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Europe's Middle-Technology Trap

KEY MESSAGES

- **The Lisbon strategy of the year 2000 failed: the share of R&D spending in Europe remains below the 3 percent of GDP target, far behind that of the US and China**
- **EU companies spend much less on R&D than their US peers and concentrate their innovation activities on midtech instead high-tech industries. Mid-tech sectors, however, tend to have lower growth rates and generate incremental innovations rather than large, disruptive ones**
- **Consequently, Europe currently lags in high-tech sectors (IT hardware, software, biotechnology, pharmaceuticals) and is losing ground to the US in terms of productivity, competitiveness, and economic growth**
- **EU funding for innovation is too small and needs reforms to focus more on disruptive leap innovations that foster business dynamics**

Research and development (R&D) are key drivers of innovation and, consequently, of future productivity and competitiveness of national economies. This is particularly true when these activities produce disruptive innovations that foster the emergence of new high-tech industries and the dissemination of key technologies. Innovations are crucial for addressing major societal challenges, such as climate change, the decarbonization of the economy, health issues, and demographic change. In Europe, however, innovations are occurring less frequently in emerging fields like artificial intelligence, being instead more driven by engineering expertise in established sectors such as the automotive industry. Europe is stuck in a Middle-Technology-Trap,[1] in which R&D investment is geared towards established sectors. Despite the inherent uncertainty regarding which sectors will drive future growth, there are indications that these established sectors may no longer be among the primary growth engines.

EU SPENDS LITTLE ON RESEARCH AND DEVELOPMENT

A common input-oriented measure of innovation activities and the future competitiveness of a country or economic area is total R&D spending. The so-called 3 percent target of the Lisbon Strategy in 2000, according to which 3 percent of gross domestic product (GDP) was to be spent on research and development by 2010 to increase EU competitiveness, has not yet been achieved. In the EU, R&D expenditure by the private and public sectors was 2.2 percent of GDP in 2021, while in the US it was 3.5 percent, more than 50 percent higher relative to economic strength. In absolute terms, R&D expenditure in the US (EUR 730 billion in 2021) was more than twice the EU's (EUR 322 billion), with the gap widening over time (Figure 1). Italy and Spain, for example, invest comparatively little in R&D, with less than 1 percent of GDP at the end of the 1990s. By 2021, however, both countries managed to increase their R&D expenditure to almost 1.5 percent of GDP. France was in line with the EU average in 2021, at 2.2 percent of GDP. Germany, in turn, with total (private and public) R&D expenditure of around 3.1 percent of GDP in 2021, is in a comparatively good position compared to other EU countries. However, it still does not meet the target set by the German government in its current High-Tech Strategy 2025, which aims to increase total R&D expenditure by the private and public sectors to 3.5 percent of GDP by that year.

Clearly, European countries are losing ground to the US in terms of R&D spending and innovation ef-

[1] The article is partly based on the policy report by Fuest et al. (2024); see also Dietrich et al. (2024).

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forts. Furthermore, China has continuously and visibly increased its R&D expenditure over the past 25 years, from less than 0.6 percent of GDP in 1995 to 2.4 percent in 2021, quickly outpacing the EU's innovation efforts. Japan's R&D investment has outstripped the EU's for decades, standing at 3.3 percent of GDP in 2021, and was only overtaken by the US in 2020 (Figure 1).

Differences become more relevant by looking at the composition of R&D spending. While the share of public spending on research and development relative to GDP is similar in the EU and the US, the differences mainly arise because European companies invest less than US ones, with the EU share of 1.2 percent of GDP only about half that in the US (2.3 percent of GDP). Meanwhile, US companies account for 67 percent of R&D expenditure in their country, against 57 percent for companies in the EU.

