UNIVERSITA' COMMERCIALE "LUIGI BOCCONI"

PhD SCHOOL

PhD program in **Social and Political Science**

Cycle: **37°**

Disciplinary Field (code): **SECS-P/02**

European Competitiveness: A new EU innovation policy to address the Middle-Technology Trap

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Year 2026

ABSTRACT

In the wake of a global productivity slowdown, rising geopolitical tensions, and protectionist challenges, economic competitiveness has returned to the forefront of academic and policy debates. This dissertation addresses the question of how innovation policy could help restore Europe's competitiveness and support its catch-up to the technological frontier represented by the US. Across three chapters, it combines evidence on the European Middle-technology Trap with new causal estimates of the impact of EU R&D support, and complementary trade-based evidence on how diversification and connectivity shape exposure to external shocks and economic resilience.

Chapter 1 maps Europe's position in global innovation using firm-level data on business R&D expenditure (BERD) and patents. It identifies the industrial sectors where European countries underperform compared to other regions and documents a pronounced transatlantic gap in innovative investment in high-tech sectors. The European Union today attracts half as much business R&D expenditure (BERD) compared to the US benchmark—most of which accrues to less R&D-intensive mid-tech sectors like the automotive industry, which make up almost 50% of European BERD. This pattern is consistent with a "Middle-technology Trap," in which industries are more likely to fund incremental innovation of mature technologies rather than generating breakthrough innovation. By contrast, Europe is largely absent in key high-tech activities such as software and computer services, where it represents only 7% of global sales and less than 3% of global BERD. The same technological imbalance can be observed when considering innovation output, as measured by patent applications to the international patent system (PCT).

Chapter 2 evaluates the productivity-enhancing potential of Horizon 2020 and Horizon Europe—the EU's flagship innovation programmes—by providing causal evidence on the long-run effects of EU R&D grants to small and medium-sized enterprises (SMEs), and how this is mediated by firms' ownership structure. The chapter introduces a novel dataset (COMPET) linking the universe of European Commission grants awarded between 2014 and 2024 to recipients' performance. To address selection bias and the potential endogeneity of receiving public support, it exploits a quality label awarded by the European Commission to high-scoring R&D grant proposals that could not be funded due to budget constraints. Event-study estimates indicate that receiving an R&D grant raises productivity in the long run on average, but the gains are driven entirely by independent firms; there is no detectable effect for SMEs belonging to corporate groups. This heterogeneity is not explained by firm size and is robust across alternative performance measures.

Chapter 3 shifts the empirical lens to another region of the world—the Caribbean—to study how trade diversification and infrastructural connectivity contribute to competitiveness and resilience. Using goods and services trade data, this chapter sets up a two-way fixed effects gravity framework to study regional trade integration and diversification. It shows that geographic distance and weak sea and air connectivity are a binding constraint for goods exports and are associated with more concentrated trading partners and higher vulnerability to external shocks. Similar concentration dynamics emerge in services, where tourism and financial inflows depend heavily on a limited set of source countries. Overall, the results highlight the role of policies that strengthen shipping and air connectivity in facilitating the diversification of goods and services trade partners, thereby reducing exposure to external shocks.

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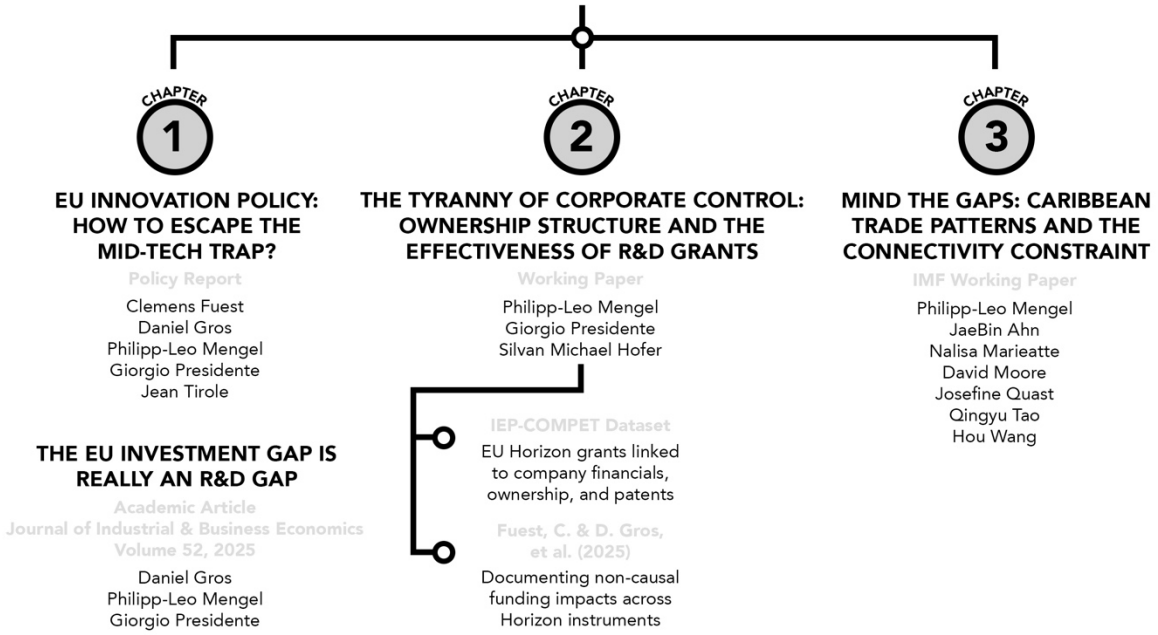
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INTRODUCTION

The 2025 Nobel Prize in Economic Sciences, which recognises Joel Mokyr, Philippe Aghion, and Peter Howitt for their work on innovation-driven growth, highlights how economic competitiveness ultimately hinges on how well an economy can create, adapt, and diffuse disruptive new ideas. Their contributions show that productivity growth and long-term prosperity emerge when new technologies replace old ones and institutions support experimentation, risk-taking, and the shift of resources toward more productive activities.

Such research comes at a crucial time for European economies, where, in the wake of a global productivity slowdown, increasing geopolitical tension, and protectionist challenges, the topic of economic competitiveness has experienced a renewed interest among scholars and policymakers (Bartelme *et al.*, 2021; Juhász, Lane, & Rodrik, 2023). In contrast to a similar discussion in the 1990s, which was less academic and revolved around the vague notion of a "win-lose" competition for world markets (Krugman, 1996), the current debate on European competitiveness is grounded in the theory of industrial organisation. Among the main issues emerging from this literature are the possibility of deindustrialisation, the acceleration of high-tech innovation to sustain European technological leadership, and the necessity of building resilience to external trade shocks through diversification.

Figure 1 Dissertation Structure



This dissertation sits at the intersection of Innovation, Industrial Organisation, International Trade and Economic Policy. It consists of three chapters developed from individual research projects **(Figure 1)**. Chapter 1 introduces the middle-technology trap and evaluates whether existing EU programmes are suited to closing the transatlantic R&D gap. Chapter 2 provides a causal assessment of Horizon grants, with a focus on how effects depend on recipient firms' ownership structures. Chapter 3, drawing on evidence

from a different geographic region, shows how deeper connectivity in goods, services, and financial flows can foster diversification and resilience to external shocks

The Middle Technology Trap

At the turn of the century, European policymakers set an ambitious objective: catching up to the technological frontier represented by the United States. This objective has not been achieved. Using firm-level evidence on business R&D expenditure (BERD) and patents—respectively the inputs and outputs of innovation—**Fuest *et al.* (2024)** identify the industrial sectors where European countries underperform compared to other regions. The European Union today attracts roughly half as much business R&D expenditure as the US benchmark, and much of this spending remains concentrated in less R&D-intensive mid-tech industries, such as automotive—which together account for almost half of European BERD. The authors describe this pattern as a "*middle technology trap*", since these industries tend to fund incremental improvements to mature technologies rather than generating breakthrough innovation. By contrast, in many high-tech sectors—such as software and computer services—the EU is nearly absent, accounting for only 7% of total net sales and less than 3% of global BERD. The same imbalance appears on the innovation output side, as reflected in patent applications under the international PCT system.

To close this transatlantic gap in terms of innovation input and output, the Draghi (2024) report estimates that the European Union would require an additional €750–800 billion of investment per year (about 4.4–4.7% of EU GDP). **Gros, Mengel and Presidente (2025)**, however, argue that the prevailing notion of a transatlantic "investment gap" is misleading. Overall investment as a share of GDP is higher in Europe than in the United States, and returns on domestic investment are correspondingly lower in the EU. What aggregate figures conceal are sharp compositional differences: the EU devotes a larger share of GDP to three of four investment categories—dwellings, buildings and structures, and industrial machinery—but it lags in the crucial category of ICT equipment and intellectual property products, where complementarities and spillovers are strongest. This pattern largely reflects differences in industry composition, with R&D-intensive high-tech sectors accounting for a larger share of US value added. In this sense, the transatlantic "investment gap" is more accurately interpreted as an R&D gap. More of the same type of tangible investment is therefore unlikely to lift EU productivity and long-run growth; what is needed are policies that spur high-risk, high-return projects by easing the institutional frictions that currently deter them.

The Effectiveness of R&D Grants

Escaping the European middle-technology trap ultimately requires mobilising *private* investment into high-tech industries to scale and commercialise frontier innovations.[1] However, well-designed *public* R&D funding can catalyse this process by crowding in private capital where markets underprovide it. While recent studies analyse successful

[1] In the EU, €1 of public-sector spending is associated with €2 spent by the private sector. In the US, the private-sector multiplier is equal to 3.

innovation policy in the United States (Bloom, Van Reenen, & Williams, 2019; Howell *et al.*, 2021), the evidence for Europe remains comparatively sparse (Santoleri *et al.* 2022). **Fuest *et al.* (2025)** analyse Horizon Europe—the EU's main ecosystem for innovation—and reach a sobering conclusion: compared to the United States, EU innovation funding is disproportionately directed toward middle-technologies—particularly sectors such as automotive—rather than toward cutting-edge, high-tech industries. They estimate that less than 5% of funding supports breakthrough innovation capable of creating new markets. Instead, much of the roughly €10 billion annual R&D budget goes to mid-tech firms or even consultancies, with little lasting impact on growth. Moreover, many beneficiaries are repeat recipients—some participating in up to 200 projects—typically belonging to large corporate groups in mid-tech sectors, where the growth effects of the grants dissipate after an average of three years.

To assess the productivity-enhancing potential of the EU's largest programme supporting SMEs, **Hofer, Mengel and Presidente (forthcoming)** exploit a novel dataset (IEP COMPET) linking the universe of European Commission grants awarded between 2014 and 2024 to recipient performance outcomes. To address selection bias and the potential endogeneity of receiving public support, they leverage the fact that some companies seeking support were awarded the *Seal of Excellence (SoE)*, a quality label granted to high-ranking Horizon Europe project proposals that ultimately did not receive funding due to budget constraints. Event-study regressions show that R&D grants to funded SMEs raise long-run productivity on average. However, the gains are driven entirely by independent firms, with no detectable effect for firms belonging to corporate groups. Given that independent companies receive only 22% of total Horizon Europe funding (Fuest *et al.*, 2025), this evidence raises the question of whether scarce public resources are being allocated to the projects where they generate the largest and most persistent returns.

Trade, Connectivity & Diversification

Competitiveness also depends on the ability of a region to integrate its internal market, while at the same time diversifying its trading partners outside the region. Deep integration paired with diversified trading relationships matters not only for growth, but also for managing exposure to external shocks—an issue made more salient by geoeconomic fragmentation and heightened geopolitical tensions. A common empirical strategy is to estimate a gravity model of trade and compare observed bilateral exports with model-predicted flows to detect partner-specific under- or overtrading. Applying this approach to the Caribbean, **Ahn *et al.* (2026)** show that weak infrastructural connectivity—by sea and air—acts as a constraint on competitiveness because it increases the concentration of trade partners. Such concentration heightens vulnerability to external disruptions, reduces resilience, and raises reliance on re-exports through a small number of regional gateways. Similar concentration dynamics appear in services, where tourism and financial inflows remain concentrated in a handful of source countries. While this evidence comes from outside Europe, it sharpens a general lesson: connectivity shapes diversification, and diversification is a key ingredient of resilience—especially when shocks are increasingly geopolitical rather than purely economic.

Internal & external competitiveness

Innovation performance, firm dynamics, and trade-connected resilience—can be examined through the lenses of the framework proposed by **Mengel and Ottaviano (2024)**, which distinguishes two complementary dimensions of competitiveness: internal and external competitiveness **(Table 1)**.

