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R&D productivity: Are ideas harder to find or does Europe suffer from a commercialisation gap?

HIGHLIGHTS

→ It has been a long-standing debate whether Europe suffers from an innovation gap.

→ Recent studies indicate a global decline in research and development (R&D) productivity across various sectors, raising concerns about the efficiency of innovation investments.

→ New panel data from the EU Industrial R&D Investment Scoreboard allow examining long-term relationships between firm productivity and R&D.

→ The results show that EU top R&D investors struggle more than their global counterparts to convert their R&D into new ideas and marketable products.

This policy brief discusses a global decline in research productivity and the extent of a European R&D commercialisation gap in comparison with other industrialised global regions.

WHAT IS THE ISSUE?

Concerns about EU R&D and innovation performance

In the political guidelines for the next European Commission, Ursula von der Leyen underscores the necessity of putting research and innovation at the heart of the European economy, emphasising that 'Europe cannot afford to fall behind and lose its competitive edge' ([1]).

This emphasis was also put forward in a recent report about the future of European competitiveness, in which Mario Draghi says that Europe is entering a period of major challenges ([2]). One of them is that Europe's productivity growth is slowing more than that of China and the United States, threatening its long-term standing as a leading industrialised region.

The Draghi report outlines that Europe suffers from an innovation gap relative to China and the United States because 'Europe is stuck in a static industrial structure with few new companies rising up to disrupt existing industries or develop new growth engines. In fact, there is no EU company with a market capitalisation over EUR 100 billion that has been set up from scratch in the last fifty years, while all six US companies with a valuation above EUR 1 trillion have been created in this period' (p. 6).

According to the Draghi report, only 4 of the world's top 50 tech companies are European. EU companies also lag behind in emerging technologies that

([1]) https://commission.europa.eu/document/download/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en?filename=Political%20Guidelines%202024-2029_EN.pdf, p. 6.

([2]) https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en.

promise high future growth, and tend to specialise in mature technologies with limited potential for breakthroughs. For the past two decades, Europe's top investors in R&D have been automotive companies, whereas in the United States the top positions have changed from automotive and pharma to ICT.

Recent debate about R&D productivity

At the same time, recent academic discussions have highlighted that while research efforts are rising substantially, research productivity is declining. This suggests that breakthrough ideas, crucial for (exponential) economic growth, are becoming harder to find (Bloom et al., 2020; Boeing and Hünermund, 2020; Goldin et al., 2024).

A well-known example relates to Moore's law: the number of researchers required in the 2020s to achieve the famous doubling of computer chip density is more than 18 times the number required in the early 1970s. While this example concerns a very specific technology, similar trends have been observed in other sectors, such as agriculture and health, according to Bloom et al. (2020). Their research indicates that this decline in research productivity is also evident across the entire US economy when analysing firm-level data on performance and R&D efforts from 1980 to 2015. Comparable firm-level patterns have also been found by Boeing and Hünermund (2020) for China and Germany, using data from 1992–2019.

Empirical approach

This brief presents an empirical analysis of the R&D productivity of the top 2 500 global R&D performers. If declining R&D productivity is particularly pronounced in mature sectors, where the bulk of EU top R&D performers operate, the EU's future competitiveness could be at risk. Such a trend would widen the R&D productivity gap between the EU and other global regions like China, Japan and the United States, making it increasingly difficult for Europe to invest sufficiently to realise (exponential) growth.

In order to measure the decline in research productivity as well as the commercialisation of R&D, two empirical research designs are implemented.

The first looks at whether ideas are harder to find, using patent data ([3]) as an indicator of valuable discoveries firms make through their R&D. A decline in R&D–patent elasticities ([4]) would suggest ideas are increasingly harder to find over time. This analysis is the first to estimate these elasticities for top global R&D performers, contributing to the debate on declining research productivity in industrialised regions.

These estimations are then compared with to R&D–labour-productivity elasticities ([5]). Comparing these results enables us to understand if a potential gap in research productivity between EU firms and their competitors is more pronounced in terms of R&D commercialisation (R&D–labour-productivity elasticities) or of transforming R&D into ideas (R&D–patent elasticities) ([6]).