EU COMPANIES FOCUS ON MIDDLE-TECHNOLOGY

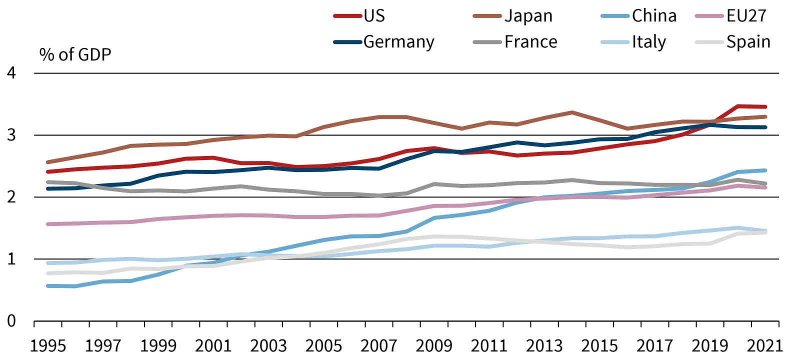
Innovation activities in the EU and the US differ not only in terms of R&D expenditure, but also in terms of the technology fields on which they focus their investments. Private R&D expenditure in the EU is concentrated in so-called mid-tech industries, which include cars and industrial machinery, chemicals or telecommunications systems, as the sectoral composition of business R&D expenditure (BERD) shows (Figure 2), with the automotive sector spending the most on research and development among all sectors. In contrast, US companies focus 85 percent of their R&D expenditures on high-tech industries, particularly in the fields of software and computer services, as well as pharmaceuticals and biotechnology. In the EU, private-sector expenditure is evenly split, at 45 percent each, between in high-tech and mid-tech industries. The sectoral composition of business R&D expenditure by EU-headquartered firms is more similar to that of Japan and China than that of the US. Interestingly, German companies spent roughly as much on R&D as all the companies in the rest of the EU combined, with the share of mid-tech industries even higher, at 57 percent (high-tech share: 36 percent; others: 7 percent). That said, private R&D spending in Germany concentrates on the automotive industry, while companies from other EU countries invest comparatively more in the pharmaceutical industry and other high-tech sectors. This concentration on the automotive sector represents a major risk for the resilience of the German economy and could explain some of its recent structural problems.

Some may argue that the EU's focus on mid-tech is not a problem, since the sectoral composition of R&D spending in different economies could simply reflect an efficient international division of labor in which the EU focuses on its comparative advantages. At the same time, however, it should be noted that the sectors classified as high-tech have been growing faster than the mid-tech ones for many years (see below for a detailed discussion).

Figure 1

Gross Expenditure on Research and Development

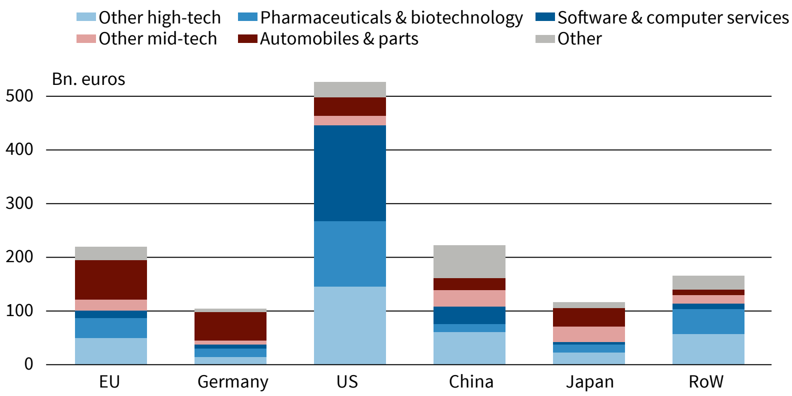
National private and public expenditure on R&D



Source: OECD. © ifo Institute

Figure 2

Private Sector R&D Expenditure (Berd) by Tech Level (Top 2,500 Companies)



Source: EU Industrial R&D Scoreboard 2023. © ifo Institute

PATENT ACTIVITY: LOWER INNOVATION OUTPUT IN EUROPE

R&D expenditure is not the only measure of countries' investment efforts to foster innovation: another yardstick is patent activity, which is more likely to be seen as the output of these efforts. In this regard, the trend points to Europe falling behind the US and China in