Internal competitiveness refers to a country's or region's ability to "compete with itself" by boosting innovation, efficiency, and productivity—without treating other economies as direct rivals. Different institutions place different emphasis on this dimension of competitiveness: for example, the World Bank (2012) links it to GDP growth, the World Economic Forum (2012) to sustaining high and rising living standards, the European Investment Bank (2016, 2024) to wealth creation, and Draghi (2024) to scaling innovative start-ups. Some definitions add that competitiveness requires meeting core economic goals while also achieving secondary objectives such as environmental targets and broad-based inclusion. However, all definitions have in common that policies that expand innovation inputs and outputs—and, crucially, shift them toward the technological frontier—strengthen internal competitiveness.

Table 1 Definitions of Competitiveness in recent official reports

INTERNAL COMPETITIVENESS "Competition with yourself"	EXTERNAL COMPETITIVENESS "Competition with others"
• Productivity and efficiency within a country or region • Various dimensions: ○ GDP growth (World Bank, 2012) ○ High living standards (World Economic Forum, 2012) ○ Wealth creation (European Investment Bank, 2016) ○ Being the most cost-efficient producer (European Investment Bank, 2024) • In its 2023 report, EU Commission highlights achieving growth alongside environmental and equitable concerns ("secondary goals")	• Offering desirable goods (World Bank, 2012), retaining dominant industry roles (European Commission, 2023; Monti, 2010) • Having local production of strategic technologies (European Investment Bank, 2024) • Maintaining a leading economic position at the technology frontier • Achieving significant market shares at home and abroad • All of the previous implies a more confrontational attitude

Source: Mengel and Ottaviano (2024)

External competitiveness, by contrast, captures the ability to "compete with others" in global markets. It is inherently more outward-facing and, in some interpretations, more confrontational: the emphasis is on whether firms can retain or gain significant market shares in foreign markets, and how regions position themselves in strategic industries. While some definitions of external competitiveness adopt a largely non-zero-sum stance, emphasising the ability to sell attractive products in foreign markets (e.g., World Bank, 2012), others prioritise defending the EU market (Monti, 2010, European Commission,

2023), leading in strategic sectors, and pursuing self-sufficiency for strategic industries (Draghi, 2024). To quantitatively evaluate Europe's external competitiveness, **Mengel and Ottaviano (2024)** use the concept of *Revealed Comparative Advantage* (RCA), which benchmarks a country's export specialisation by comparing its export share in a product group to that of a reference economy (Balassa, 1965).[2] Focusing on strategic industries, measured using Advanced Technological Products (ATP) as defined by the National Census Bureau (2025), they show that Europe lags behind the United States and other global competitors. While EU exports in biotechnology and life sciences are comparatively strong, its export share in high-tech sectors such as ICT and electronics is roughly half that of other advanced economies **(Appendix Figure 1)**. Moreover, in critical industries like semiconductors and solar panels, the EU falls short of its own targets for technological autonomy: by the Balassa Index, Europe displays a revealed comparative disadvantage that has widened over the past two decades, particularly relative to China **(Appendix Figure 2)**. These findings remain robust when constructing an updated, value-added-based Balassa index that accounts for global value chains.

Both concepts, internal and external competitiveness, are neither sequential nor mutually exclusive; they co-evolve and reinforce each other. Internal competitiveness— through innovation inputs and outputs—raises productivity and, via exporters, can translate into higher foreign market shares. Yet external competitiveness is not merely the downstream expression of productivity: greater integration with global markets and learning-by-exporting can themselves lift productivity and, in turn, strengthen the domestic innovation base. The World Bank's flagship report *TIDES of Change* highlights four complementary pathways through which external competitiveness can drive aggregate productivity growth: reallocation between incumbent firms, firm upgrading, creative destruction, and structural transformation (Iacovone *et al.*, 2025). At the firm level, the first pathway is **reallocation via a selection effect**: trade openness intensifies competitive pressure, shifting market share toward more efficient producers and allowing productive firms to expand while inefficient ones contract, raising aggregate productivity (Berthou *et al.* 2020; Fernandes 2007; Melitz 2003; Melitz and Ottaviano 2008; Pavcnik 2002). Second, **within-firm upgrading** is spurred as openness and the reallocation of market shares fosters "learning by exporting" (De Loecker 2007) and "learning by importing" (Amiti and Konings 2007; Goldberg *et al.* 2009; Halpern *et al.* 2015), giving firms access to superior technologies, inputs, and larger markets that justify productivity-enhancing investments (Acemoglu and Linn 2004). Third, openness accelerates **creative destruction**, whereby more productive entrants displace less competitive incumbents and push inefficient firms to improve or exit (Bloom *et al.* 2016; Javorcik 2004, Foster, Haltiwanger, and Krizan 2001). Finally, at the economy-wide level, **structural transformation** reallocates resources

[2] RCA is measured using the *Balassa Index*, defined as the ratio of a product's share in a country's total exports to that product's share in the total exports of a reference group. It can be computed against a set of countries or bilaterally against a single comparator. The resulting Balassa Index is positive, with a value greater than 1 indicating that the country has a revealed comparative advantage in a given product category (Brakman & Marrewijk, 2017). Conversely, a value between 0 and 1 indicates a comparative disadvantage. For example, if automobiles account for about 20% of Germany's exports and 10% of South Korea's exports, Germany's RCA in automobiles relative to Korea equals 2, and Germany is said to possess a revealed comparative advantage.

toward higher-productivity sectors in line with comparative advantage (Harrison and Rodríguez-Clare 2010; McMillan and Rodrik 2011).

From Evidence to Policy

Building on research conducted with co-authors over the past two years, this dissertation contributes to the academic debate on how to boost innovation and restore European industrial competitiveness—and it draws out direct implications for policy. Combining firm-level evidence on innovation and performance with data on trade flows, the dissertation arrives at three overarching conclusions. First, the EU lags behind other advanced economies in both the development and export of critical future-proof technologies, consistent with the diagnosis of a middle-technology trap. Second, while EU innovation grants can raise long-run productivity for independent SMEs, the impact for firms embedded in larger corporate groups appears limited and short-lived, dissipating after roughly two to three years. Third, competitiveness is not only about inventing and scaling technologies internally: trade connectivity and diversification shape resilience, and resilience has become an essential component of competitiveness in a world of more frequent and more geopolitical shocks.

These findings fill a gap in the literature on the European context—where causal evidence on public innovation policy, knowledge spillovers, and the crowding-in effects of R&D subsidies remains comparatively scarce. They also point to a clear policy implication: if Europe aims to escape the middle-technology trap, innovation policy must be redesigned to prioritise persistent productivity effects—by targeting frontier innovation, improving allocation toward organisational forms with stronger long-run responses, and complementing funding with reforms that reduce institutional frictions to scaling.

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I.

THE MIDDLE TECHNOLOGY TRAP

EU INNOVATION POLICY

How to escape the Middle Technology Trap?

C. FUEST, D. GROS, P.-L. MENGEL, G. PRESIDENTE AND J. TIROLE



ABSTRACT

The EU is losing the global innovation race. EU industry invests less than its peers in R&D, it lags way behind in software, hardware and artificial intelligence, and its pharmaceutical component is at risk. For over 20 years the same companies, mostly from the automotive sector, have dominated EU innovation activity. We call this the middle technology trap.

Existing EU programmes to foster innovation, including those under the heading of the European Innovation Council (EIC), are far from the gold standard – the US Advanced Research Projects Agency (ARPA) model. They rarely finance disruptive innovation and instead bring funds to rather mature entities. Their decision processes are still very political, they impose collaborations instead of accompanying them, they devote too much of their limited resources to venture capital investment rather than to supporting breakthrough innovation, and the few project managers are over-stretched.

We propose an ARPA-style model of governance and a budget-neutral shift of resources to support high-risk, high-return projects that are far from commercial application. Project selection and management should be improved by increasing the scientific and engineering excellence of the EIC Board and by delegating more to scientists. The current venture capital activities, if maintained, should be outsourced to a specialised fund.

I. INNOVATION SPENDING COMPARED

Does the EU have an innovation problem?

European leaders perceive that Europe has an innovation problem. An expenditure on R&D of 3% of GDP has been an official goal of the EU since the launch the Lisbon Strategy in 2000. However, gross domestic expenditure on R&D in the EU is still roughly 2% of GDP, lower than in other major economies such as the US, Japan and China.

The reason why the EU lags behind other regions is *not* that governments (national and EU) spend less on R&D than its rivals. In 2020, government-funded R&D amounted to €110 billion in the EU (mostly by national governments[1]) and €150 billion in the US, accounting for a very similar percentage of GDP, around 0.7%.[2] In the other regions of the world, government R&D spending is somewhat lower at 0.5% of GDP.

The key reason for the overall transatlantic difference is the lower engagement in R&D by the business sector, whose spending amounts to only 1.2% of GDP in the EU, versus 2.3% of GDP in the US.

These oft-cited OECD figures, however, do not allow us to decompose them among the different sectors. To analyse in more detail the sectoral composition of R&D, we use data from the EU Industrial R&D Scoreboard, which are based on the accounts of the 2,500 largest companies in the world in terms of R&D spending.[3] A cross-check with the OECD data shows that these 2,500 companies account for 80 to 90% of the R&D spending in the regions we analyse, making our data representative of the actual total R&D spending.

The Middle Technology Trap

Figure 2 shows the sectoral composition of business R&D spending (BERD) in nominal terms for businesses headquartered in the four regions, plus a residual the rest of the world (ROW).[4] In the US, high-tech industries – mostly software & computer services and pharmaceuticals & biotechnology – account for 85% of BERD. In the EU, by contrast, mid-tech industries – especially automobiles & parts – account for roughly 50% of BERD, a much higher share for mid-tech industries than in the US.[5] The sectoral composition of

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[1] National funding is very concentrated, with Germany alone accounting for over 40% and France for almost 20% of the EU (and national) total. It is sometimes argued that a selection of projects based on merit alone could favour the richer Member States. But this is not the case. Appendix Figure 3 shows that across EU countries there is very little correlation between income per capita and EU research funding as a percentage of GDP

[2] There are no substantial differences in government tax support for BERD either, since the EU spends 0.1% of GDP, while the US spends 0.12%. See the OECD data here.

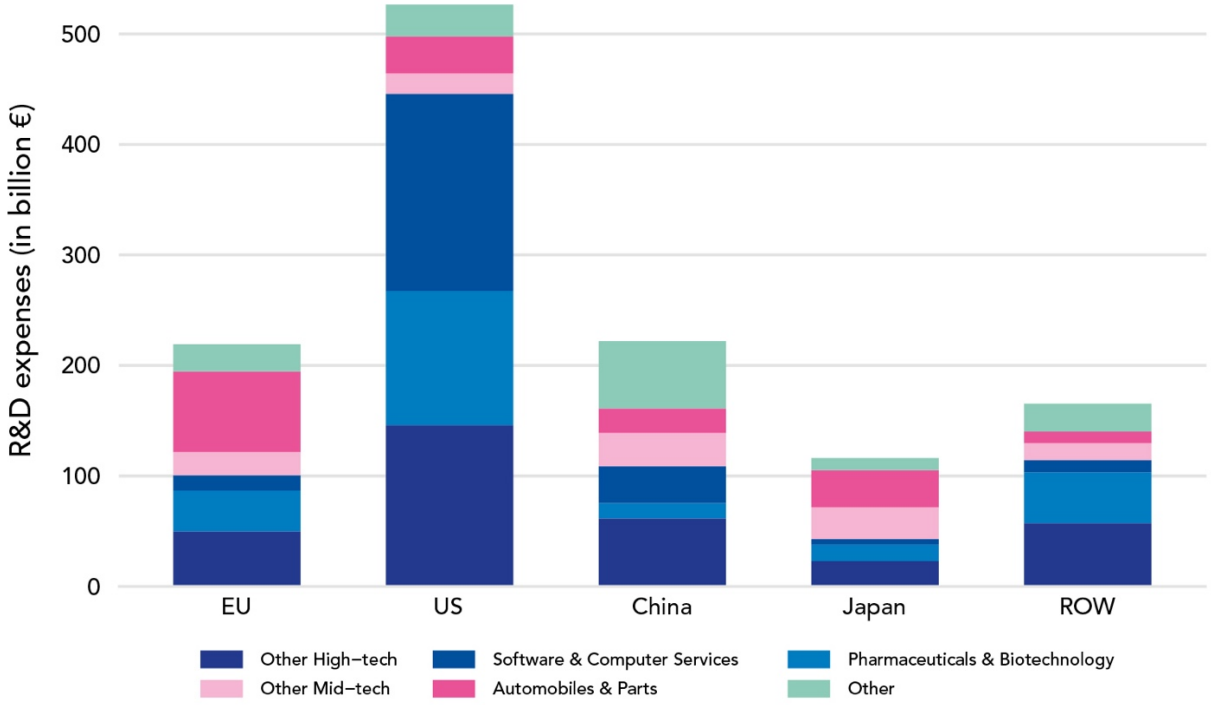
[3] The data are taken from the EU Industrial R&D Scoreboard: https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard. Representativeness should not be compromised, as global R&D is concentrated among the world's top R&D investors. Other sources provide scant data on R&D spending by industrial sectors. The OECD provides some, but the classification varies and some EU member countries are either absent or have missing data for key industries/ years.

