ensure the full effectiveness of R&D investments. This includes the early identification of potential barriers and drivers to research and innovation (e.g. regulations, standards, access to finance, and customer acceptance), the synergies between different instruments for R&D, but also the global evolution of the socio-economic, technological and scientific context. Involving end-users, standardisation bodies, regulators and citizens in co-designing the R&D agenda and co-creating solutions should stimulate greater up-take and attract additional investments (Rakic et al., 2021[3]).

Several case studies highlight that in less technologically advanced countries the R&D and innovation policy priority should be to enhance the absorptive capacity of firms and other actors in STI ecosystems. In that sense, STI policy in Hungary focuses primarily on promoting the innovation capacity of SMEs, which is on average low, mainly by facilitating the adoption of new technologies and digital business solutions, and supporting non-technological innovation (e.g. organisational innovation, design, marketing innovation) (Sóvágó, 2021[9]). The Greek case study emphasises that increasing absorptive capacity (particularly of laggard regions and sectors) is a condition for those countries to benefit from R&D spill-overs. This depends on many factors such as education, scientific infrastructure, availability of human capital and international networking, structural characteristics of the productive fabric and the overall performance of the national system of innovation. The case study also underlines the key role of government in supporting the development of appropriate innovation diffusion channels (Spilioti et al., 2021[8]).

Another priority of STI policy in less technologically advanced countries is to support R&D and innovation efforts to address internal economic and social needs (e.g. related to healthcare, environmental protection, climate change mitigation) by adapting existing technologies, rather than developing new-to-the-world technologies, as emphasised in the Polish case study. In a context of limited resources, "frugal innovation" becomes particularly relevant – defined here as the process of creating useful and affordable solutions at scale that can improve the quality of life of societies. The prevention of brain drain is also a key priority for these countries (Sarul, 2021[13]).

To set in place appropriate framework conditions, the Finnish case study highlights the importance of having "insightful leadership and more diplomacy pushing aside organisational agendas and short-term wins for the common economic and societal good of the entire country. Given the grand challenges the world faces, visionary STI policy leaders, bridge-builders and intermediaries will continue to be in high demand" (Deschryvere, Husso and Suominen, 2021[6]).

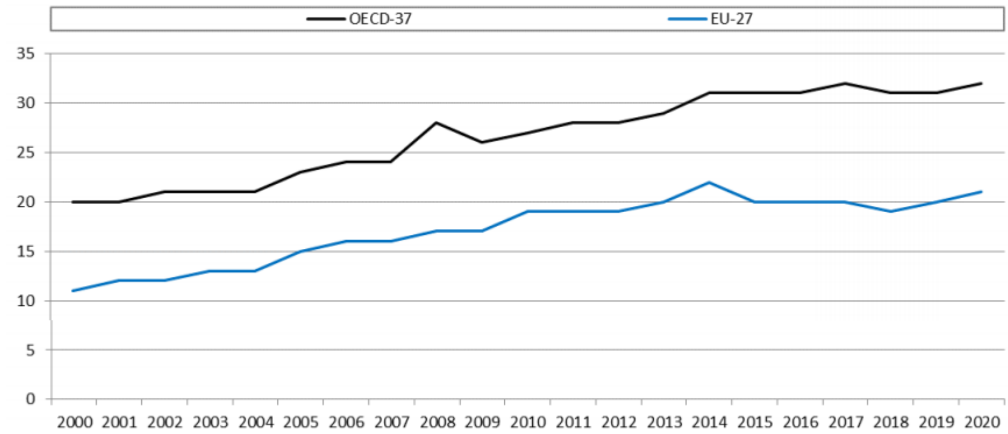
Policy mixes in support of business R&D are shifting towards tax incentives in many countries

In 2020, 32 out of 37 OECD countries offer R&D tax incentives at the central government level, up from 19 in 2000 (Figure 9) (Appelt et al., 2020[39]). These include the following instruments in case study countries: the Australian Research and Development tax incentive (2011), the French Research Tax Credit ("Crédit d'impôt recherche"); the German Research Allowance Act ("Forschungszulagengesetz"); the Greek programme for tax incentives (Law 4172, 2013); the Irish RD&I Tax Credit and the more recent program

"Knowledge Development Box"; and the Polish tax allowance programme (Calder et al., 2021[5]) (Schulz, 2021[4]) (Spilioti et al., 2021[8]) (Hughes, 2021[10]) (Sarul, 2021[13]). Finland and Latvia are the only countries that have repealed their R&D tax provisions (in 2015 and 2018 respectively). New Zealand and Mexico also cancelled their R&D tax incentive schemes in 2009 but reintroduced them in 2015 and 2017 respectively (OECD, 2020[40]). The amount of tax support to BERD across the 37 OECD and 27 countries of the European Union has also increased over time, and in many countries (France, the United Kingdom, Austria, Belgium, Italy, Canada, Portugal, the Netherlands, Australia, Ireland and Japan), it represents the lion's share of total public support to BERD (Figure 10).