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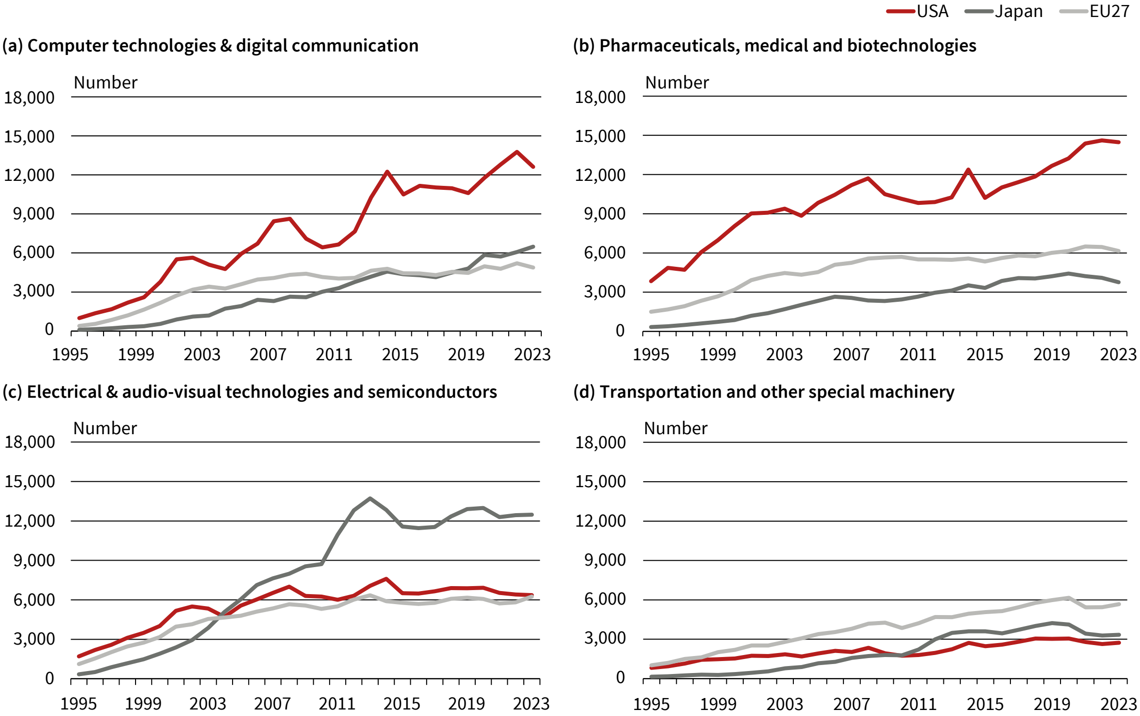
Figure 3

International Patent Applications by Technology Field



Note: Panel (a) summarizes PCT applications in the WIPO technology fields "Computer technology" and "Digital communication" (share of all PCT applications: 15.1 % in 2010, 19.6 % in 2023). Panel (b) summarizes PCT applications in the WIPO technology fields "Medical technology", "Pharmaceuticals" and "Biotechnology" (share: 16.3 % in 2010; 15.0 % in 2023). Panel (c) summarizes PCT applications in the WIPO technology fields "Electrical machinery, apparatus, energy", "Audio-visual technology", "Semiconductors", and "Optics" (share: 18.7 % in 2010, 17.7 % in 2023). Panel (d) summarizes PCT applications in the WIPO technology fields "Transport" and "Other special machines" (share: 7.7 % in 2010, 6.7 % in 2023).
Quelle: WIPO.

recent years, and that Europe's innovation efforts – again – are mainly focused on mid-tech industries.

In 2023, around 270,000 Patent Cooperation Treaty (PCT) applications[2] were filed with the World Intellectual Property Organization (WIPO) from all over the globe. China filed the most applications, with just under 70,000, followed by the US (55,700), Japan (48,900) and the EU27 (46,500), with all four accounting for over 80 percent of global patent applications. The number from China has risen rapidly since 2010 and continues to show very high growth rates. However, this could be partly due to government subsidies for patent applications (Prud'homme 2012). In some cases, moreover, quantity certainly outweighs quality (USPTO 2021). For this reason, the figures for China need to be taken with caution. Since it is not possible to disentangle the real from subsidy-induced Chinese patent activity, we concentrate the further analysis of patent data by technology field for the EU, US and Japan. Each region tends to specialize in a different technology field.