ANALYSIS OF PATENTING AND LABOUR PRODUCTIVITY OF TOP 2 500 R&D PERFORMERS

Data

The EU Industrial R&D Investment Scoreboard (Scoreboard) has been monitoring the activities of the top corporate R&D investors worldwide for two decades. The Scoreboard firms account for 85 % to 90 % of worldwide R&D funded by the business sector. These firm-level data are used here to estimate R&D–patent elasticities as well as R&D–labour-productivity elasticities.

For this brief, all annual Scoreboards have been compiled into a firm-level panel of the global top

([3]) Patent data are a paper trail of discoveries that firms make and that they consider valuable enough to invest in obtaining intellectual property rights protection.

([4]) R&D–patent elasticities measure the relationship between a firm's investment in R&D and the number of patents it produces. Essentially, it tells us how much an increase in R&D spending translates into more patents. High R&D–patent elasticity means that extra spending on R&D leads to a significant increase in patent output, indicating efficient innovation processes. Conversely, low elasticity suggests that additional R&D investment results in fewer patents.

([5]) R&D–labour-productivity elasticities measure how changes in a company's investment in R&D affect its labour productivity, which is calculated as net sales per employee. In simple terms, it shows the extent to which increasing R&D spending boosts the productivity of each worker in terms of sales.

([6]) The work with the EU Industrial R&D Investment Scoreboard panel builds on prior studies that addressed corporate R&D investment (Moncada-Paternò-Castello et al., 2010, 2022) and R&D productivity (Aristovnik et al., 2023; Kancs and Siliverstovs, 2016; Montresor and Vezzani, 2015).

2 500 R&D performers from 2004 to 2022. As the members of the top 2 500 list vary over the years, the panel comprises a total of 3 846 different firms. The panel is unbalanced, resulting in 44 480 firm-year observations, supplemented with patent data from the PATSTAT database. In order to collect the patent data, a consolidated list of the Scoreboard companies and all their subsidiaries was matched with the records of patent applicants. Out of the 3 846 firms in the panel, 2 382 have at least one patent family (7).

The analysis aggregates data into five eras: (i) before the global financial crisis (2004–2007), (ii) the global financial crisis (2008–2010), (iii) after the financial crisis (2011–2015), (iv) before the COVID-19 pandemic (2016–2019) and (v) the COVID-19 pandemic (2020–2022).

Descriptive analysis

This section provides a descriptive analysis of the top 2 500 global R&D performers, highlighting differences in firm size, R&D investment, patenting activities and labour productivity across regions and over time (8).

Table 1 shows the average firm size in terms of employees in the top 2 500 performers. EU firms have on average the highest number of employees among the five global regions that are considered. The United States has on average the lowest number of employees in this sample.

Table 1 – Average employment per firm across regions and time

Region	Before financial crisis	Global financial crisis	After financial crisis	Before COVID-19	COVID-19 pandemic
China		19 223	15 666	17 027	18 573
EU	27 297	28 656	29 046	29 862	31 396
Japan	8 589	13 004	15 595	20 048	20 852
ROW	20 048	21 983	23 870	21 902	25 308
US	11 651	11 728	12 457	12 619	13 308

NB: Employment is measured in headcounts. ROW, rest of world.
Source: EU Industrial R&D Investment Scoreboard.

When the firm size is contrasted with the average R&D spending, a different picture emerges. As Table 2 shows, the firms from the United States spent by far the most on R&D in recent years.

Although the EU was still leading in the time before the financial crisis, with EUR 197 million versus EUR 176 million in the United States, the United States passed the EU during the financial crisis, and this gap has widened since then. In the most recent period in the data, the COVID-19 pandemic, the United States was leading, with EUR 358 million compared with EUR 255 million in the EU. Firms located in the rest of the world (ROW), among them South Korea, Switzerland, Taiwan and the United Kingdom, rank second, with EUR 257 million, followed by the EU, and then Japan with EUR 222 million and China with EUR 157 million.

Table 2 – Average R&D investment per firm across regions and time (million EUR)

Region	Before financial crisis	Global financial crisis	After financial crisis	Before COVID-19	COVID-19 pandemic
China		47	57	97	157
EU	197	191	209	242	255
Japan	77	121	153	192	222
ROW	117	148	172	223	257
US	176	218	237	291	358

NB: R&D is measured in inflation-adjusted (real) values.
Source: EU Industrial R&D Investment Scoreboard.