Figure 9. R&D tax incentives in the OECD and EU area, 2000-2020

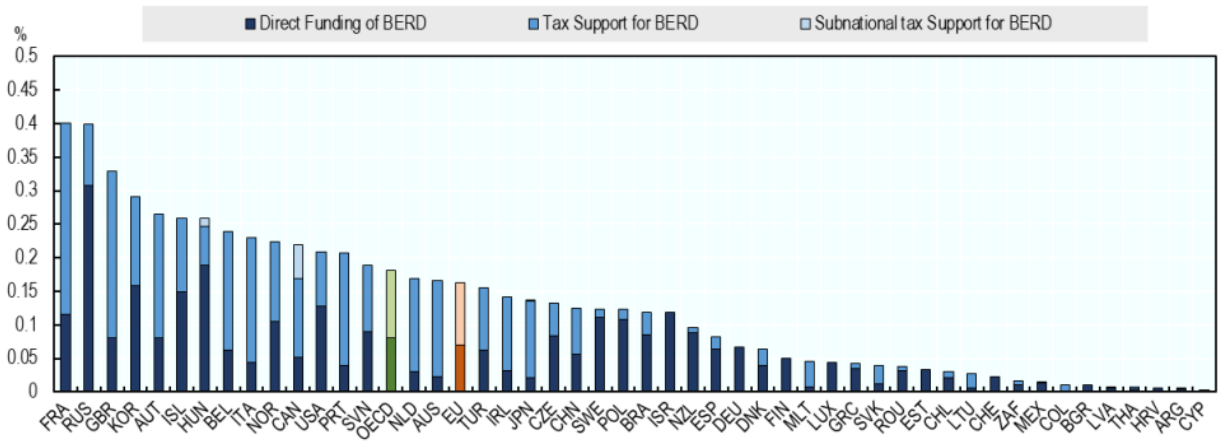
Number of OECD-37 and EU-27 countries offering R&D tax support (central government level)



Source: OECD (2020[40]), based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, December 2020.

Figure 10. Direct government funding and government tax support for business R&D, 2018

As percentage of GDP



Note: Data on subnational tax support for business R&D are only available for a group of countries. Estimates of government tax relief for R&D (central government level) are not available for Israel. EU government-financed BERD in 2018 based on OECD estimate.
Source: OECD (2020[40]), based on OECD R&D Tax Incentives Database, http://oe.cd/rdtax, December 2020.

Recent OECD analysis finds that R&D tax incentives are effective in boosting business R&D but their effectiveness differs sharply across firms of different sizes and across countries. Tax incentives are also better suited for supporting R&D projects closer to the market while direct government funding – such as through grants and R&D procurement – is more conducive to research that may not immediately result in new goods or services (Appelt et al., 2020[39]). In Ireland, an economic evaluation of the R&D Tax Credit conducted by the Irish Department of Finance in October 2016 estimates that 60% of the research and development conducted by firms since 2009 would not have been occurred in the absence of the tax credit policy. However, the older, larger and non-Irish firms are generally the ones which benefit more from the repayable credit element of the scheme (Hughes, 2021[10]).

Finland reported a failure in the introduction of R&D tax incentives during the 1980s and in 2013-2014, due to structural flaws, challenges in implementation, and a lack of uptake. Tax incentives for R&D are again on the policy agenda and appeared as a recommendation on the new RDI roadmap of the Finnish government (Deschryvere, Husso and Suominen, 2021[6]).

Participatory governance models and political commitment are essential for systemic changes

The ability of STI policy to shape changes in STI policy frameworks highly depends on the level of political commitment and the mandate of the institutions in charge of implementing reforms. In Finland, the Research and Innovation Council (RIC), established in 1987 and active until 2014, offered a forum for discussion and consensus-making and an independent soundboard beyond the government. Simultaneously, multiple STI agencies and ministries were coordinating their actions. Through the organisation of sectoral committees, strong coordination also existed between national policies and initiatives undertaken by sectors/firms. All these coordination actions ensured the stability and enhanced the impact of STI policies. The RIC was re-established in 2016 but with significant changes in its role and functioning (Deschryvere, Husso and Suominen, 2021[6]). In Australia, the engagement of relevant agencies across the government to promote programs through their respective networks, both domestically and internationally, has been critical to increasing program uptake (Calder et al., 2021[5]).