European countries are not at the forefront of patent applications[3] in high-tech sectors. In 2023, most PCT applications were published in the field of computer technology, followed by applications for new patents in the digital economy, mainly by applicants from the US (Figure 3a).[4] These two high-tech sectors, which are regarded as indicators of future growth and competitiveness, together accounted for around 20 percent of all PCT applications in 2023 (2010: 15 percent), with their PCTs growing the fastest compared to other fields since 2010, at rates of more than 10 percent . On average, the number of published PCT

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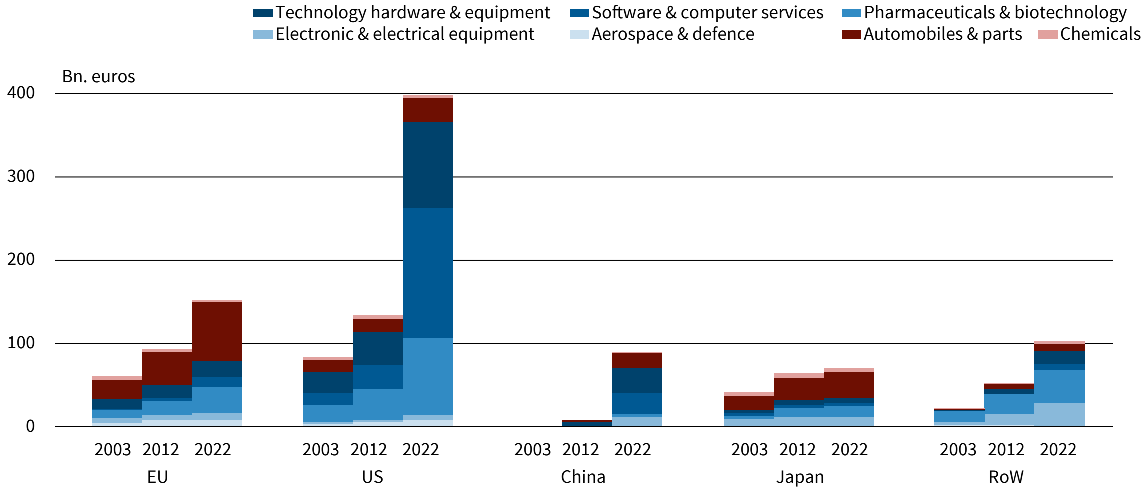
[2] If the patent is accepted in the so-called "international phase," applicants in so-called "national phases" can (but do not have to) simultaneously seek patent protection for their invention in a large number of countries, so that it de facto becomes an "international" patent. Further information can be found at https://www.wipo.int/portal/en/index.html. Statistical database of the WIPO; https://www3.wipo.int/ipstats/pmh-search/pct.

[3] WIPO assigns the PCT applications to 35 fields of technology based on the International Patent Classification (IPC). For confidentiality reasons, data on PCT applications by technology field is only available after publication (after 18 months of examination in the so-called "international phase").

[4] More than 30 percent of Chinese PCT applications in 2023 were in computer and digital technologies. Together with more than 20 percent in electrical, audio-visual and semiconductor technologies, more than half of the strong increase in Chinese innovation output can be attributed to these technology fields.

Figure 4

Private Sector R&D Expenditure (Top 500 Companies)



Source: EU Industrial R&D Scoreboard. © ifo Institute

applications has increased by around 5 percent per year since 2010. However, Europe has missed the boat in the past two decades when it comes to the growth drivers of the computer and digital economy. On the contrary, Europe has hardly seen any growth in patent applications. The situation is similar in the EU in terms of patent applications in the high-tech sectors of medical technology, pharmaceuticals and biotechnology. Although Europe has recorded slight growth here in recent years, the US has held the top position by a growing margin for decades (Figure 3b). Patents in the healthcare and pharmaceutical industries account for a solid 15 percent of PCT applications. Together with the other high-tech sectors of the computer and digital economy, this amounted to around 35 percent of all published PCT applications in 2023.