Table 3 shows patented inventions, which we use as a proxy for ideas. Instead of considering mere patent counts, inventions are only counted if they are filed as a patent family in at least two of the large global intellectual property (IP) offices (USPTO, EPO, JPO, KIPO, CNIPA). If an invention is only sought to be protected in one single national patent office, it is thus not counted. This avoids bias in counting inventions if, for example, firms in one country tend to protect every marginal discovery in their home country but refrain from protecting it internationally because the invention is possibly not considered to be worth the effort.

As patent data are recorded in the database only with a considerable time lag (patent applications are only published after 18 months), the patent analysis can only cover 2004–2019.

As can be seen in Table 3, Japanese top R&D performers file by far most patent families across all time periods. The reason is the patenting behaviour of Japanese firms: it is known that Japanese firms

(7) In this study, 'patent family' refers to inventions filed in at least two of the five major patent offices (USPTO, EPO, JPO, KIPO, CNIPA). 38 % of our firms do not have patent families due to the varying patenting propensities across sectors.

(8) Some outliers showed exceptionally large changes in R&D and labour productivity across time within the firm and were removed.

file a patent for each discovery separately, in other words many patents contain a single claim. In other countries, patents most often contain multiple claims that belong to the same invention. Given these differences, it is preferable to compare changes in patenting over time rather than to compare the levels of patenting across regions.

Table 3 – Average number of patented inventions per firm across regions and time

Region	Before financial crisis	Global financial crisis	After financial crisis	Before COVID-19
China		5	6	12
EU	44	42	40	37
Japan	73	90	101	114
ROW	22	22	28	29
US	39	39	32	28

NB: Patenting activity is measured as the number of patent families, that is, the number of inventions (not just patent documents) that have been filed with a least two of the five large global patent offices (USPTO, EPO, JPO, KIPO, CNIPA).
Source: EU Industrial R&D Investment Scoreboard.

It is a striking observation that firms in China, Japan and the ROW filed more patent families over time, but the patent filing rates from EU and US firms fell. In the EU, the average firm among the top R&D performers filed patents for 44 inventions per year before the financial crisis, but this number reduced to 37 in the period before the COVID-19 pandemic. In the United States, the reduction is even larger, from 39 to 28 patents.

Finally, Table 4 compares labour productivity, measured as sales per employee in millions of euro, adjusted for inflation. EU top R&D performers have maintained relatively low labour productivity since the early 2000s, increasing from EUR 280 000 before the financial crisis to EUR 330 000 during the COVID-19 pandemic. Only Chinese firms show lower labour productivity. Before the financial crisis, Japanese firms had the highest labour productivity, but it has declined since then. Since the period before the COVID-19 pandemic, firms in the ROW and the United States have shown the highest labour productivity.

Table 4 – Average sales per employee across regions and time (million EUR)

Region	Before financial crisis	Global financial crisis	After financial crisis	Before COVID-19	COVID-19 pandemic
China		0.22	0.17	0.20	0.25
EU	0.28	0.30	0.31	0.31	0.33
Japan	0.54	0.38	0.39	0.34	0.37
ROW	0.37	0.35	0.38	0.40	0.40
US	0.37	0.39	0.38	0.37	0.38

NB: The numbers show the average sales per employee, transformed into inflation-adjusted (real) values.
Source: EU Industrial R&D Investment Scoreboard.

Econometric analysis: are ideas harder to find?

The subsequent econometric analysis, in Table 5, relates the relationship between firms' R&D investments and their patenting activities as a measure of generating new ideas, showing estimated R&D–patent elasticities ([9]). Two main results emerge.

First, firms in the EU have rather low R&D–patent elasticity. A reason for this could be the fact that the EU firms are mostly active in rather mature sectors, where it is difficult to make new discoveries compared with more dynamic sectors. In the final period for which patent data are available (2016–2019), the EU companies show the lowest R&D–patent elasticities with only 15 %. The US companies achieve 18 %, Japan 28 % and the ROW 30 %. Chinese companies show the highest R&D–patent elasticities, at 61 %, although their overall patenting rates remain low (see Table 3), making it comparatively easier to achieve high elasticities with increased R&D investments.