The engagement of stakeholders in STI policy design through participatory governance models is also found to be critical to enhance adoption and alignment of efforts across actors. In Germany, participatory structures for designing and implementing the High Tech Strategy were key in rallying all relevant stakeholders behind the common target of increasing R&D intensity. The implementation of HTS 2025 is based on an exchange between a broad range of policy-makers and members of the research community. Furthermore, it is continuously evaluated and developed in terms of content (Schulz, 2021[4]). In Australia, incorporating stakeholder feedback in policy programme design has improved their efficiency and leveraged more investment by industry into research, as pointed out by several evaluation reports (Calder et al., 2021[5]). In Hungary, a number of initiatives were implemented to stimulate communication across all actors in the ecosystem and jointly shape the future of the national STI system. An example is the "National Innovation Forum" organised at 25 locations in 2019. As part of the forum, consultations were held with the representatives of local and regional businesses, knowledge centres and professional organisations. Those events laid the foundations for reorganising Hungary's innovation ecosystem, and allowed collecting proposals related to the new research and innovation strategy (Sóvágó, 2021[9]).

Governance models for STI may change after the COVID-19 crisis, as the pandemic led to more intensive civil society and industry involvement compared to the pre-COVID-19 period and highlighted the importance of improving intergovernmental coordination and science communication (Paunov and Planes-Satorra, 2021[37]).

4. Conclusion

This document summarizes some key takeaways from the 11 case studies conducted in the context of the TIP project on R&D intensity (2021-22). It aims at reflecting some of the main insights, trends and policy lessons that stem from the country cases, yet capturing the full richness of those analyses would be impossible in a few pages. The reader is therefore highly encouraged to directly access the case studies to learn more about the policy experience of those countries in setting (or not) R&D intensity targets and other policies to enhance R&D and innovation performance. The case studies will be publicly available in this dedicated project website: http://oe.cd/tiprd.

The new project of the OECD Working Party on Innovation and Technology Policy (TIP) on "Innovation policies for collaborative transitions" (2021-22) will continue to analyse the conditions for effective R&D and innovation policies, extracting lessons from international best practices and stimulating cross-country exchanges. R&D and innovation policies are critical to support systems transitions towards more inclusive, environmentally sustainable and inclusive systems after the COVID-19 crisis. The new project, which will focus in particular on collaborative approaches to support systems transitions toward better futures, will build on two policy papers developed in the context of the TIP R&D project: the first one analyses the short-term impact of the COVID-19 crisis on STI systems, and the immediate policy responses implemented across countries (Paunov and Planes-Satorra, 2021[41]); the second discusses the effects that the COVID-19 pandemic could have on the future of STI, and how it may affect the purpose, design and execution of STI policies (Paunov and Planes-Satorra, 2021[37]).

Annex: Overview of case studies

	Overview
Australia	While the Australian Government has not introduced an R&D intensity target, there has been a focus on how to best support R&D and innovation in the context of declining national R&D expenditure (from 1.88 % of GDP in 2015-16 to 1.79% in 2017-18). Business expenditure on R&D (BERD) is a significant driver of GERD. However, Australia's BERD as a proportion of GDP has been declining since its peak at 1.37 per cent in 2008-09, which coincided with the peak in R&D investment by Australia's mining sector. The Australian Government supports R&D (and innovation more broadly) by investing in education, science and research, and infrastructure; incentivises business R&D and innovation investment; and removing regulatory obstacles such as restrictions around employee share ownership and access to crowd-sourced equity funding. Some of Australia's R&D initiatives described in the case study include the R&D tax incentive, the Research Training Program (RTP), the ARC Linkage Programme, the Medical Research Future Fund, the Next Generation Technologies Fund, the Rural Research and Development for Profit Program, and the Industry Growth Centres Initiative. It also provides an overview of policies aimed at addressing innovation disparities and fostering digital innovation. The case study explores the success factors of two programmes (the Cooperative Research Centres and the Global Innovation Strategy) as well as the challenges faced when implementing policies aimed at increasing R&D performance (including those related to engaging businesses effectively with the research sector, the changing global R&D landscape, and the complex delivery models including multiple agencies and policy teams). Based on the analysis, it presents a range of lessons learned and areas for potential improvement.
France	France has set its R&D intensity target at 3% of GDP (1% for public expenditures and 2% for private ones), following both the Lisbon Strategy agreed in 2000 and the target set by the European Union for its research program. No specific target has been set at the regional level, but universities, higher education institutions and national research organizations sign multiannual contracts with the Ministry for Higher Education, Research and Innovation. The case study provides an overview of the main policy initiatives implemented in France to foster research and innovation. Major recent reforms include the Research Programming Law, the Productive Pact 2025, France's Recovery Plan, the Great Plan for Investment, the Innovation and Industry Fund, and the Action Plan for Business Growth and Transformation. Indirect financial support has historically been the most important policy tool used to support business R&D in France. This includes the Research Tax Credit (CIR). Available to all firms, the CIR is one of the most generous tax credits in the world. Other tax incentives that complement the CIR are the Innovation Tax Credit (CII), the Young Innovative Companies Scheme (JEI), and the Young PhD program. The case study also explores France's policies aimed at addressing the opportunities and challenges brought about by digital and AI-driven innovation. Already characterized by a high level of investment in software and numeric tools, the country has launched other plans to enhance its knowledge on those sectors, including the national Plan for AI launched in 2018, "AI for Humanity" and the National Open Science Plan.
Finland	Finland has almost half a century of experience with national R&D target setting and its implementation. Foremost, Finland is unique in that it has reached the R&D intensity targets it had set. Since the great recession that hit Finland exceptionally hard in 2009, R&D intensity target setting and its implementation has been less ambitious and the commitment to achieving targets has diminished. The government has still set targets, explicitly or implicitly, but concrete actions to create a path to the targets have not been taken. The focus of the Finnish case study is mainly on the period between 2005 (when the current 4% target was set for the first time) and the present covering the policy target R&D intensity and other STI objectives directly linked to it. The innovation policy impact of the study is twofold: it highlights the lessons learned for other countries and makes policy recommendations for the future of the Finnish Innovation System. The methods used in the Finnish case study were desk-research, an online survey questionnaire with open questions and semi-structured interviews. The desk research included the in-depth analysis of official reports, such as the minutes of the Research and Innovation Council meetings and other key meetings publicly available. The online survey questionnaire targeted four types of Finnish stakeholders: (1) Ministers and their close team members, (2) civil servants, (3) council members and (4) experts. A total of 27 stakeholders - including two Prime Ministers – participated in the survey.