While the US has become more specialized in its patent applications in computers and digital communications over the past two decades, Japan has built up a clear lead over the US and the EU in PCT applications in the technology fields of electrical (7.9 percent) and audio-visual (3.6 percent) machines and devices, as well as optical (2.7 percent) and semiconductor (3.5 percent) technologies (Figure 3c). Together, these technology fields account for almost 18 percent of international patent applications and are therefore of great importance. In contrast, the increase in the number of international patent applications in the EU occurred in the field of transportation, which also includes the automotive industry, as well as in "other special machinery," clearly expanding its lead in the field (Figure 3d). Germany alone is already on a par with the US and Japan in the transport technology and special machinery fields. Still, the technology fields in which Europe leads in patent applications tend to be mid-tech, which accounted for only 6.7 percent of PCT patent applications in 2023 (2010: 7.7 percent).

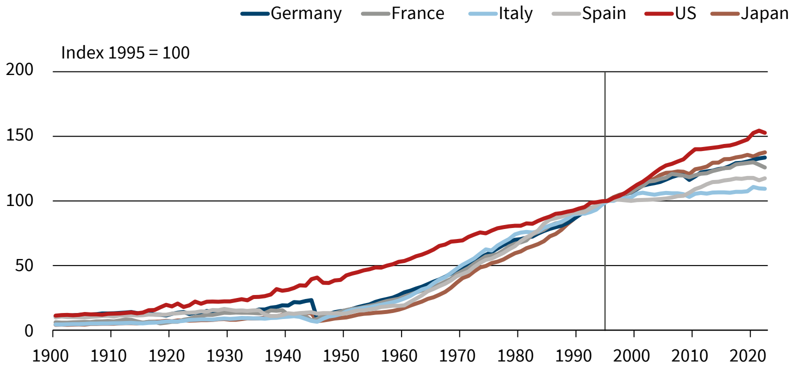
PATH DEPENDENCE IN EUROPE

While private R&D spending has almost doubled in the EU over the past two decades, it has quadrupled in the US. The sharp rise in private-sector R&D expenditure in the US is driven by high-tech sectors, particularly software (Figure 4), which accounted for a large fraction of the strong US growth in private R&D spending between 2012 and 2021. Similarly, China appears to be pursuing a strategy of concentrating its R&D efforts on high-tech sectors rather than mid-tech ones. China's private-sector expenditure reached the same level as Europe in the high-tech industries already in 2022. In Europe, by contrast, there has been almost no change in the sectoral distribution of private sector R&D expenditure over the past 20 years. In 2003, two of the three top US R&D spenders were in the automotive industry, but this changed over time. The software industry (ICT services and producers) became more and more important over the years; by 2022, all top-3 spenders are software companies

Figure 5

Long-term Development of Labor Productivity

Productivity per hour worked



Source: Longterm-Productivity Database 2024. © ifo Institute

Table 1

Top-3 R&D Spenders by Region and Their Industries Compared over Time

	2003	2012	2022
US	Ford (auto) Pfizer (pharma) General Motors (auto)	Microsoft (software) Intel (hardware) Merck (pharma)	Amazon (software) Alphabet (software) Meta (software)
EU	Mercedes (auto) Siemens (electronics) VW (auto)	VW (auto) Mercedes (auto) Bosch (auto)	VW (auto) Mercedes (auto) Bosch (auto)
Japan	Toyota (auto) Panasonic (electronics) Sony (electronics)	Toyota (auto) Honda (auto) Panasonic (electronics)	Toyota (auto) Honda (auto) NTT (telecom)

Note: Amazon does not report R&D investment, but only a combined figure for "Technology and Content" investment in its accounts. Since no information is given on how to extract the R&D component, Amazon is not listed in the EU Industrial R&D Investment Scoreboard. However, using statements in Amazon's accounts it is estimated that Amazon's R&D is likely larger than Alphabet's. That is why Amazon should probably have been #1 in the R&D ranking.

Source: EU Industrial R&D Investment Scoreboard (2023); ifo Institute.