[4] The figure does not include Amazon, which does not provide information on R&D expenses in its financial statement. As an approximation we refer to the aggregate category "Technology and content", that merges R&D spending with infrastructure costs.

[5] For the purpose of this exercise, we have used three broad categories – high- and mid-tech plus the remainder, 'other', mostly including services and utilities. *(Footnote continues on the following page)*

corporate R&D spending by EU-headquartered firms is more similar to that of Japan and China than to the US.[6]

Figure 2 BERD by technology level 2022 (Top 2,500 companies)



Source: Industrial R&D Investment Scoreboard (2023).

Not surprisingly, high-tech industries are much more R&D-intensive than mid-tech industries, as shown in **Figure 3**. Therefore, the larger share of high-tech industries in the US contributes to explaining why BERD is so much higher than in other economies. What is more, evidence suggests that public-sector support is more likely to crowd out business R&D in low R&D-intensity industries (e.g. Marino *et al.*, 2016; Szücs, 2020), which might explain the low business-sector multiplier in the EU relative to the US.[7] [8]

Figure 3 shows that US and EU R&D intensity within high- and mid-tech industries was similar until 2013. This implies that up to that point most of the difference in aggregate

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Our classification is similar to that adopted by Eurostat and the OECD:

- **High-tech** includes aerospace & defence, alternative energy, electronic & electrical equipment, health care equipment & services, pharmaceuticals & biotechnology, software & computer services, and technology hardware & equipment.
- **Mid-tech** includes automobiles & parts, chemicals, financial services, fixed line telecommunications, industrial engineering, industrial metals & mining, industrial transportation, leisure goods, mobile telecommunications, and personal goods.
- **Other** includes banks, beverages, construction & materials, electricity, food & drug retailers, food producers, forestry & paper, gas, water & multiutilities, general industrials, general retailers, household goods & home construction, life insurance, media, mining, nonlife insurance, oil & gas producers, oil equipment, services & distribution, real estate investment & services, support services, tobacco, and travel & leisure.

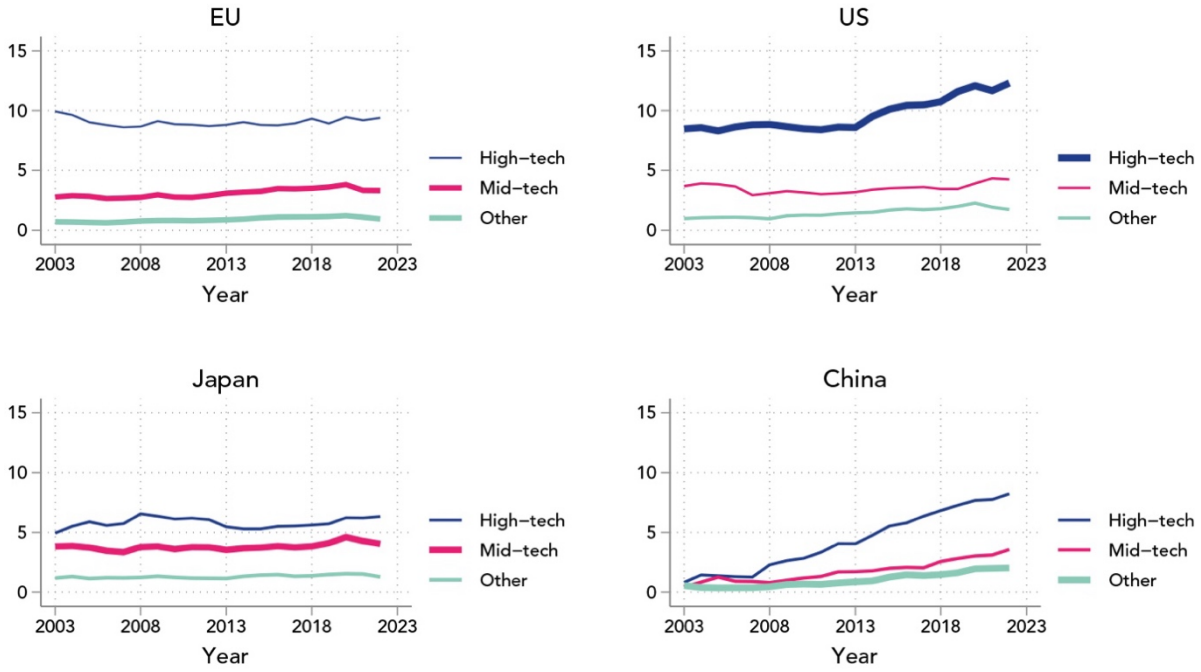
[6] The high-/mid-tech classification reflects the idea that mid-tech industries might use advanced technologies as inputs (e.g. autonomous driving software in autos), but the latter are created in "upstream" sectors.

[7] One reason might be that R&D-intensive industries need resources far exceeding the typical amounts of a grant.

[8] In the EU, €1 of public-sector spending is associated with €2 spent by the private sector. In the US, the private-sector multiplier is equal to 3.

BERD was driven by differences in the sectoral composition. After 2013, however, the R&D intensity of US high-tech industries (and of others) began an upward trend. In China, the R&D intensity increased even more: starting from close to zero, it has now reached the EU level.[9]

Figure 3 R&D intensity by technology level (% of sales)



Note: Sector lines weighted by share of total net sales. Sector R&D Intensity is the ratio of R&D expenditures within a sector to the total net sales.

Source: Industrial R&D Investment Scoreboard.

Specialisation in mid-tech industries is associated with weaker sustained growth. While there are examples of successful high-tech industries in the EU (see **Box 1** for aerospace and defence), the current pattern may be problematic, as **Appendix Figure 6** and **Appendix Figure 7** suggest that sales and profits tend to grow more slowly in mid-tech industries.

The mid-tech trap is a piece of a related and broader European problem: most of the largest market caps in Europe are firms that (often under other names) incorporated 50 or 100 years ago (or even more). This is not the case in the US. This suggests a limited contestability that favours incumbents. A loose competition policy enforcement does not seem to be the explanation for this incumbency advantage, at least for the recent past: Europeans have become at least as tough antitrust enforcers as the Americans. For the purpose of this report, we did not have the time to investigate the respective roles of insufficient disruptive R&D and of political lobbying in generating such industrial inertia.

[9] This is not due to a reallocation across sectors within high-tech industries. More broadly, we observe very similar trends if we focus on the main sectors separately.

BOX 1

The EU aerospace & defence industry

This industry represents one of the few sectors where EU companies spend almost as much on R&D as those in the US (€8.7 billion versus €9.4 billion). The main difference is the size of the market, as can be seen from net sales of €260 billion for the US and €140 billion for the EU: defence spending is much higher in the US and most of this spending naturally benefits US companies.

The near equality in R&D efforts (in terms of capital expenditure, the figures would be similar) suggests that EU industry should be competitive in the open market. That is, EU firms should be able to satisfy a large share of the increases in defence expenditure that are required immediately to support Ukraine and also those in the medium and longer term, as Member States ramp up defence expenditures.

The European Defence Industrial Strategy can therefore count on a strong industrial base. The problem here pertains much more to the market fragmentation within the EU and the limited role of joint procurement.

The recently-created European Defence Fund should at least partially address these long-standing problems. But its main focus will be technologies close to commercial application, which carries the risk that it might substitute, rather than complement, existing industrial R&D. At least some of its budget could be devoted to bold transformative projects, like the Defense Advanced Research Projects Agency (DARPA) in the US.

Decomposition of the US–EU R&D intensity gap by sector and firm size

We decompose the difference in R&D intensity between the US and EU and find that by 2024, around 60% of it was due to differences in composition—the R&D-intensive high-tech industry is larger in the US—and the remaining 40% to a generally higher R&D intensity in the US across broad technological sectors. In the early 2000s, the composition effect explained close to 80% of the disparity in average R&D intensity between the US and EU (Panel A of **Figure 4**).

To formalise the result, we apply a standard shift-share decomposition of the R&D intensity (RDI) gap between the US and EU. Let i index the three broad sector groups—high-tech, mid-tech, and other—and let $S_{r,i}$ denote sector i's share in total sales in region r. Aggregate R&D intensity in region r can then be written as the sales-weighted average of sectoral R&D intensities:

$$RDI_r = \sum_i S_{r,i}\, RDI_{r,i}$$

The US–EU gap can be decomposed as:

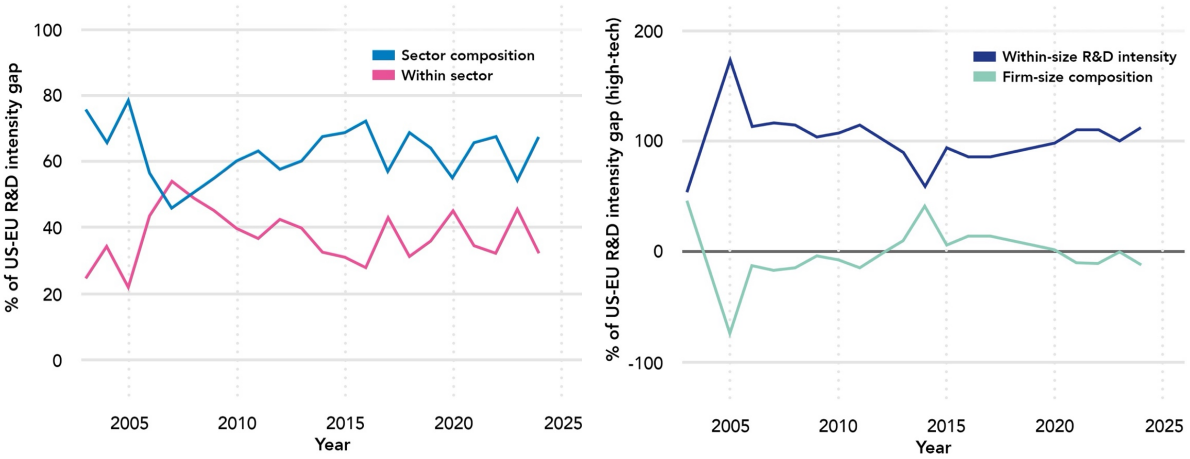
$$RDI_{US} - RDI_{EU} = \sum_i RD\, I_{EU,i}(S_{US,i} - S_{EU,i}) + \sum_i S_{US,i}\,(RDI_{US,i} - RDI_{EU,i})$$

This expression separates the US–EU gap into a between-sector term and a within-sector term. The first term captures the composition effect, that is, whether the US has a larger weight in sectors that are already R&D-intensive from the EU benchmark perspective. The second term captures whether, holding broad sector composition fixed, firms in the US still exhibit higher R&D intensity than firms in the EU. The results of this exercise are shown in Panel A of **Figure 4.**

Figure 4 R&D intensity gap decomposition

Panel A. Sector composition vs. within-sector intensity

Panel B. Firm-size composition vs. within-size intensity (high-tech sector)



Source: Author's calculations based on the global top 2,500 corporate R&D investors. Panel A uses broad sectors (High-tech, Mid-tech, and Other); Panel B uses global employment-based firm-size bins within each year.

We next turn to the role of firm size in the R&D intensity gap. A substantial share of global R&D spending is concentrated in a relatively small number of very large firms. If Europe hosts fewer such firms, its aggregate R&D intensity may appear lower even when firms within the same sectors behave similarly. To examine this possibility more directly, we focus on the high-tech sector and decompose the difference in high-tech R&D intensity between the US and the EU across firm-size classes.