The second main result is that ideas indeed seem to be harder to find. All regions suffer from declining R&D–patent elasticities. The EU and the United States experience the largest reductions, – 24 % and – 26 % respectively. In contrast, the decline was less severe in the ROW (– 18 %), Japan (– 12 %) and China (– 2 %). These are alarming trends for the EU and the United States. This suggests that firms in other regions may be more successful in shifting their R&D activities to sectors or fields where new discoveries are more feasible.

([9]) The R&D–patent elasticities were estimated using quasi-maximum-likelihood Poisson models with firm-level fixed effects. The firms' patent family filings have been regressed on the R&D investment and have been interacted with five time dummies. The models account for common macroeconomic trends.

Table 5 – Estimated R&D–patent elasticities across regions and time

Region	Before financial crisis	Global financial crisis	After financial crisis	Before COVID-19	Change 2004 (*) to 2019 (%)
China		0.62	0.58	0.61	– 2
EU	0.19	0.20	0.16	0.15	– 24
Japan	0.32	0.33	0.29	0.28	– 12
ROW	0.37	0.36	0.33	0.30	– 18
US	0.25	0.24	0.20	0.18	– 26

NB: The numbers are estimated R&D–patent elasticities. They should be interpreted as follows: if EU firms had increased their R&D by 100 % (i.e. doubled their expenditure) in the period before the financial crisis, they would have obtained 19 % more patents. All coefficient estimates of the R&D variables are statistically significant at the 5 % level. *F*-tests on coefficient differences within each region across time show that the downward trends are also statistically significant at the 5 % level except in China. Further *F*-tests reveal that the differences between regions are statistically significant in each period.
(*) For China, the relative change in elasticities is calculated from 2008 to 2019 because of lacking data in the earlier years.
Source: EU Industrial R&D Investment Scoreboard.

Econometric analysis: the commercialisation of R&D

This section examines the relationship between firms' R&D efforts and their commercial performance, measured by labour productivity (i.e. sales per employee) ([10]).

Table 6 shows that the EU has always been lagging behind the United States and China in successfully commercialising R&D. Before the financial crisis, EU firms achieved elasticity of 17.3 %, compared with 21.5 % in the United States. The EU elasticity declined to about 15 % during the COVID-19 pandemic, compared with 20 % in the United States. China achieved the highest R&D–labour-productivity elasticity, with a potential 24 % increase in labour productivity if R&D spending doubled. These higher elasticities in China can be explained by the lower levels of R&D. Given that there are decreasing marginal returns on R&D, since Chinese firms still invest less than the average EU or US firm, the outcomes are more responsive in relative terms.

The decline in R&D–labour-productivity elasticity becomes very evident when the elasticities are compared between the first and last periods covered with the sample. EU firms experienced a 13 % decline, while Japan and the ROW saw even larger decreases of 22 % and 18 % respectively. China and the United States faced smaller declines of 8 %.

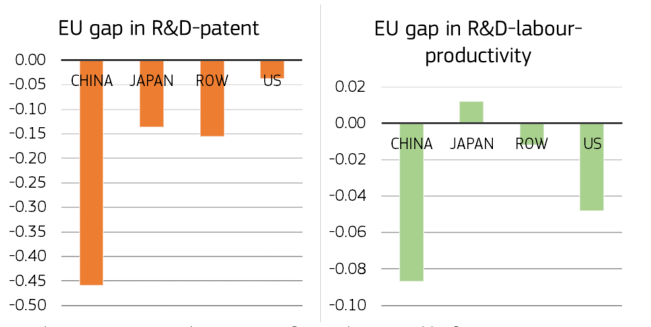
Table 6 – Estimated R&D–labour-productivity elasticities across regions and time

Region	Before financial crisis	Global financial crisis	After financial crisis	Before COVID-19	COVID-19 pandemic	%-change 2004 (*) to 2022 (%)
China		0.26	0.24	0.24	0.24	– 8
EU	0.17	0.17	0.18	0.16	0.15	– 13
Japan	0.18	0.15	0.16	0.15	0.14	– 22
ROW	0.20	0.19	0.19	0.17	0.16	– 18
US	0.22	0.22	0.22	0.21	0.20	– 8

NB: The numbers are estimated R&D–labour-productivity elasticities. They should be interpreted as follows: if EU firms had increased their R&D by 100 % (i.e. doubled their expenditure), in the period before the financial crisis, they would have achieved 17.3 % higher labour productivity. All coefficient estimates of the R&D variables are statistically significant at the 5 % level. *F*-tests on coefficient differences within each region across time show that the downward trends are also statistically significant at the 5 % level except in China. Further *F*-tests reveal that the differences between regions are statistically significant in each period except the first one.
(*) For China, the relative change in elasticities is calculated from 2008 to 2022 because of lacking data in the earlier years.
Source: EU Industrial R&D Investment Scoreboard.