Germany	Germany has a specific R&D intensity target of 3.5% of GDP by 2025 at the national level - laid down in the coalition agreement for the 19th legislative period (since 2017) and defined in the High-Tech Strategy 2025 (the national innovation strategy). This is in line with the targets of the "Europe 2020 Agenda" to increase R&D intensity in Europe to 3% of GDP by 2020. Germany had already achieved this goal by 2017 (3.07%); in 2018, 3.13% of GDP was spent on R&D. This is why the Federal Government already set a new target in 2017: by 2025, Germany now intends to invest 3.5% of its GDP in research and development. Based on the target of 3.5%, specific innovation policy missions were defined in the national innovation strategy: the High-Tech Strategy (HTS). These missions address societal challenges in particular and are backed up by specific measures. The HTS coordinates German innovation policy across all government departments. Most recently (2017), German R&D expenditure amounted to €99.6 billion, a quarter of which was publicly funded (€27.6 billion). On average (2005 to 2017), the public sector invested 25 to 28 percent. Although the German corporate structure is characterised by a pronounced small-scale structure with a comparatively very high proportion of SMEs, R&D expenditure is disproportionately high in large companies. The most R&D-intensive sectors are automotive engineering, mechanical engineering and the chemical industry. The sectoral and regional differences in the German innovation system are particularly evident in the east-west and north-south divide.
Greece	Greece is one of the countries that have adopted a national target for R&D intensity since 2003. The target was initially set at 1.5 % of the GDP by 2020 and since then it was revised several times upwards and downwards in an effort to steer growth or to adjust to economic crisis. The R&D intensity indicator presents great variations along the country's regions as well as the economic sectors. On a regional level, high regional R&D intensity value does not necessarily correspond to a "rich" region (GDP per capita). On the contrary, sometimes a "poor" region with a low GDP might present a high R&D intensity, if a dynamic research sector is present, combined with the fact that GDP is the denominator of the fraction. For laggard regions, a policy mix aiming at increasing absorptive capacity is needed, in order to benefit from innovation spillovers created elsewhere. From the sectoral point of view, the national Smart Specialization Strategy 2014-18 identified 8 priority thematic domains where research and innovation are expected to provide a competitive advantage to the country. The case study explores initiatives that are considered to have successfully contributed to the increase of the indicator, as well as one initiative that failed to achieve its goals. R&D tax incentives, mostly used from 2015 onwards, contributed in particular to the strong positive trend in business R&D that is recently observed. Until recently, R&D expenditure in Greece did not follow the developments of GDP, but a rather inverse trend was recorded. Specifically, while GDP had been falling constantly during the years of economic crisis, the R&D intensity has been steadily increasing and this increase is mainly based on firms' research activities that possibly reacted to the challenges of the crisis by adopting R&D strategies in order to secure their competitive position in the markets.
Hungary	The R&D expenditure/GDP ratio is a central element of the Hungarian RDI policy. The case study acknowledges that a major advantage of this indicator is that it reflects the R&D activity's weight within the national economy, and it has a stimulating effect on the evolution of the volume of public funds invested in R&D, but using it as a single indicator also entails risks. Importantly, during RDI policy making, countries should consider the sectoral structure and innovation capacity of their enterprises and adjust their responses and support given to RDI actors accordingly. The R&D expenditure indicator, however, measures only a part of innovation processes, namely the research and development activities. Initiatives promoting non-R&D-based innovations are not reflected in the R&D expenditure indicator. This poses a difficult dilemma for those involved in the policy planning process if they intend to meet the R&D expenditure targets. The case study suggests adding other targets as part of R&D strategies, both to capture inputs and outputs of innovation activities. The case study explains how the National Research, Development and Innovation Fund supports three types of RDI programmes: first, calls to support market-based innovation for micro, small- and medium-sized enterprises and large companies, where public funding is combined with significant own corporate resources; second, institutional excellence programmes, to finance the projects and research infrastructure developments of universities/research institutes; and third, research excellence programmes to finance basic research. RDI-related communication activities have also been enhanced through a number of initiatives, including the National Innovation Forum and the Territorial Innovation Platform.