Let s index firm-size classes within high-tech, defined as the bottom 50%, the 50–90th percentile, the 90–99th percentile, and the top 1%. Let $W_{r,s}^{ht}$ denote the share of size class s in total high-tech sales in region r, and let $RDI_{r,s}^{ht}$ denote the R&D intensity of firms in size class s within the high-tech sector in region r. High-tech R&D intensity in region r can then be written as:

$$RDI_r^{ht} = \sum_s W_{r,s}^{ht} \, RDI_{r,s}^{ht}$$

Using the same shift-share logic, the US–EU gap in high-tech R&D intensity can be decomposed as:

$$RDI_{US}^{ht} - RDI_{EU}^{ht} = \sum_s RD\, I_{EU,s}^{ht}(W_{US,s}^{ht} - W_{EU,s}^{ht}) + \sum_s W_{US,s}^{ht}\,(RDI_{US,s}^{ht} - RDI_{EU,s}^{ht})$$

The first term captures the firm-size composition effect within high-tech. It asks whether the US has a larger sales share in the largest firm-size classes than the EU. The second term captures the within-size effect. It measures whether US firms exhibit higher R&D intensity than EU firms even within the same high-tech size class.

Panel B of **Figure 4** presents the results of this exercise. Since the decomposition is conducted within the high-tech sector—where scale economies and R&D complementarities make firm size most likely to matter—the findings are particularly informative. They suggest that differences in firm-size distributions are unlikely to be the main driver of the US–EU R&D intensity gap in the high-tech sector. When firm size is measured by employment, differences in firm-size composition explain only a small share of the gap and in some years even contribute slightly negatively, implying that the employment-size distribution of firms tends to narrow rather than widen the transatlantic difference. Repeating the exercise with net sales as an alternative measure of firm size yields very similar results.

Overall, while differences in sectoral specialization explain a substantial share of the EU–US R&D gap, further decomposition shows that differences in firm-size distributions within high-tech sectors account for only a negligible fraction. Instead, most of the remaining gap arises from lower R&D intensity of European firms even within narrowly defined sector and size classes. This points to the importance of institutional and policy factors—such as differences in financial systems, regulatory environments, and innovation policy—as the more likely explanations for the residual within-sector, within-size gap, though fully disentangling these mechanisms lies beyond the scope of this dissertation.

Patents as a measure of innovation output

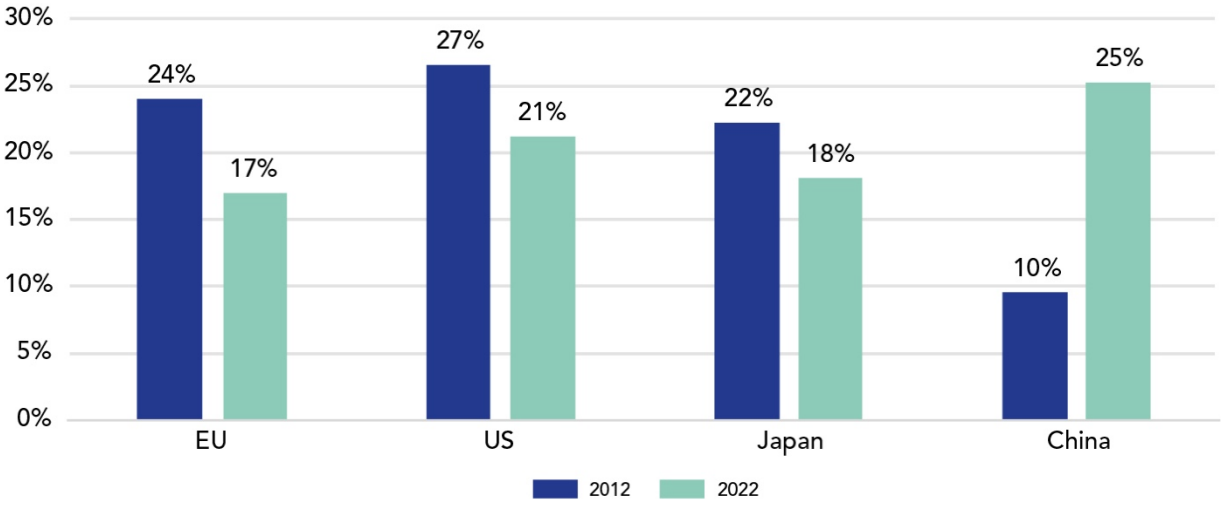
R&D spending is an important indicator of public- and private-sector innovation *efforts*. Another key measure of innovation *output* is patent activity. Although the most consequential patents—typically those that are highly cited—matter most, the overall volume of patenting and its composition can still provide useful insights.

In 2022, around 270,000 Patent Cooperation Treaty (PCT) applications were filed with the World Intellectual Property Organization (WIPO) from all over the globe. Four regions, the EU, US, Japan and China, dominate patent activity with a combined total of 220,000 filings. **Figure 5** shows the shares of all patents filed in the various regions under the PCT.[10]

This figure shows that in the same year, the EU accounted for 17% of all applications, down from 24% in 2012. A similar decline is observed for the US, which accounted for 27% in 2012 and 21% in 2022.

[10] If the patent is accepted in the 'international phase', applicants can (but do not have to) simultaneously seek patent protection for their invention in 'national phases' 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. See also the statistical database of the WIPO: https://www3.wipo.int/ipstats/pmh-search/pct.

Figure 5 International patents applications (PCT) (% of global applications)



Source: WIPO.

China's share, by contrast, soared from 10% in 2012 to 25% in 2022. Still, a number of sources suggest that this increase is the result of domestic subsidies, potentially exceeding the cost of filing a patent (see **Box 2**). 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 on data for the EU, US and Japan.

BOX 2

Subsidies for patents and trademarks in China

China appears to lead in many patent statistics, at least in terms of the sheer number of patents granted. Yet, the Chinese numbers are most probably inflated by government subsidies.

A recent report (USPTO, 2021) discusses a number of measures introduced by the Chinese government since 2008, including patent subsidies, government mandates, bad-faith trademark applications and defensive countermeasures, which together have contributed to inflating the number of patent filings in the region. In particular, the report provides examples of subsidies that exceed the cost of registering a trademark, therefore leading Chinese economic actors to pursue a trademark application even without any intention to use it commercially.

Along similar lines, Beebe and Fromer (2020) present empirical evidence that in 2017, almost 70% of the patents registered at the USPTO originating from China included fraudulent specimens, and that a substantial fraction of these ended up being published.

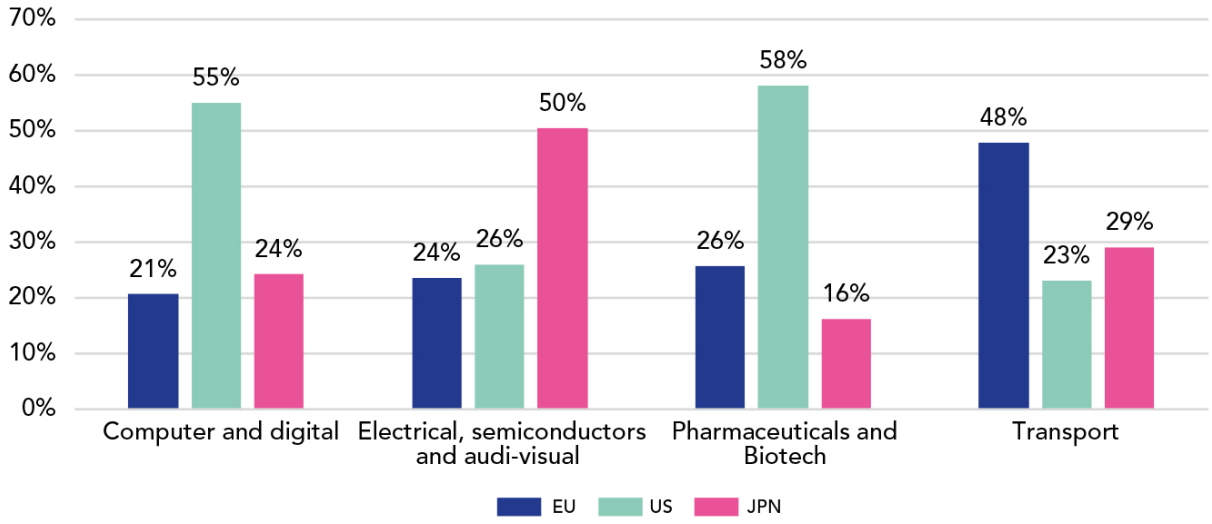
Thus, non-market factors can explain why, despite the inflation of Chinese patents over the period of analysis, few Chinese inventors file for patent protection overseas. They also explain the low commercialisation rate of patented Chinese inventions.

All this does not imply that China is making little progress in science and technology, but that one has to look more closely at the quality than the quantity of output.

Thus, in terms of aggregate innovation output and with the previous caveat that we look at patent quantity rather than quality, the EU does not appear to have a significant innovation problem. All the same, a closer look at the specific technologies being patented reveals a different picture.

Figure 6 shows that each region tends to specialise in a different technological field. We consider four broad technological domains: ICT (computer and digital); electronics (electric, semiconductor and audio-visual); pharmaceutical and biotech; and transport-related technologies, which together accounted for roughly 20% of global applications in 2022.

Figure 6 PCT applications by technology class (% of all applications in all regions, 2022)



Source: WIPO

The US accounts for more than half of the patents filed across these regions in two sectors: ICT, and pharmaceuticals and biotech. Japan leads in electronics. Thus, the EU lags behind other major economies in patenting in these key high-tech fields.

Instead, the EU dominates in patents filed for mobility technologies, accounting for almost 50% of the total. Thus, the evidence on patents echoes the evidence of the previous section about the specialisation of EU R&D activity.

Furthermore, the specialisation of the EU in mobility-related technologies has increased over time. EU patent filings in the other three industries considered have stagnated over the last 10 years. By contrast, US patent filings in ICT and pharma have continued to grow strongly over this period (see **Appendix Figure 4**).

The EU seems stuck in a middle technology trap not only in terms of innovation efforts, but also in terms of innovation output, as measured by patent counts.

Path dependency

How can one interpret such a large difference (in level and trend) in industry composition of R&D efforts and patents between the EU and US?

Prospective profit margins are usually a key driver of R&D investment. One possible explanation for the strong R&D effort by automotive producers in Europe could be that their profit margin is high, thus justifying the strategic orientation of EU producers. But this does not seem to be the case. **Appendix Figure 8** shows that in all regions, mid-tech industries tended to deliver lower profit margins than high-tech ones.[11]

This difference in profitability should be the main incentive to move from the mid-tech to the high-tech sector. This incentive was much lower in Europe, where on average over the last twenty years, the profit margin of high-tech industries was only about 2 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. More recently, many European software firms tended to report losses, further reducing the incentive to invest in such a key high-tech industry.

It is possible that the higher profit margins of US high-tech firms at least partially reflect the near-monopoly position of US software giants in their respective markets. But this does not alter the fact that the availability of higher profit margins for US firms presented a strong incentive to invest in these industries. R&D-intensive industries can be considered natural oligopolies, in which a few market leaders emerge, sustained by the dynamics of large market shares fuelling R&D, which in turn sustain large market shares in a virtuous cycle leading to dominant positions.[12] In these industries, sales and R&D expenditures follow a similar pattern (Sutton, 2007).

The evolution of profits in our data reflects these patterns of natural oligopoly formation. In 2003 (the first year for which data are available), profits for US high-tech firms were already 3 times larger than for their mid-tech counterparts. By 2022, US high-tech firms made 6 times more profits. By contrast, in 2003 the profits of EU high-tech firms amounted to only a quarter of mid-tech ones and by 2022, this ratio had only marginally increased. Looking at sales likewise reveals stark differences.

Table 2 shows the top-3 R&D spenders and their industries over time as a further illustration of the diverging development of industries.[13] It gives the top-3 companies in terms of R&D spending and their respective industries over a recent 20-year period in the US, EU and Japan.[14] In the US, Microsoft is the only company appearing more than once among the top-3 R&D spenders. Meanwhile, in the EU and Japan, Volkswagen (VW), Mercedes and Toyota remain in the top-3 over the 20 years, while Panasonic, Bosch and

[11] If one removes the software industry, the difference goes to around 4 percentage points. Thus, it is not exclusively the software industry that drives the higher profitability.

[12] We wish to thank Michele Polo for pointing this out.

[13] As noted above, the table does not include Amazon, which in its 2022 financial statement reported €69 billion for "Technology and content", which comprises infrastructure costs in addition to R&D and cannot be disentangled. For comparison, Alphabet reported €37 billion for R&D – three times what the EU spends annually with Horizon Europe, which is described further below.

[14] We do not include China because some companies there have changed their reference industry over the years.

Honda appear at least twice (see **Box 3** on the Japanese high-R&D, weak productivity dilemma).