(Table 1). In fact, the top-5 in worldwide R&D investment are from the US and all belong to the software and ICT industry: Amazon, Alphabet, Meta, Microsoft, Apple.[5] The following comparisons also shows how dominant the US is in terms of private-sector R&D spending. In 2022, Meta (rank 3) alone spent more on research and development as the top-50 companies in France; in fact, based on company figures, it can be assumed that Amazon even spent more on R&D than the total (private and public) R&D expenditure of the second-largest European economy.

In the EU and Japan, the automotive industry dominated throughout the 20-year period. These patterns are consistent with the literature on path dependency of innovation and industrial specialization in developed economies (e.g., Acemoglu 2023). Around half of private-sector R&D in the EU flows into the mid-tech industry, particularly the automotive industry, and half into the high-tech industry. One could argue that the delimitation of industries is problematic in that there has been a strong build-up of IT within the European automotive industry, for example among German carmakers (see Falck et al. 2023).[6] However, German carmakers keep making headlines with their IT problems, especially in the context of the switch to electric vehicles.

Comparative Advantage of the EU Automotive Industry Is Dwindling

European companies are leaders in the automotive industry, while the US dominates in the software industry. However, the EU is much less dominant in the automotive industry than the US is in the software industry. In 2022, US companies accounted for around three quarters of all global R&D expenditure in the software sector, compared to the EU companies' 6 percent share. EU companies, on the other hand, accounted for 45 percent of the global R&D expenditure in the automotive industry, while Japan, the US, and other regions contributed just below 20 percent each. While the EU still enjoys a comparative advantage over other regions in car manufacturing, it runs the risk of losing its competitive edge as the world moves from the internal combustion engine towards electric vehicles, and ultimately being overtaken by the US and China.

Middle-Technology Trap

There are inherent risks in focusing R&D efforts on incremental improvements to mature technologies, such as in the automotive industry, since such industries offer limited potential for high, sustainable growth. Fostering innovation in high-tech sectors, in contrast, offers significantly higher growth potential. Revenues and profits in the high-tech sectors have grown much faster than in other sectors in all major economic regions – the EU, US, Japan, and China – over the past 20 years. Mid-tech industries had lower profit margins than high-tech ones in all the world regions.

Between 2020 and 2022, the profit margin was on average 5.5 percentage points lower in the EU than in the US. However, the transatlantic difference in profit margins was even larger for high-tech industries (6 percentage points) than for mid-tech ones (less than 2 percentage points). Still, the incentive to transition from mid- to high-tech sectors should not be measured by the transatlantic gap, but by the difference in profitability within each region. Europe's incentive to move up the tech ladder was much lower, with high-tech profit margins being only about 3 percentage points higher than mid-tech ones, whereas in the US the difference between high-tech and mid-tech industries was about 7 percentage points.

High-tech revenue in the US exceeded that of mid-tech sectors in 2015. In the EU, Japan, and China, in contrast, it was mid-tech companies that generated the largest share of revenue in the economy. The share of R&D expenditure in the revenue of high-tech industries has risen from 8 percent to 13 percent in the US over the past 20 years, while it has remained at around 9 percent in the EU over the same period. China shows a similar pattern to the US, while Japan is more similar to the development in the EU. In contrast, R&D expenditure as a share of revenue in mature technologies (mid-tech industries) has remained constant at around 3 percent in all regions of the world for 20 years (including some minor fluctuations). This suggests that R&D intensity in established mid-tech industries is not significantly influenced by region-specific factors and that the constancy is possibly due to the maturity of the technologies in these industries. Following the reasoning that the persistent concentration of EU companies on established mid-tech technologies is problematic, one may argue that Europe is caught in a "middle technology trap."

[5] Half of the world top-50 private companies in R&D investments are from the US, 12 are from the EU.

[6] The same applies to the development of skills and innovation with green technologies in industry (Falck and Kaura 2023).