Ireland	Ireland's current research target is to raise combined public and private investment in R&D to 2.5% of GNP (Gross National Product) by 2020. Ireland's GERD has increased substantially in recent years, but GNP has increased at an even faster rate. As a result, Ireland's R&D intensity rate expressed as a percentage of GNP declined from 1.81% of GNP in 2014 to 1.46% in 2017. For a small economy like Ireland, the dramatic changes in GNP associated with the financial crisis and subsequent recovery, has limited the utility of the R&D intensity measure, if considered in isolation, over the period. But economic cycles are not the only challenge with using a measure based on GDP or GNP. Globalisation presents significant challenges in terms of measuring economic activity. While this is the case in most advanced economies, the issues are particularly acute in an Irish context, given the large multinational footprint. Ireland's National Innovation Strategy 'Innovation 2020' includes a range of quantitative targets, going beyond R&D intensity. The case study highlights the success of actions aimed at increasing innovation across Ireland's enterprise base by increasing both the number of R&D performers and the R&D intensity for those who already innovate. At a high level, the success of Ireland's policy-mix in building innovative capacity and excellence can be illustrated by successes in supporting the mobility of research talent, increasing the quality of research, and increasing BERD. The case study also explores several challenges for firms to engage in R&D.
Korea	South Korea first set the national R&D intensity target at 5% of GDP in 2012 through the "577 Initiative" in 2008. Large conglomerates account for a significant portion of private R&D investment in the country. However, while the government set the goal for the R&D intensity, its funding of business R&D was concentrated on various companies including small companies, medium companies, venture businesses, and start-ups. Government policies were expected to enhance R&D performance by increasing R&D input and improving the R&D ecosystem through a number of actions. First, the government expanded R&D investments and their efficiency. Second, it increased investments in human capital. Third, it improved the research environment by reorganising the management system (e.g. by encouraging the shared use of research facilities and maintenance). Fourth, it promoted the collaboration with research institutes abroad. Fifth, it enhanced regional science and technology capabilities to reduce R&D gaps across regions. Sixth, it supported the spread of science and technology culture. While R&D investment goals presented in the 3rd Science and Technology Basic Plan (2013-2017) were achieved and investment-related plans were easily implemented, performance-related goals such as ranking in the top 1% of highly cited papers paper, technological competitiveness of small businesses, and industrial value-added per capita were not achieved. This indicates that it is difficult to secure a process from investment to performance and that policies such as establishing R&D ecosystems and capacity building have not performed well.
The Netherlands	The Netherlands has an R&D intensity target of 2.5% of GDP. In the Top Sector Policy approach, a total investment of 800 million Euro has been targeted, of which 50% should come from business. One of the main features of the Dutch innovation policy system discussed in the paper is its new focus on missions. This brings two problems with implementation: first, making choices on the scope and size of these missions, and second the relationship between missions and R&D-intensity. The study also argues that R&D aggregate performance is not sufficient as an indicator of business-led innovation the country. First, a number of reports note that Dutch firms invest in R&D abroad, which is not compensated completely by foreign firms investing in R&D in the Netherlands. While R&D in the Netherlands is below policy targets on average, Dutch companies are innovative, even if they do not invest enough in the Netherlands. Second, the country is in a top position when it comes to R&D in a number of sectors (including agriculture and semiconductors). These sectors, while profiting from the Netherlands as an innovation ecosystem, are regionally oriented and are only a small part of total Dutch R&D. Such clusters have an important role in global value chains and are an indicator of innovativeness. Third, the strongly digitalised Dutch economy, in combination with solid investments in intangible assets, are also a reflection of broader investment in innovation.
Poland	The Polish Responsible Development Strategy (2017) specifies the R&D intensity goals to be achieved by 2020 (1.7% of GDP) and 2030 (2.5%). In addition, each region of Poland (NUTS-2) has its own development strategy, which also takes into account R&D objectives, with targets that vary significantly. The case study argues that R&D intensity indicators (and related ones) are not sufficient, mainly for three reasons. First, in cases of large weight of the public sector in the economy, the level of R&D expenditure does not reflect real market demand, but shows the level of financing political priorities (e.g. of structural funds schemes). Second, during periods of expansive economic policy, where economic growth is stimulated by the "cheap factors' of production, increasing expenditure on R&D are not visible. Third, in the age of globalisation, the R&D expenditure in individual countries can translate into economic benefits in other countries. The case study suggests that there is a need to consider new indicators of innovation that are complementary to existing ones. The case study also provides a comprehensive overview of the main policies implemented to enhance R&D performance, including to address territorial disparities, given that about 35-40% of the research potential is located in Warsaw. It also explores the challenges faced in Poland when implementing policies aimed at increasing R&D performance, and distils key policy lessons, including the need to build on domestic potential and implement policies to prevent brain drain.