Table 2 Top-3 R&D spenders and their industries compared over time

	2003	2012	2022
US	Ford (auto) Pfizer (pharma) GM (auto)	Microsoft (software) Intel (hardware) Merck (pharma)	Alphabet (software) Meta (software) Microsoft (software)
EU	Mercedes-Benz (auto) Siemens (electronics) VW (auto)	VW (auto) Mercedes-Benz (auto) Bosch (auto)	VW (auto) Mercedes-Benz (auto) Bosch (auto)
JPN	Toyota (auto) Panasonic (electronics) Sony (electronics)	Toyota (auto) Honda (auto) Panasonic (electronics)	Toyota (auto) Honda (auto) NTT (telecom)

Source: Industrial R&D Investment Scoreboard (2004, 2013 and 2023).

Interestingly, in the US two of the three top R&D spenders in 2003 were also in the automotive industry, but this changed over time. The software industry became increasingly important over the years; by 2022, all top-3 spenders produced software. In the EU and Japan, the auto industry tended to dominate throughout the 20-year period. These patterns are consistent with the literature on path dependence in innovation and industrial specialisation (e.g. Acemoglu, 2023; Aghion *et al.*, 2021, 2016).[15] [16] **Appendix B** develops a simple Schumpeterian framework that formalises these mechanisms, linking inherited specialisation, incumbent concentration, and startup entry to the persistence of the mid-tech trap.

The initial advantage of the US in high-tech was magnified over time, whereas EU (and Japanese) industries remained in their specialisation pattern. Breaking this path dependency might justify public-sector intervention to provide the seeds for an alternative model of specialisation.

Appendix Figure 9 shows how global R&D shares in the automotive and software sectors have evolved over the years. US companies have always dominated in software and accounted for about three-quarters of worldwide BERD in that category in 2022, while the EU is almost absent. The EU has long had a strong position in automobiles. Unsurprisingly,

[15] Typically, in these models increasing returns to scale resulted in past advances in a given sector technology facilitating further advances in the same sector.

[16] These patterns are also consistent with evidence of declining business dynamism in many sectors around the world (e.g. Akcigit, 2024; Biondi *et al.*, 2023; Decker *et al.*, 2020), and the existence of within-industry frictions hampering the process of creative destruction (e.g. Cincera and Veugelers, 2014; Veugelers, 2021). Analysing these aspects goes beyond the purpose of this study.

BOX 3

Japan's Mid-Tech Trap: High R&D, Weak Productivity Growth

Although Japan remains one of the world's largest economies, its labour productivity growth has lagged behind that of other advanced economies, including most European countries. This is surprising given that Japan's R&D expenditure has exceeded 3% of GDP since the turn of the century and, among OECD peers, has been surpassed only by Korea (Gros, 2024; OECD, 2026). This raises the question of whether Japanese R&D spending is being allocated along the most innovative margins.

Figure 7 plots, for all industrial sectors, average R&D intensity over 2022–2024 (defined as R&D expenditure divided by net sales) against the compound annual growth rate (CAGR) of net sales over 2003–2024 for Japan, Germany, and the United States. The figure suggests a positive association between R&D intensity and sales growth, but the strength of this relationship differs substantially across countries and across technology groups. Two patterns stand out. First, Japan and Germany display a relatively large number of sectors clustered in the lower-left part of the figure, indicating combinations of low R&D intensity and weak sales growth. By contrast, the United States exhibits a clearer upward-sloping pattern, with more sectors combining comparatively high R&D intensity and stronger long-run sales growth. Second, in Japan the positive association is particularly strong in high-tech sectors, whereas mid-tech and other sectors show little, if any, comparable positive relationship.

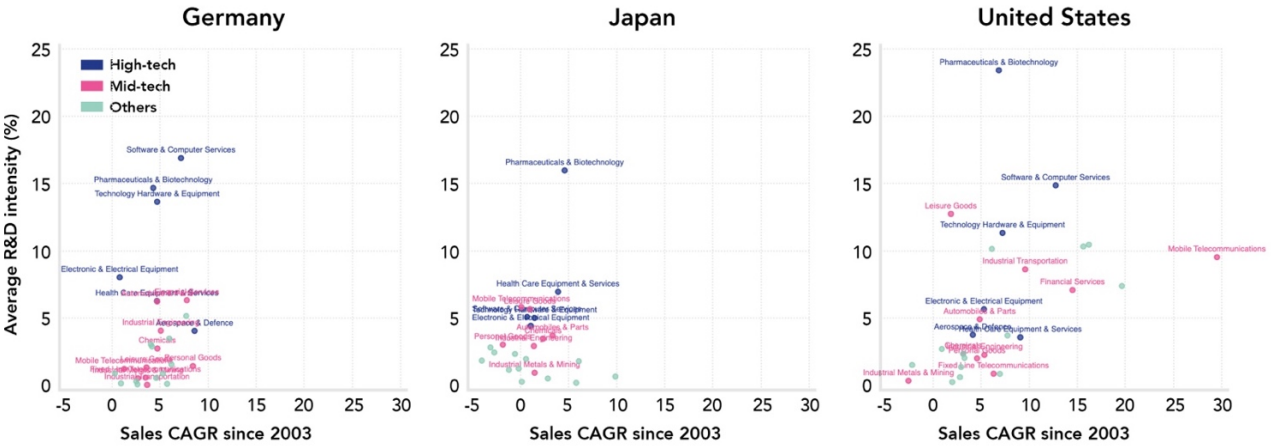
This interpretation is consistent with Schumpeterian models in which growth at the technological frontier depends on the extent of creative destruction, that is, the capacity of new technologies to displace old ones (Aghion and Howitt, 1992). Especially when the scope for imitation is limited, what matters is not only how much a country invests in innovation, but also where those investments are directed and what productivity gains they generate. In this respect, Bahar *et al.* (forthcoming) document the composition of Japan's private R&D expenditure and show that Japan invests disproportionately in relatively mature mid-technology sectors, whose share in total R&D exceeds their contribution to productivity growth. They conclude that this pattern is "consistent with the notion of a mid-tech trap." This does not, of course, imply that Japan would be better off reducing overall R&D spending. Rather, it suggests that the productivity returns to an additional marginal yen of R&D may be higher if directed toward more disruptive high-tech sectors.

Japan, its biggest competitor in the sector so far, is also a major R&D spender in this area. Thus, the EU has much less of a stronghold in the automotive industry than the US has in software.

Recent developments furthermore show that the large weight of the automotive sector exposes it to vulnerabilities, such as the risk of being leapfrogged by vehicles from the US and China. This illustrates the broader danger for the EU of being locked in a middle technology trap, where the current policy programmes are focused on incremental improvements of mature technologies, rather than on industries with greater potential for

radical innovation. One policy implication is that EU innovation policy may need to place greater emphasis on providing the initial impetus for the growth of new sectors and to support the key role of *new firms* in developing EU high-tech industries.

Figure 7 R&D intensity vs sales growth by sector



Source: R&D intensity is averaged over 2022–2024; sales growth is measured over 2003–2024. Outliers excluded: Alternative Energy (High-tech) and Electricity (Other) in the United States.

China's Distinctive Innovation Trajectory

As part of an exceptional surge in innovation activity, China's domestic expenditure on R&D rose from 0.9% of GDP in 2000 to 2.7% in 2024 (OECD, 2026). This increase is evident in both business and government R&D expenditure. China's innovation trajectory has not only been historically unprecedented in scale, but has also differed markedly from that of the United States and Europe.

First, the rapid increase in private-sector innovation spending was not primarily driven by a compositional shift toward research-intensive high-technology sectors. Looking at the top Chinese R&D spenders in the EU Industrial R&D Scoreboard, **Figure 8** points to a change in the industrial composition of leading innovators. However, unlike in the United States, the surge in private-sector innovation activity has not been led mainly by high-technology industries, but rather by lower-technology sectors, particularly construction and materials. The increase in total BERD instead appears to reflect a general rise in research intensity across virtually all sector categories, as documented in **Figure 3**. This pattern is consistent with the fact that China started from very low levels of research intensity two decades ago. Even so, China appears to be the only major region to have achieved such a broad-based increase across the sectoral spectrum.

Another important distinction is that China remains a net recipient of R&D from foreign-headquartered firms. Gros, Molteni, and Presidente (2026) propose an indicator that captures the balance between territorial R&D spending, as measured by OECD data on national R&D expenditure, and the innovation activity carried out by firms headquartered in a given country, as measured by the EU Industrial R&D Scoreboard. They find that China exhibits a considerably higher ratio (1.5 in 2021) than the United States (1.2 in 2021) and the European Union (1.0 in 2021), indicating that a substantial share of R&D conducted in China is undertaken by foreign-headquartered companies. Although this ratio has

declined rapidly in recent years as large Chinese firms have expanded their overseas R&D investments, China still stands out as a net recipient of cross-border R&D **(Table 3)**. The authors also show that this pattern is driven primarily by the manufacturing sector. In more intangible-intensive sectors, such as ICT, China appears to be less attractive to foreign firms, while Chinese companies are increasingly investing in R&D abroad.

Table 3 Chinese territorial-to-headquartered R&D ratio (H-T Ratio)

Variable	2008	2012	2016	2020	2022
Scoreboard HQ BERD (€ bn)	6.6	31.3	73.8	147.2	226.0
OECD Territorial BERD (€ bn)	35.6	95.4	165.9	232.8	324.5
H-T Ratio	5.43	3.05	2.25	1.58	1.44

Source: Authors' calculations based on Grassano *et al.* (2022) and OECD (2026).

A third distinctive feature, and one possible explanation for China's catch-up in innovation activity, is its unprecedented expansion of higher education and STEM training. In line with endogenous growth theory, human capital—especially education—is a crucial determinant of innovation (Romer, 1990; Aghion and Howitt, 1992; Acemoglu, 1996; Aghion and Howitt, 1998). Despite the contraction of China's working-age population and declining fertility rates, the skill level of its labour force has continued to increase (Gros and Galeone, 2026). With college enrolment rising from 1 million in 1999 to 9.6 million in 2020, this skill upgrading has strengthened China's technological capabilities and affected innovation through two main margins: within-sector reallocation and between-sector reallocation.

Within sectors, a more educated workforce may have enabled firms to become more innovative, while competitive pressure helped translate these gains into a reallocation of resources towards more productive producers. Consistent with this view, empirical evidence suggests that China's 1999 higher-education expansion increased workers' probability of becoming entrepreneurs (Huang, Tani, and Zhu, 2021; Qin and Kong, 2021) and improved firms' patenting and citation performance, especially among exporting firms (Kong, Zhang, and Zhang, 2022; Ma, 2024).

The second margin suggests a between-sector reallocation with more research-intensive sectors expanding over time. Several studies show that the post-1999 expansion of higher education had exactly this effect and contributed to the growth of human-capital-intensive technologies, while more traditional industries tended to contract (Che and Zhang, 2018). However, the trend shown in **Figure 8** suggests that China's skill upgrading has affected innovation primarily through within-sector dynamics rather than through between-sector compositional change.

Figure 8 Chinese Top-10 R&D spenders and their industries compared over time



BOX 4

Does the EU have an investment problem?

Over the last decade there have been several EU initiatives to encourage (private) investment, the low level of which is perceived to be a key obstacle to growth. For example, increasing investment is the purpose of the InvestEU programme and its predecessor, the Juncker Plan. However, the total capital expenditure (CapEx) of the top-2,500 companies in the Scoreboard is similar in the EU and US, as shown in **Appendix Figure 5**. Actually, the overall investment-to-GDP ratio is at 23%, slightly higher in the EU than in the US (21%).

Once again, what is different is the composition of investment, with the share of high-tech industries being much greater in the US than in Europe. Importantly, in 2022 the US software sector spent €104 billion on capex, mostly on the computing power essential for the AI revolution, while EU companies spent only €1 billion. Such a 1-to-100 ratio will make it very difficult for EU companies to catch up, or even to carve out significant niches in the market for generative AI, which requires huge computing power to train large foundational models.

Aghion *et al.* (2024) propose a number of policies to support the development of AI in France and Europe. But the scale of US companies' spending is so large that even generous government support is unlikely to provide EU companies with the required computing power.

II. ALTERNATIVE EXPLANATIONS FOR EUROPE'S MIDDLE-TECHNOLOGY TRAP

The previous chapter argued that sectoral specialisation and path dependence are central to understanding Europe's innovation gap. Yet the broader literature identifies a range of additional, complementary mechanisms that shape R&D investment and may contribute to locking the European economy into middle technologies. These span product and labour markets, financial systems, firm dynamics, education and university systems, and the strategic use of public policy. While this dissertation cannot examine all of these channels empirically, the following chapter situates the argument within the broader literature by reviewing each mechanism in turn and complementing the discussion with additional empirical evidence where available.