Figure 1 illustrates the EU's current gap in both R&D–labour-productivity and R&D–patent elasticities compared with other regions. It indicates that EU firms are currently less efficient than their global counterparts in converting R&D efforts into patents and labour productivity gains. The EU exhibits negative gaps in both specifications with all regions except Japan in the context of R&D–labour-productivity elasticity. The largest gap is with China in both specifications.

Figure 1 – Estimated EU innovation gap in the latest available period for R&D–labour-productivity and R&D–patent elasticities (percentage points)



NB: The R&D–patent elasticities refer to the period before COVID-19, whereas the R&D–labour-productivity elasticities refer to the COVID-19 period.
Source: EU Industrial R&D Investment Scoreboard.

The current large EU gap in R&D–patent and R&D–labour-productivity elasticities, combined with the decline in both elasticities over time, suggests a

([10]) In order to obtain the R&D–labour-productivity elasticities, linear fixed effects within regressions have been estimated at the firm level. The firms' logarithms of labour productivity have been regressed on their R&D stocks (obtained with the perpetual inventory method from annual R&D expenditure) that have been interacted with five time dummy variables. The models account for common macroeconomic trends and heterogeneity in firm size.

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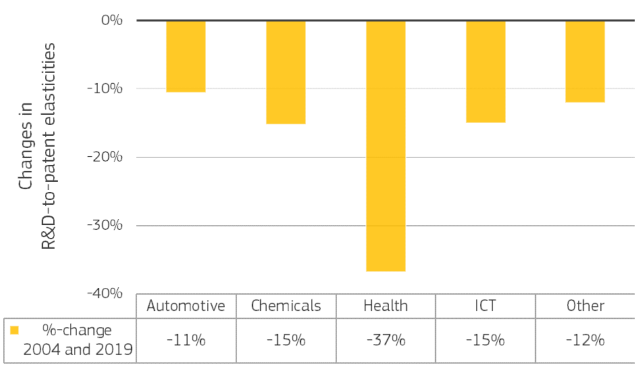
challenging future for EU innovation performance. EU firms not only lag behind the United States and other regions in generating new ideas and commercialising R&D, but are also facing significant declines in these areas over time. While the declines in new ideas are comparable in the EU and the United States (– 24 % vs – 26 %), the loss of R&D commercialisation in terms of labour productivity of R&D is worse in the EU than in the United States (– 13 % vs – 8 %).

Econometric analysis: sectoral decomposition

The final analysis of this brief investigates R&D elasticities across four main sectors: automotive, chemicals, health and ICT, with other sectors grouped as 'other'.

Figure 2 shows the estimated decline in R&D–patent elasticities across sectors between 2004 and 2019. The total decline is largest in the health sector, at – 37 %. This can be explained by the fact that a large part of the health sector is pharmaceutical products ([11]). The process of discovering new drugs has become very difficult over the years, as drugs are what are called discrete technologies: a discovery typically leads to a patent and that often equals a product, namely a new drug. In complex industries, in contrast, products may consist of hundreds of patented ideas, and therefore improvements can be made more easily in relative terms. The remaining three sectors also suffer from falling research productivity: automotive by – 11 %, chemicals – 15 %, ICT – 15 % and other – 12 %.

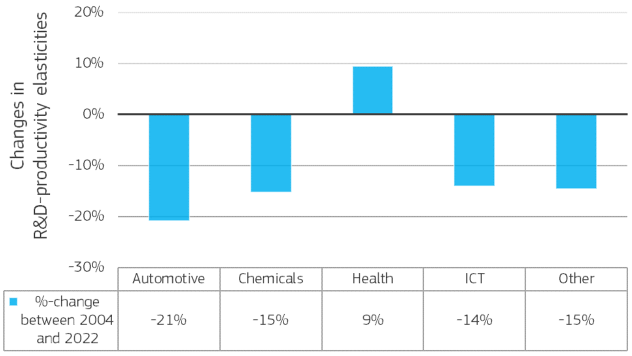
Figure 2 – Estimated total decline in R&D–patent elasticity across sectors, 2004–2019 (*) (%)



(*) The first observation from China is from 2008 instead of 2004 because of data availability.
Source: EU Industrial R&D Investment Scoreboard.