EU LOSES COMPETITIVENESS

High levels of investment in fast-growing high-tech sectors in the US correlate with an increasing economic disparity between the US and the EU. This is starkly illustrated by the fact that none of the newly established, world-leading technology companies come from Europe. This disparity also becomes clear when looking at the development of labor productivity (Figure 5). By the mid-1990s, EU countries had been catching up with the US. Labor productivity in the major EU countries – Germany, France, Italy, and Spain – rose more strongly than in the US after the end of the Second World War and had reached the same level of productivity per hour worked before the turn of the millennium. However, this trend has since reversed, with the EU falling behind the US once again. In the US, labor productivity has increased more strongly since the turn of the millennium than before. Over the same period, growth in the four major Eurozone countries has slowed. Between 1995 and 2022, labor productivity rose by almost 53 percent in the US, but only by 34 percent and 26 percent in Germany and France, and by 17 percent and 9 percent in Spain and Italy. At 37 percent, labor productivity in Japan has also grown faster than in the four major Eurozone economies since the turn of the millennium, although here too growth has not kept pace with that in the US. In 2022, the productivity level of the four major Eurozone countries was therefore almost 20 percent lower than in the US. Germany achieved almost 94 percent of US labor productivity, France 89 percent, Italy and Spain only 74 percent and 72 percent respectively. However, at 67 percent of the US level, Japan was still behind the Europeans, although the gap to Europe has narrowed over the past two decades. Although labor productivity is influenced by many factors, innovations play a crucial role in productivity development and future economic growth.

EU INNOVATION POLICY – ROLE MODEL USA?

EU innovation policy has failed to reduce the US's technological lead. On the contrary, the gap has widened over the past two decades. A closer look at the structures of R&D funding policy in the EU and the US reveals that the European funding landscape for R&D activities is complex. The flagship program for R&D in the EU is Horizon Europe (HE, 9th Framework Program for Research and Technological Development), with a total budget of 95.5 billion euros over 7 years (2021–2027) – almost 14 billion euros per year. It consists of several funding programs in three program pillars (Pillar I: Scientific Excellence, Pillar II: Industrial Competitiveness, Pillar III: Innovative Europe) and many agencies, each pursuing specific goals while having different governance structures. One example is the European Innovation Council (EIC), which is located in Pillar III alongside the instruments of the European Innovation Ecosystems (EIE) and the European Institute of Innovation and Technology (EIT). The EIC strives for market-creating innovations that pave the way for radically new, ground-breaking products, services, processes and business models (so-called "breakthrough innovations").

Promoting Breakthrough Innovations – DARPA versus EIC

One of the main functions of strategic innovation policy – the promotion of breakthrough innovations that are far removed from market applications and therefore not privately funded – is given too little importance in the European context. This is particularly evident in a direct comparison with the Defense Advanced Research Projects Agency (DARPA) in the US which is widely regarded as a leading example in this field and served as a model for the EU's flagship program for the European Innovation Council (EIC).[7] The EIC oversees three main funding schemes: Pathfinder (EUR 0.35 bn), Transition (EUR 0.11 bn) and Accelerator (EUR 0.41 bn).[8] Only the first two of these programs finance the types of low-TRL (technological readiness levels) projects that are too early for private-sector investment or for market applications and typical of the DARPA model. So less than 5 percent (approximately EUR 470 million) of the EU's annual R&D budget is earmarked for a "DARPA-like" program (a good tenth of DARPA's budget) to support breakthrough innovations that have the potential to create new markets but are remote from commercial applications. A significant portion of this amount (around 70 percent) is reserved for EU SMEs and start-ups. Whether such a high proportion for SMEs is justified is questionable and seems more likely to improve access to the capital market for smaller companies (to compensate for the shallow European capital market for start-ups). That said, there is also evidence that it is precisely the smaller companies – especially in the software sector – that are more likely to produce disruptive innovations (Akgicit and Stantcheva 2020).