European Union	The EU's target of investing 3% of EU GDP in R&D was set at the 2002 Barcelona European Council and then subsequently confirmed in the Europe 2020 strategy (2010). Although the EU has not fulfilled its R&D investment ambition, the 3% target has proven to have had a clear mobilising effect as all Member States have set their own national targets. It has also stimulated reflections across Member States on their policy mix in support of R&I and the contribution of R&I to economic growth. The 3% target is widely known target, enhancing the visibility and recognition of R&I policy. At the EU level, the main policy initiative supporting the achievement of Europe 2020 Strategy, including the 3% R&D target, is the European Semester. Closely monitoring Member States' progress and issuing Country Specific Recommendations, the Commission supports Member States' structural reforms and investment policies towards the achievement of their national R&D targets. Furthermore, the Horizon Policy Support Facility provides policy advice to Member States and Associated Countries (to Horizon 2020) in the design, implementation and evaluation of R&I reforms to improve the quality and impact of their R&I systems, investments and policies. Finally, the European Research Area (ERA) helps countries be more effective together, by aligning their research and innovation policies and programmes. Considering funding instruments at the EU level, the most important is the Framework Programme that offers a seven-year financial perspective, which greatly helps academia, centres, and enterprises in their recruitment plans and thus increases the overall absorption capacity and leverages additional investment from the public and private sector. This gives a paramount role to the Framework Programme in the European context. Horizon 2020 represents 6-8% of total public investment in R&I in Europe. New avenues are opened up with Horizon Europe, especially through the R&I Missions, European Partnerships, and the European Innovation Council.

Note: All case studies are available at: http://oe.cd/tiprd
Source: Case study contributions to the TIP R&D intensity project.

References

Aghion, P. and P. Howitt (1992), "A Model of Growth Through Creative Destruction", *Econometrica*, Vol. 60/2, pp. 323-351, http://dx.doi.org/10.3386/w3223. [29]

Appelt, S. et al. (2020), "The effects of R&D tax incentives and their role in the innovation policy mix: Findings from the OECD microBeRD project, 2016-19", *OECD Science, Technology and Industry Policy Papers*, https://www.oecd-ilibrary.org/fr/science-and-technology/the-effects-of-r-d-tax-incentives-and-their-role-in-the-innovation-policy-mix_65234003-en (accessed on 27 November 2020). [39]

Becker, B. and S. Hall (2013), "Do R&D strategies in high-tech sectors differ from those in low-tech sectors? An alternative approach to testing the pooling assumption", *Economic Change and Restructuring*, Vol. 46/2, pp. 183-202, http://dx.doi.org/10.1007/s10644-012-9122-7. [49]

Bitard, P. et al. (2018), "The paradox of high R&D input and low innovation output: Sweden The paradox of high R&D input and low innovation output: Sweden 1". [14]

Calder, W. et al. (2021), *Fostering R&D intensity in Australia: Policy experiences and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [5]

Cincera, M. and R. Veugelers (2010), "Young Leading Innovators and EU's R&D intensity gap"*, JRC Working Papers on Corporate R&D and Innovation*, No. 2010-07, Joint Research Centre, Seville. [47]

Ciupagea, C. and P. Moncada Paternò Castello (2006), "Industrial R&D Investment: a Comparative Analysis of the Top EU and non-EU Companies Based on the EU 2004 R&D Scoreboard", *Revista de Economía Mundial*, Vol. 15, pp. 89-120. [46]