Single Market Fragmentation and Product Market Regulation

Many studies suggest that the incomplete Single Market for goods and services in Europe is a major explanation for Europe's middle-technology trap and the transatlantic productivity gap. Consistent with this view, trade between EU member states is less than half as intensive as trade across US states (IMF, 2024). As a result, Europe's effective market remains smaller, with regulatory and linguistic fragmentation limiting scale for exporters and contributing to an overabundance of small, mature, low-growth firms. This is problematic because large firms, and exporters in particular, tend to be more innovative.[17]

In measuring intra-EU trade barriers within the Single Market, scholars usually rely on the concept of tariff equivalents. The idea is to estimate a gravity model of trade and measure the extent to which trade among EU member states exceeds within-country trade, controlling for factors such as distance, language, and tariffs. The resulting estimates are then expressed in tariff-equivalent terms, under the assumption that these barriers could be reduced through European Commission policy action and through further completion of the Single Market.

Most studies find that barriers to goods trade remain substantial and that integration in services trade is even more limited. Using data from the OECD's Trade in Value Added (TiVA) dataset, Adilbish *et al.* (2025) estimate intra-EU trade costs of 44 percent for goods and 110 percent for services. Similar estimates are reported in studies by Danmarks Nationalbank (Hammershøj Bentsen *et al.*, 2025) and the ECB (Airaudo *et al.*, 2025; Bernasconi *et al.*, 2025). Estimates reported by Head and Mayer (2021) are lower, with tariff equivalents of 13 percent for the EU15 and 8 percent for the EU28 in 2017.

Both Cerdeiro and Rotunno (2026) and Head and Mayer (2025) note that much of the discrepancy across estimates is driven by differences in estimation methods and underlying data sources. Studies such as Head and Mayer (2021) rely on trade and gross-output databases, while the IMF estimates are based on global input-output databases

[17] Iacovone *et al.* (2025) highlight four complementary channels through which greater trade openness, achieved through completion of the Single Market, could drive aggregate productivity growth: reallocation across incumbent firms, firm upgrading, creative destruction, and structural transformation.

that account for missing domestic sales and correct for re-exporting. Including domestic sales and excluding re-exports reduces measured intra-EU exports and therefore leads to higher estimates of internal trade barriers.

Table 4 summarises the internal trade barrier estimates obtained across datasets and studies. Overall, most studies find self-imposed tariff equivalents in the EU of around 25 to 45 percent for goods, compared with 15 to 25 percent in the United States, with the corresponding barriers in services being even higher. Fully closing this gap and reducing internal EU trade costs to US levels could raise EU productivity by up to 6 percent (IMF, 2025). In a more realistic scenario, reducing internal trade barriers to the level of the Netherlands—the member state with the lowest estimated costs of goods trade with other EU countries—could increase intra-EU trade by 4.4 percent and generate welfare gains of 1.3 percent (Bernasconi *et al.*, 2025).

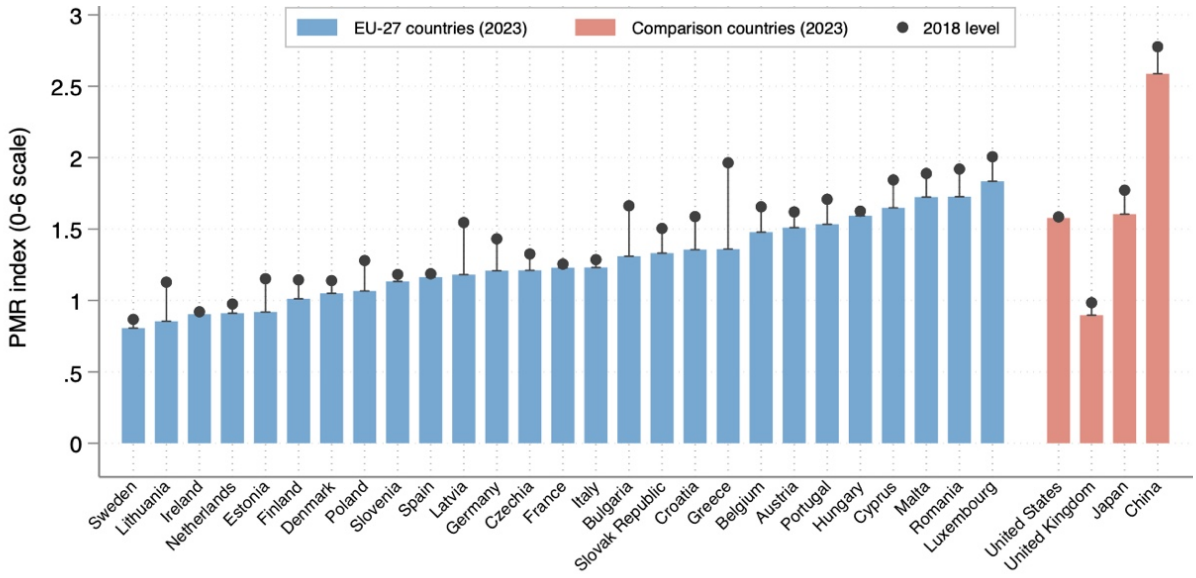
Table 4 Tariff equivalent estimates across datasets

	ERFT	TIVA	FIGARO	TRADE PROD	Head & Mayer	ITPDE
Intra-EU	44.1	38.6	32.1	30.4	24.0	10.5
Intra-US	16.6	20.7	15.2	22.9	24.6	19.3
Test (Intra-EU =Intra-US)	37.0	18.2	17.3	3.5	0.0	4.7

Source: Cerdeiro & Rotunno (2026).
Note: All ad-valorem estimates apply a trade elasticity of 5. The "Test" row reports the chi-squared statistic.

While the incomplete Single Market remains a structural constraint and potential explanation for the European middle-technology trap, a related argument concerns product market regulation. Many scholars argue that product market regulation directly affects competitive pressure by limiting firm entry, innovation, and reallocation (Blanchard & Giavazzi, 2001; Cette, Lopez, & Mairesse, 2016; Anderton, Di Lupidio, & Jarmulska, 2019). Much of the regulatory burden in the EU has been attributed to differences in national product standards, value-added tax regimes, and the recognition of professional qualifications (Bernasconi *et al.*, 2025). However, the OECD Product Market Regulation (PMR) indicator suggests that the transatlantic gap has narrowed in recent years, implying that product market regulation may be less central than before as an explanation for weak innovation performance **(Figure 9)**. At the same time, substantial disparities remain within the EU between relatively low-regulation member states, such as Sweden, Lithuania, and Ireland, and more highly regulated countries, such as Luxembourg, Romania, and Malta.

Figure 9 OECD Product Market Regulation, 2023



Source: Author's calculations based on OECD (2026).
Note: Bars show 2023 PMR. Grey dots and vertical lines indicate the 2018 level and direction of change. Lower values indicate less restrictive product market regulation.

Business Dynamism, Firm Size, and Knowledge Diffusion

The International Monetary Fund attributes a substantial share of the transatlantic productivity gap to weaker business dynamism in Europe, where markets are less permeable to disruptive entrants and tend to favour incremental innovation by established incumbent firms (IMF, 2024). In this view, Europe's corporate landscape is marked by an overabundance of small, mature, low-growth firms, alongside large leading firms that innovate less and a startup sector that is both smaller and less dynamic than in the United States. As a result, both productivity growth and R&D intensity tend to be lower among European firms (see for example **Figure 3**). The gap is particularly pronounced for firms at the technological frontier, mainly digital technologies, where the median age of the ten largest listed firms is about 100 years in Europe, compared with only around 40 years in the United States. However, Adilbish *et al.* (2025) also show that firm entry and exit rates are highly heterogeneous across Europe, with some Nordic economies even exceeding US rates, so that on aggregate the European average does not diverge substantially from the United States.

This diagnosis connects closely with the academic literature on frontier firms and the diffusion of existing technologies from the leaders to laggards (Andrews, Criscuolo, & Gal, 2015, 2016). A central insight of this literature is the rise of "best versus the rest" dynamics, and how aggregate productivity in the wider economy depends not only on the pace of innovation at the global frontier, but also on how quickly these technologies spread across countries and are absorbed by laggard firms within each country. When Europe cultivates too few, too small, or too weak firms at the technological frontier, it not only loses frontier innovation at the top end; it also weakens the domestic diffusion of these technologies, and the productivity gap between the US and Europe widens. In that

environment, firms are more likely to remain in mid-tech sectors where capabilities, supply chains, and financing models are already well established, rather than shifting towards frontier sectors that require larger fixed costs, more scale, and riskier R&D.

Akcigit and Ates (2019) build a macro general equilibrium model to study more precisely how a reduction in knowledge diffusion affects business dynamism. Their results suggest that when leaders become harder to imitate, they widen their technological lead and establish greater market power, while both followers and potential entrants are discouraged from investing in disruptive innovation or entering the market altogether. Consistent with broader firm-level work on innovation and reallocation, which emphasises the role of selection and the movement of resources towards firms with greater innovative capacity, this implies that weaker diffusion can reduce both experimentation and aggregate growth. Applied to Europe, such weak cross-firm and cross-country knowledge diffusion may reinforce the mid-tech trap, as lower competitive pressure, weaker entry into frontier activities, and less reallocation towards highly innovative firms keep production concentrated in established sectors characterised by incremental rather than disruptive innovation (see also the conceptual framework in **Appendix B**).

Financial Structure and Risk Capital

Well-developed financial markets are a prerequisite for innovation and productivity growth because they facilitate the reallocation of capital central to creative destruction, particularly in high-technology sectors (Arizala, Cavallo, & Galindo, 2013; Hall & Lerner, 2010). From this perspective, Europe's traditionally bank-based financial structure has re-emerged as a potential contributor to the middle-technology trap. The Draghi Report brought this issue back to the center of the policy debate, arguing that Europe's fragmented capital markets hinder the commercialisation and scale-up of innovative firms and risk leaving the region locked into middle technologies rather than frontier sectors (Draghi, 2024).

A central mechanism is that bank financing is generally better suited to investment backed by tangible collateral, whereas young innovative firms are typically intensive in intangible assets, offer little pledgeable collateral, and require patient equity finance. Moreover, greater reliance on bank-based debt financing exposes innovative startups to temporary liquidity shocks. This is reflected in the fact that European listed firms, especially in technology sectors, exhibit higher marginal propensities to invest than their US counterparts and are therefore more likely to cut investment in intangibles when funding conditions deteriorate (IMF, 2024, Duval *et al.* 2020).

A related institutional difference reinforces this constraint. In the United States, firms can pledge intellectual property—including patents—as collateral for debt financing (Mann, 2018; Hochberg *et al.*, 2018), partially offsetting the financing disadvantage faced by innovative firms with few tangible assets. In much of Europe, fragmented insolvency regimes and weaker secondary markets for IP rights make this difficult in practice, deepening credit constraints precisely for the firms most likely to invest in frontier R&D.

This difference in financial structure may also be reinforced on the supply side of savings. European households appear more risk-averse than US households (Bekhtiar *et al.*, 2019),

and participation in risky asset markets is correspondingly lower (Arnold, Claveres, & Frie, 2024). By contrast, financial systems such as those in the United States and the United Kingdom, where equity and risk-capital markets are traditionally more developed and household portfolios remain more tilted towards equities and direct shareholdings than towards bank deposits, are more conducive to this type of innovation (Allen, Chui, & Maddaloni, 2004).

A further mechanism emphasised in the literature concerns the knowledge-diffusion effects of venture capital, as opposed to bank financing. Beyond supplying finance, venture-capital-funded start-ups are shown to benefit significantly from knowledge spillovers arising from the interaction between an entrepreneur's skills and those of a venture capitalist (Akcigit *et al.*, 2022b). In their model, calibrated to US data, a decline in the efficiency of venture capital financing to the level of bank financing would result in aggregate welfare losses and a decline in aggregate output growth of 5 percentage points. Bank-financed European firms are likely to miss out on these effects.

Recent policy debates therefore place particular emphasis on deepening European equity and risk-capital markets rather than relying predominantly on bank credit. Yet progress on financial integration in the euro area has so far remained limited (ECB, 2024), and European markets continue to depend heavily on non-EU capital—reaching 70 to 90 percent of funding in some member states (Commission, 2025). Future developments towards a Savings and Investments Union (SIU) should therefore focus primarily on alleviating bottlenecks in equity and risk-capital markets. A study based on interviews with venture capital fund managers suggests that key structural barriers remain the fragmented regulatory landscape, tax disparities—particularly with regard to capital gains taxation—the low participation of EU-based institutional investors such as pension funds, insurers, and banks, as well as differences in market infrastructure across member states (Commission, 2025).