DARPA spends around 4 billion US dollars a year, of which only a fraction (around 100 million) flows into the US SME funding programs (SBIR and STTR). DARPA strives for disruptive innovations, not just incremental ones. Less than half of its budget is aimed at further developing existing products and services. Instead, greater emphasis is placed on basic and applied research that has no direct commercial purpose. Just under 60 percent of the funding goes to general (basic and applied) research, while the EIC devotes less than 40 percent to general research projects. Finally, compared to the EIC, DARPA focuses its funding more on research institutions rather than on private

[7] See Fuest et al. (2020) for a detailed comparison.
[8] The figure provides the breakdown of the average 2021–2022 R&D grants paid by the EU through its various research and innovation programs (Source: CORDIS).

companies. DARPA and EIC also differ greatly in their governance, personnel, and management structure. The application procedures and selection processes for EU projects appear extremely bureaucratic compared to those in the US, and are subject to a rigid and complex set of rules and mandated collaborations; and the disbursement of funding is slow. In addition, the EIC is mostly led by a few EU officials rather than a larger number of top scientists like in the US, where top scientists are given much more competencies as program managers. These serious governance issues may undermine EIC's mission of boosting breakthrough innovations.

POLICY IMPLICATIONS

Our key finding is that R&D investment in the EU is concentrated in sectors, including the automotive industry, that are classified as mid-tech, while in the US it is high-tech that dominates, including the digital economy, and the healthcare and pharma industries. This raises two questions: (1) Will the EU as a result fall behind economically in the medium term? (2) Can and should European policymakers choose a new path and, if so, how?

First, it is tempting to think that the patterns observed could reflect a sensible international division of labor and specialization in which EU companies concentrate on what they do best. However, given the manifold influences of state-imposed conditions for research and development and the considerable path dependences in this area, attributing the current situation solely to efficient market processes is unconvincing. It could also be argued that the classification of sectors as mid-tech or high-tech is questionable because it suggests that the high-tech sectors are necessarily more promising than the mid-tech ones. While it is hardly possible to predict today in which sectors the European economies will be able to achieve particularly high value added and profits in the future, it is clear that high-tech industries do show higher growth rates. Unsurprisingly, it is also in these industries that the volume of R&D expenditure is growing fastest. However, it is risky, to say the least, to stick to the idea of mere division of labor, since there is no doubt that the major EU economies are currently falling behind in terms of R&D investment.

Second, what are the economic policy implications of these findings? Simply calling for more government R&D funding to be channeled into high-tech industries is not enough. While the volume of government R&D spending shows little difference between the US and the EU, the corresponding spending structure is quite different, as is the size of private-sector expenditure. Even if there are some doubts about whether the European economy can develop any competitive advantages in the high-tech area, policymakers at both the European and national levels should examine the frameworks they have created to foster innovation.

The main reforms we propose for the EU to stay relevant in the innovation front are:

1. The EIC should focus on its core mission of supporting breakthrough innovation (low-TLR activities) rather than funding venture capital for start-ups or supporting SMEs.
2. A large part of the budget of the European Institute of Innovation and Technology (EIT), which has a similarly large budget to the EIC but does not seem to be an effective policy approach, should be reallocated to the EIC.
3. The EIC's governance structure should be reformed to streamline decision-making, reduce the influence of the European Commission, and, crucially, give more say to highly qualified scientists and engineers on the EIC Board. That way, innovation policy should promote the best ideas in Europe, independent from political influences on the regional distribution of the funds or any requirements for cross-border collaborations.
4. Program managers who are experts in the fields of the projects under their purview should also be given more decision-making power.[9]
5. The effectiveness of national innovation funding institutions should be critically reviewed.

Furthermore, while better conditions for start-ups and the provision of venture capital are also necessary, these are primarily a task for policymakers at the national level. This involves the development of venture capital markets, changes in tax law, including loss offsetting, the reduction of red tape and better collaboration between basic research and industry.

Ultimately, EU member states will not be able to avoid prioritizing the promotion of R&D more strongly in their public budgets, regardless of the fact that the gap with the US exists above all in private innovation expenditure.

Finally, there is the perennial – and ever more urgent – call for a deepening of the single market and the removal of barriers to cross-border economic activity (in particular in services) at the European and national levels, since the lack of opportunities for scaling up leads many young companies to seek their fortunes in the US rather than in Europe. A better integration of the European single market for services harbors high growth potential (Dorn et al. 2024) – provided that the member states are willing to reduce barriers at the national level and to transfer corresponding competencies to the European federal level.

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