Corrado, C., C. Hulten and D. Sichel (2005), "Measuring Capital and Technology: An Expanded Framework", in Corrado, C., J. Haltiwanger and D. Sichel (eds.), *Measuring Capital in the New Economy*, University of Chicago Press, Chicago, IL. [33]

Deschryvere, M., K. Husso and A. Suominen (2021), *Fostering R&D intensity in Finland: Policy experiences and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [6]

Dosi, G. (1997), "Opportunities, Incentives and the Collective Patterns of Technological Change", *The Economic Journal*, Vol. 107/444, pp. 1530-1547, http://dx.doi.org/10.1111/j.1468-0297.1997.tb00064.x. [42]

Erken, H. and F. van Es (2007), "Disentangling the R&D shortfall of the EU vis-a-vis the US", *Jena economic research papers*, No. 2007-107, Max-Planck-Institut für Ökonomik und Universität Jena, https://www.econstor.eu/handle/10419/25681 (accessed on 10 February 2020). [44]

European Commission (2020), *European innovation scoreboard | Internal Market, Industry, Entrepreneurship and SMEs*, https://ec.europa.eu/growth/industry/policy/innovation/scoreboards_en (accessed on 22 April 2021). [36]

European Commission (2010), *EUROPE 2020: A strategy for smart, sustainable and inclusive growth (COM/2010/2020 final)*, EUR-Lex, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52010DC2020 (accessed on 13 February 2020). [2]

European Commission (2003), *Investing in research: An action plan for Europe, Communication from the Commission {SEC(2003) 489}, COM/2003/0226 final*, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52003DC0226R%2801%29. [1]

Galindo-Rueda, F. and F. Verger (2016), "OECD Taxonomy of Economic Activities Based on R&D Intensity", *OECD Science, Technology and Industry Working Papers*, No. 2016/04, OECD Publishing, Paris, https://doi.org/10.1787/5jlv73sqqp8r-en (accessed on 20 April 2021). [17]

Goreichy, E., F. Hafied and G. Roulleau (2021), *Fostering R&D intensity in France: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [7]

Griliches, Z. (1979), "Issues in Assessing the Contribution of Research and Development to Productivity Growth", *The Bell Journal of Economics*, Vol. 10/1, p. 92, http://dx.doi.org/10.2307/3003321. [30]

Grossman, G. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, The MIT Press, Cambridge, MA, https://mitpress.mit.edu/books/innovation-and-growth-global-economy (accessed on 29 April 2021). [28]

Guellec, D. and B. Van Pottelsberghe de la Potterie (2004), "From R&D to Productivity Growth: Do the Institutional Settings and the Source of Funds of R&D Matter?", *Oxford Bulletin of Economics & Statistics*, Vol. 66/3, pp. 353-378, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=565065 (accessed on 10 February 2020). [34]

Han, H. and Y. Lee (2021), *Fostering R&D intensity in Korea: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [11]

Harrison, R. and R. Griffith (2003), *Understanding the UK's poor technological performance*, The IFS, http://dx.doi.org/10.1920/bn.ifs.2003.0037. [18]

Hughes, I. (2021), *Fostering R&D intensity in Ireland: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [10]

Iorwerth, A. (2005), "Canada's Low Business R&D Intensity: the Role of Industry Composition", *Working Papers-Department of Finance Canada*, No. 2005-03, Department of Finance Canada. [45]

Larrue, P. (2021), "The design and implementation of mission-oriented innovation policies: A new systemic policy approach to address societal challenges", *OECD Science, Technology and Industry Policy Papers*, No. 100, OECD Publishing, Paris, https://www.oecd-ilibrary.org/fr/science-and-technology/the-design-and-implementation-of-mission-oriented-innovation-policies_3f6c76a4-en (accessed on 10 March 2021). [38]

Mathieu, A. and B. Van Pottelsberghe de la Potterie (2010), "A Note on the Drivers of R&D [22]

Intensity", *Research in World Economy*, Vol. 1/1, http://dx.doi.org/10.5430/rwe.v1n1p56.