Beyond these formal barriers, the study finds that a crucial soft barrier to cross-border venture capital and private equity investment remains the home bias of fund managers. While this may reflect Europe's more risk-averse investment culture, weaker international networks, and a preference for familiar jurisdictions, such barriers are likely to prove more difficult to overcome in the long run.

Employment Protection and Innovation Incentives

Differences in labour market outcomes across the Atlantic have often been linked to the interaction between adverse shocks and Europe's relatively high institutional firing costs, particularly the limited capacity of these institutions to absorb and accommodate such shocks (Blanchard & Wolfers, 2000). Building on this logic, subsequent work has extended a similar argument to Europe's innovation gap. In this view, labour market rigidities operate as an implicit tax on layoffs, thereby constraining firm restructuring and reducing innovative capacity.

Saint-Paul (2002) was among the first to formalise this mechanism in a model of job creation and destruction under employment protection legislation (EPL). His argument suggests that employment protection strengthens the position of workers employed in

vintages further from the technological frontier and, in doing so, impedes the reallocation processes needed for technological upgrading. In general equilibrium, lower firing costs may therefore foster restructuring and raise aggregate productivity growth.

Subsequent work has developed this argument further by identifying two competing channels through which EPL may affect firms' incentives to invest in productivity-enhancing innovation (Griffith & Macartney, 2014). The first emphasises adjustment costs: high firing costs can reduce firms' ability to reorganise production and workforce composition, thereby discouraging investment in disruptive innovation. This mechanism is particularly relevant where innovation requires substantial restructuring, experimentation, or the replacement of obsolete activities.

A second, competing channel points in the opposite direction. By providing workers with greater job security and employment rents, stronger employment protection may increase unobserved effort and thereby support innovation within firms. Proponents of this view argue that EPL may raise the expected returns to innovation investment and can additionally serve as a commitment device that helps firms discipline innovation failure (Acharya & Subramanian, 2009; Ueda & Claessens, 2016).

Yet this positive effect is often seen as applying primarily to incremental rather than disruptive innovation. Several studies suggest, for example, that multinational firms are more likely to undertake routine or incremental innovative activity in high-EPL countries, while relocating more radical R&D activities to low-EPL environments (Griffith & Macartney, 2014; Bartelsman, Gautier, & De Wind, 2016). More generally, while much of the literature finds that firing costs depress aggregate productivity growth, this effect appears to operate mainly through reduced firm dynamics and slower reallocation, even if incumbent firms may in some cases intensify their own innovation efforts (Mukoyama & Osotimehin, 2019; Francis *et al.*, 2018).

Empirically, however, much of this evidence relies on difference-in-differences designs in cross-country settings (primarily OECD), where identification is complicated by the potential endogeneity of labour market regulation to unobserved country characteristics. More recent studies have therefore turned to firm-level data and quasi-experimental designs. For Spain, García-Vega, Kneller, and Stiebale (2021) exploit a natural experiment that differentially reduced firing costs across firms and find that lower EPL encourages product innovation among small firms. Another strand of the literature examines the relationship between EPL and venture capital in Europe (Bozkaya & Kerr, 2014; Coatanlem & Coste, 2024). The argument here is that rigid EPL raises the expected restructuring costs associated with high-risk technology start-ups, thereby reducing the ex-ante returns to venture capital investment in Europe relative to the United States.

Education, University Systems, and Frontier Innovation

Another potential explanation for the transatlantic productivity gap, which follows directly from endogenous growth models, lies in differences in education and university systems between Europe and the US. In this regard, universities are not merely sites of basic research, but can also generate direct spillover effects for commercial innovation (Jaffe, 1989). Recent work points to at least three channels through which universities affect firm

innovation (Arora *et al.*, 2023): they train researchers who later move into the private sector, they generate inventions that can be commercialised directly, and they produce public science that may lower the cost of corporate R&D.

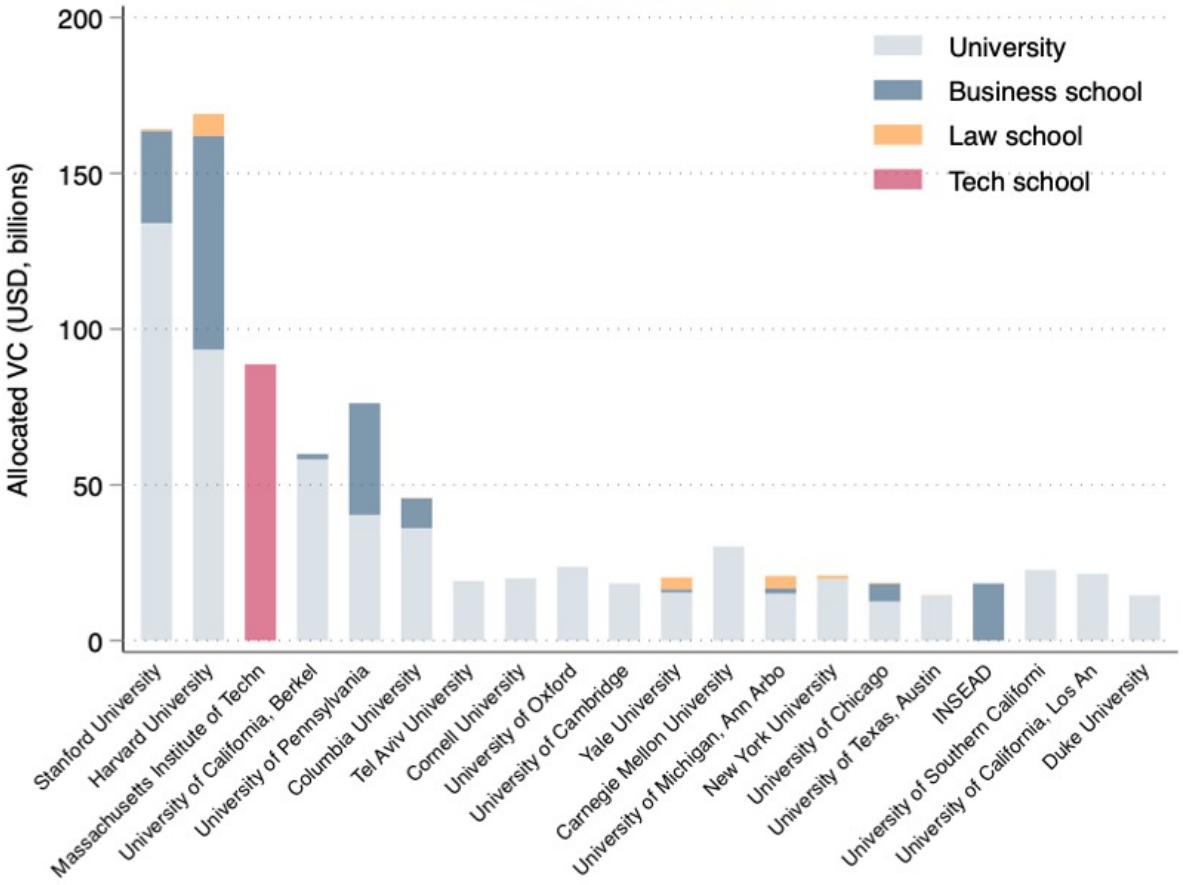
A large literature examines the role of human capital in innovation, technology adoption, and growth (Nelson & Phelps, 1966; Benhabib & Spiegel, 1994). Especially for economies operating close to the technological frontier, the composition of human capital also matters: tertiary and high-skill education become relatively more important because innovation is more skill-intensive than imitation (Vandenbussche, Aghion, & Meghir, 2006). From this perspective, the issue for Europe is likely less one of broad educational access, where Europe is generally considered to exceed the US in terms of educational opportunities (Draghi, 2024), than one of frontier-oriented talent and research excellence. In international university rankings such as QS, THE, or Shanghai, continental European universities regularly lag behind US and British institutions, which some scholars have attributed to relatively lower university autonomy and competition in Europe (Aghion *et al.*, 2009). This may matter not only for the supply of frontier researchers to high-technology firms, but also for the supply of potential inventors and entrepreneurs. **Figure 10** illustrates the total venture capital raised by founders affiliated with different universities. While alumni from Stanford and Harvard have raised more than €150 billion in aggregate, only three European institutions—Oxford, Cambridge, and INSEAD—appear among the top 20. Although such evidence is only descriptive, it is consistent with the idea that better-targeted higher-education policy could help narrow the innovation gap, especially when combined with R&D subsidies (Akcigit, Pearce, & Prato, 2025).

Universities not only supply inputs into private-sector innovation, but also participate directly in the commercialisation of research. One increasingly important channel is through university spin-outs (USOs), that is, start-up firms created to commercialise university intellectual property, often with the university retaining an equity stake. A smaller literature studies the contribution of USOs to the innovation ecosystem and to venture financing (Di Gregorio & Shane, 2003; Wright *et al.*, 2006; Munari & Toschi, 2011; Fu, Harrison, & Li, 2022). This literature suggests that USOs can be disproportionately successful start-up firms and may serve as important vehicles of commercialisation, while outcomes depend on university policies, scientific eminence, investor networks, and local financing conditions. In that sense, USOs may represent one channel through which Europe's stronger university research base could be connected more effectively to venture capital and scale-up finance. **Figure 11** fits this interpretation: European universities appear to perform somewhat better on spin-out counts than on founder-linked venture-capital fundraising, with five European institutions appearing in the top 20 by founders' alma mater.

Finally, universities may affect innovation indirectly through the positive externalities generated by basic research. A long tradition, going back to Jaffe (1989), argues that university research produces local knowledge spillovers that can foster entrepreneurship and commercial invention. This view is reinforced by more recent work showing that basic research plays a distinct role in innovation and long-run growth (Akcigit, Hanley, and Serrano-Velarde, 2021). Additional causal evidence from Kantor and Whalley (2014) suggests statistically significant local spillovers from research university activity,

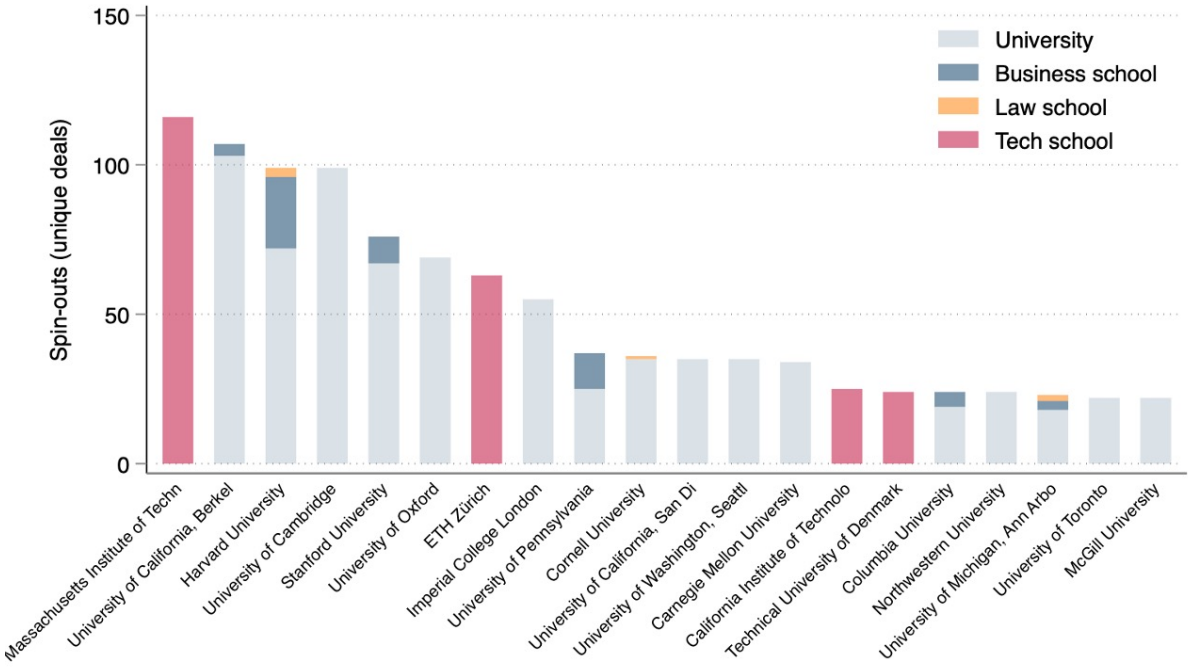
particularly when local firms are technologically close to the university research base. Hausman (2022) shows that university innovation can drive local industry agglomeration and corporate innovation. Using runner-up counties as counterfactuals, Andrews (2023) finds that establishing a college increases local patenting by almost 50%, with most of the effect stemming from inventors not directly affiliated with the university. Taken together, this literature suggests that differences in university quality, governance, and commercialisation may contribute to Europe's weaker frontier innovation performance, even if they are unlikely to be the sole explanation for the middle-technology trap.