Similarly, Figure 3 shows the development of the estimated R&D–labour-productivity elasticities between 2004 and 2022. Remarkably, the health sector realised a moderate increase of 9 % in elasticity. This may be partly due to the COVID-19 pandemic, in which certain segments of the health sector boomed. At the same time, the results show a strong decline (– 21 %) in automotive, in which EU firms are strong. The ICT, chemicals and other sectors show smaller declines in R&D–labour-productivity elasticity (between – 14 % and – 15 %)

Figure 3 – Estimated total decline in R&D–labour-productivity elasticity across sectors, 2004–2022 (*) (%)



(*) The first observation from China is from 2008 instead of 2004 because of data availability.
Source: EU Industrial R&D Investment Scoreboard.

DISCUSSION

The detailed data analysis of the world's top R&D performers shows that EU firms are struggling to translate their R&D into new ideas and marketable products, compared with other global regions.

R&D productivity in terms of patents has been falling globally, but most strongly in the United States and the EU. Coupled with the EU's persistent weakness in transforming its R&D into commercially successful product innovations, as the estimated R&D–labour-productivity elasticities show, that seems to warrant urgent policy action to bring the EU back on a growth path that secures its long-term global competitiveness.

A particularly concerning finding from our sectoral analysis is that automotive firms have experienced the largest decline in R&D–labour-productivity elasticity. This is especially troubling given that the automotive sector has been a stronghold for EU firms as R&D leaders over the past 20 years. Given the current paradigm shifts affecting the sector, for which

([11]) The decline in R&D productivity has been studied intensely in the pharmaceutical sector; see for example Pammolli et al. (2011) or Schuhmacher et al. (2023).

EU companies may not be adequately prepared ([12]), without significant policy actions the outlook for the EU automotive industry – and consequently for EU innovation – appears bleak.

However, it is not obvious what policy actions are the most promising instruments to achieve higher growth and to close the innovation gap with China and the United States. Among other recommendations, the EU should make an effort to position universities and research institutions at the frontier of academic excellence, and make it easier for researchers to commercialise their ideas. In addition, scaling-up after commercialisation should be facilitated better. Achieving these goals may involve developing more robust and integrated financial and venture capital markets ([13]). Also, as von der Leyen's policy guidelines and the Draghi report point out, making business easier and deepening the single market by reducing bureaucratic hurdles that currently restrict goods, services, money and people from moving freely across the EU Member States can be expected to strengthen the EU's innovation competitiveness.

Despite the significant policy challenges ahead, some initiatives have been implemented that promise improvements in the European innovation ecosystem.

The convention on a European patent took more than 30 years to become effective, but on 1 September 2024 the European unitary patent was finally born. Since then, companies have been able to obtain patent protection in 18 Member States (not in all 27 yet) with a single filing at the European Patent Office, streamlining a process that previously required activation in each national office individually. Expanding the IP protection of the European unitary patent to all 27 Member States would promise even more improved IP management in Europe.

Furthermore, the EU has implemented policy reforms that allow the strengthening of demand-side policies for innovation. Revised public procurement directives (Directives 2014/24/EU and 2014/25/EU) adopted by the European Parliament and Council in 2014 encourage public procurers to issue tenders that include functional and performance-based specifications in order to promote innovation (Directive 2014/24/EU, recital 74). These directives also allow for the consideration of innovative features and life-cycle costs in procurement decisions, establishing a legal framework that improves the chances of selecting innovative products and services in procurement auctions. The adoption of these rules constituted a major milestone in removing obstacles to using public procurement as an effective policy tool for innovation. By reinforcing the use of these demand-side policies, governments, as significant purchasers, can drive the development of new products, services and technologies, thereby accelerating the implementation and dissemination of innovations through procurement contracts (Czarnitzki et al., 2020).

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