Mohnen, P. (2019), *Disparities in R&D and innovation - Presentation at the meeting of the OECD Working Party on Innovation and Technology Policy, 10 December 2019*. [24]

Moncada Paternò Castello, P. (2016), "A review of corporate R&D intensity decomposition: Theoretical, empirical and policy issues", *JRC Technical Reports - IPTS Working Papers on Corporate R&D and Innovation*, No. 02/2016, Institute of Prospective Technological Studies, Joint Research Centre – European Commission, https://ec.europa.eu/jrc/sites/jrcsh/files/JRC101372.pdf (accessed on 10 February 2020). [23]

Moncada-Paternò-Castello, P. et al. (2010), "Does Europe perform too little corporate R&D? A comparison of EU and non-EU corporate R&D performance", *Research Policy*, Vol. 39/4, pp. 523-536, http://dx.doi.org/10.1016/j.respol.2010.02.012. [35]

OECD (2020), *Mapping Business Innovation Support (MABIS): OECD R&D tax incentives database, 2020 edition*, OECD, https://www.oecd.org/sti/rd-tax-stats-database.pdf (accessed on 21 April 2021). [40]

OECD (2020), *Mission Driven Top-Sector Policy*, STIP Compass - Mission-oriented innovation policies, https://stip-pp.oecd.org/stip/moip/case-studies/3?answerId=A1-3 (accessed on 30 April 2021). [25]

OECD (2016), *OECD Reviews of Innovation Policy: Sweden 2016*, OECD Reviews of Innovation Policy, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264250000-en. [15]

OECD (2015), *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development*, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264239012-en. [20]

OECD/Eurostat (2018), *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition*, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg, https://dx.doi.org/10.1787/9789264304604-en. [21]

Ortega-Argilés, R. and A. Brandsma (2009), "EU-US differences in the size of R&D intensive firms", *JRC Working Papers on Corporate R&D and Innovation*. [26]

Paunov, C. and S. Planes-Satorra (2021), "Science, technology and innovation in the time of COVID-19", *OECD Science, Technology and Industry Policy Papers*, No. 99, OECD Publishing, Paris, https://doi.org/10.1787/234a00e5-en (accessed on 14 February 2021). [41]

Paunov, C. and S. Planes-Satorra (2021), "What future for science, technology and innovation after COVID-19?", *OECD Science, Technology and Industry Policy Papers*, No. 107, OECD Publishing, Paris, https://doi.org/10.1787/de9eb127-en (accessed on 23 April 2021). [37]

Paunov, C. and S. Planes-Satorra (2019), "How are digital technologies changing innovation? : Evidence from agriculture, the automotive industry and retail", *OECD Science, Technology and Industry Policy Papers*, No. 74, OECD Publishing, Paris, https://dx.doi.org/10.1787/67bbcafe-en. [32]

Pianta, M. (2009), "Innovation and Employment", in *The Oxford Handbook of Innovation*, [43] Oxford University Press, http://dx.doi.org/10.1093/oxfordhb/9780199286805.003.0021.

Rae, J., J. Phipps and H. Bakhshi (2017), *The new UK R&D target: Why it's now time to move the measurement goalposts*, Nesta, https://www.nesta.org.uk/blog/the-new-uk-rd-target-why-its-now-time-to-move-the-measurement-goalposts/ (accessed on 17 April 2019). [19]

Rakic, R. et al. (2021), *Fostering R&D intensity in the European Union: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [3]

Romer, P. (1990), "Endogenous Technological Change", *Journal of Political Economy*, Vol. 98/5, pp. 71-102, https://ideas.repec.org/a/ucp/jpolec/v98y1990i5ps71-102.html (accessed on 11 October 2018). [27]

Sarul, J. (2021), *Fostering R&D intensity in Poland: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [13]

Schulz, S. (2021), *Fostering R&D intensity in Germany: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [4]

Sheehan, J. and A. Wyckoff (2003), "Targeting R&D: Economic and Policy Implications of Increasing R&D Spending", *OECD Science, Technology and Industry Working Papers*, No. 2003/8, OECD Publishing, Paris, https://dx.doi.org/10.1787/072772055603. [16]

Sóvágó, K. (2021), *Fostering R&D intensity in Hungary: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [9]

Spilioti, A. et al. (2021), *Fostering R&D intensity in Greece: Policy experience and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [8]

Stancik, J. and F. Biagi (2015), "Characterizing the evolution of the EU R&D intensity gap using data from top R&D performers", in Crespi, F. and F. Quatraro (eds.), *The Economics of Knowledge, Innovation and Systemic Technology Policy*, Routledge, Abington, UK, http://dx.doi.org/10.4324/9780203795071-13. [48]

Teurlinx, J. and P. Donselaar (2021), *Fostering R&D intensity in the Netherlands: Policy experiences and lessons learned. Case study contribution to the OECD - TIP project on R&D intensity*, https://community.oecd.org/community/cstp/tip/rdintensity. [12]

Ugur, M. et al. (2016), "R&D and productivity in OECD firms and industries: A hierarchical meta-regression analysis", *Research Policy*, Vol. 45/10, pp. 2069-2086, http://dx.doi.org/10.1016/j.respol.2016.08.001. [31]