Figure 10 Top 20 universities by total VC amount raised by affiliated founders



Source: Author's calculations based on data from PitchBook (2026).
Note: If a deal involved multiple owners, equal split across founders. University = most recent graduation year < deal year. Totals shown are USD billions.

Figure 11 Top 20 universities by PitchBook spin-out count (all years)



Source: Author's calculations based on data from PitchBook (2026).

Mission-Oriented Public Procurement

Another mechanism concerns the extent of mission-oriented public procurement, whereby the state acts as an early, large, and reliable customer, giving firms greater planning certainty in the innovation process. While the economic literature on public, and especially defence, procurement has long emphasised contract design and incentive problems (Laffont & Tirole, 1986, 1993; Rogerson, 1994), more recent work has also examined procurement as a demand-side innovation policy (Aschhoff & Sofka, 2009; Guerzoni & Raiteri, 2015). By contrast, there has been much less research on whether differences in the strategic use of procurement help explain diverging innovation performance across the Atlantic.

Despite broadly similar levels of government R&D spending (around 0.7% of GDP), large-scale procurement remains an underexploited tool, and there have been few joint procurement projects in Europe—e.g., COVID-19 vaccines or the EDIRPA Act (Nicoli & Beetsma, 2024). Draghi (2024) estimates that European collaborative procurement accounted for less than a fifth of spending on defence equipment procurement in 2022. Furthermore, only 22% went to EU suppliers, mostly incumbent contractors (Kapstein, Ospital & Wolff, 2026), while the rest favoured overseas suppliers, mainly in the US.

Evidence from the US Small Business Innovation Research (SBIR) programme further indicates that the design of public procurement also matters. Howell *et al.* (2021) find that open calls generate stronger effects on follow-on defence contracts and patenting than more top-down, mission-directed calls. One possible explanation is that open calls, which play an important role in parts of the US innovation system, allow firms to identify and propose technological opportunities that public authorities may not yet fully recognize.

Risk tolerance & Bankruptcy

A broader argument states that higher public risk aversion in Europe, relative to the US, is holding back innovation. Data from the Global Preference Survey (GPS) indeed suggests that, on average, European countries are more risk-averse than the US, and that willingness to take risks may foster entrepreneurship (Falk *et al.*, 2018). However, the same study documents that within-country heterogeneity is larger than cross-country heterogeneity. This evidence is consistent with the Flash Eurobarometer ("Entrepreneurship in the EU and Beyond"), which shows that 45% of Europeans would prefer self-employment, compared to 55% of Americans, and that fear of bankruptcy is cited as one of the largest obstacles for many people (European Commission, 2010). Given these preferences, a natural policy to promote entrepreneurship and innovative activity might be to alleviate the consequences of personal bankruptcy law. Studying 15 countries in Europe and North America over time, Armour & Cumming (2005) suggest that more "forgiving" bankruptcy laws are associated with higher self-employment rates, although the study does not necessarily establish a causal link.

III. CAN THE EUROPEAN INNOVATION COUNCIL HELP EUROPE ESCAPE THE MID-TECH TRAP?

A successful EU innovation policy should break the path dependency discussed in the previous section and promote the creation of new companies in the high-tech industry. EU resources should support projects that are initially too risky to be financed by private funds, but offer the potential of attracting business R&D once they reach a sufficiently mature stage to scale them up.

In the US, spurring breakthrough innovation is a key objective of the Advanced Research Projects Agencies—or 'ARPA model' of innovation. There are several ARPA-style programmes in the US, each associated with a respective government agency. Examples include the Defense Advanced Research Projects Agency (DARPA) associated with the Department of Defense, ARPA-E with the Department of Energy and ARPA-H with the Department of Health.[18] Below we refer to "ARPAs" as the set of agencies conforming to the ARPA model.

A key characteristic of ARPAs is their mission-oriented approach to innovation.[19] The EIC devotes roughly half of its budget to predefined thematic calls, or 'missions'. Some of the literature suggests that mission-oriented R&D funding can be an effective tool to crowd in private R&D (Pallante *et al.*, 2021). On the other hand, predefined thematic calls might prevent promising projects in other fields from being financed; relatedly, they might also reflect the preferences of the European Commission rather than the best technological prospects (see **Box 5**).

This section compares the ARPA model with the EU funding scheme that is explicitly devoted to breakthrough innovation and was officially inspired by ARPAs: the European Innovation Council (EIC).[20] [21]

Is the ARPA Model the right benchmark?

The ARPA model is regularly cited as the gold standard for fostering breakthrough innovation (Draghi, 2024). Yet the institutional environment of the European Union differs fundamentally from that of the United States. Multi-country governance, regulatory heterogeneity across Member States, and the need to coordinate budgets across 27 national governments all impose constraints that have no direct American counterpart.

The EU already attempts to address many of its unique structural characteristics through existing programme design. For example, large parts of the Horizon Europe budget—most notably Pillar II—already incorporate member state representation requirements and

[18] There are other ARPAs, such as ARPA-I, related to the Department of Transportation, and IARPA, an arm of the Office of the Director of National Intelligence. These agencies create the advanced technologies that are then used in the relative "downstream" sectors.
[19] Mission-oriented policies refer to a set of public-sector interventions aimed not only at promoting innovation but also at directing technical change towards the achievement of well-defined technological or societal goals (Mazzucato, 2018).
[20] The flagship EU programme for research and innovation is Horizon Europe. Later, in Section 3, we discuss in detail its composition.
[21] The EIC underwent a pilot phase between 2018 and 2020, and became fully operational only in 2021. See: https://eic.ec.europa.eu/about-european-innovation-council_en.

mandatory consortia structures that reflect the EU's multi-country governance reality. Moreover, EU-level funding accounts for only roughly 11% of total public R&D expenditure in Europe (compared to 96% in the United States), with the remainder coming from Member States (Bunde et al., 2020). This suggests that large parts of European innovation funding are already addressing Member State heterogeneity.

BOX 5

Mission-oriented agencies vs. bottom-up project selection

It is customary to oppose a mission-oriented agency with predefined thematic goals, and a more open and bottom-up approach. Of course, each support policy entails a bit of both. Even a bottom-up approach requires allocating the total budget across programmes: the ERC for example has to allocate funds between mathematics and economics, say, and there are multiple ways of proceeding to that purpose. Conversely, a mission-oriented agency has discretion as to the strategy to be employed to achieve the stated goals. Indeed, this discretion is a strength: the fact that the US government did not settle on one approach to a COVID-19 vaccine but only defined a target was a wise policy (at the time it was far from certain that mRNA would be the most efficient approach).

A mission-oriented agency facilitates accountability and adequacy to the needs; it makes most sense when there is a clear view of what is needed, as in the case of DARPA (although even there, the DARPA inventions, perhaps unexpectedly, went way beyond defense). On the other hand, the choice of thematic goals may miss key research opportunities; and if political, it may reflect the officials' preferences more than the scientific value.

Overall, choosing between the two approaches and their variants is a delicate balancing act. It is our feeling, though, that the European pendulum has swung too far in the direction of a top-down approach.

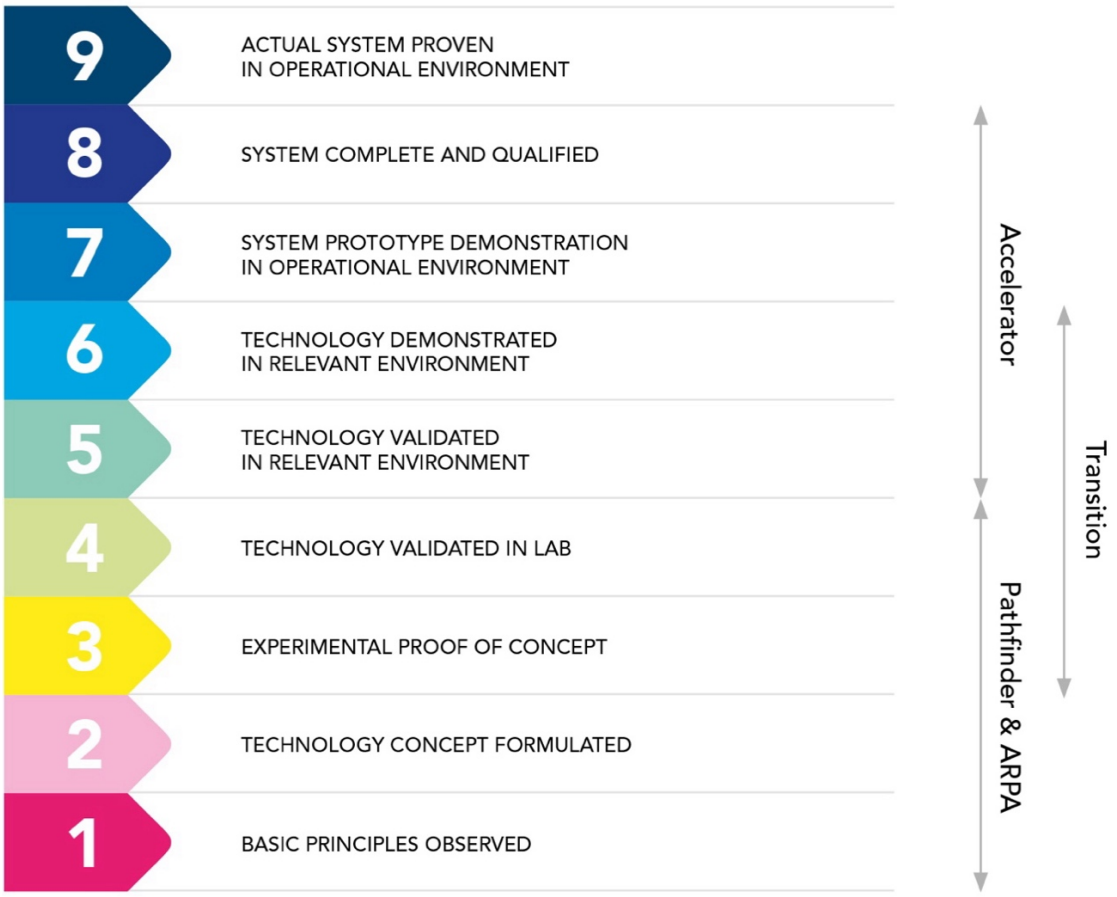
For the share of the budget dedicated to breakthrough projects of common interest—those with substantial cross-border spillover effects—we argue that the ARPA model provides the appropriate inspiration. Its core principles have proven effective across a range of institutional contexts and retain their force regardless of the specific governance arrangements in which they are embedded. Rather than replicating the model one-to-one, however, we argue that several of its core principles should be selectively adapted to the European context. These include a mission-oriented approach to research funding, scientific independence in project selection, a person-centered model of innovation support built around empowered programme managers, and a genuine tolerance of failure—meaning that unsuccessful projects are stopped early and resources are reallocated to more promising ones (Bunde *et al.*, 2020). Crucially, adapting these principles to the EU's multi-country context need not be a disadvantage: as argued in **Box 9**, a European-level intergovernmental agency may in fact be better placed to implement them than any single national counterpart.

The ARPA Model and the EIC

Similar to ARPAs, the details of EIC calls are set by *programme managers* in line with the overarching objectives of the European Commission. Programme managers refine the broad goals set in the work programme and include them in thematic portfolios. Still, relative to the ARPA benchmark, the EU approach appears more limited in several respects.

One key aspect, the type of projects financed by the EIC, can best be explained using a technology readiness level (TRL) indicator, described in **Figure 12**. ARPAs typically focus on developing 'proof-of-concept' (Azoulay *et al.*, 2019) or projects up to TRLs 3-4 at most. Once projects reach a sufficient maturity, usually taken to be the demonstration stage (TRL 5 or above), they 'graduate' and leave ARPAs with the expectation that private capital will flow and scale them up. Instead, the EIC focuses on projects with TRLs above 5.[22]

Figure 12
Technology Readiness Levels (TRL)



Sources: authors' representation based on official sources.

[22] Public support for projects whose TRL is below 5 can also be found at the national Level. For instance, in both France and Germany there exist several programs/agencies aimed at supporting innovations that are still far from commercial applications, i.e. low TRL projects (examples include in France the CEA, CNES and France 2030, in Germany the recently created Federal Agency for Disruptive Innovation, Sprin-D). As our focus is on the efforts at the EU level, we did not investigate how these national efforts could be better coordinated among themselves and with the EU level.

Azoulay *et al*. (2019) position ARPA-funded projects on the initial flat part of the innovation S-curve, relating research effort and technical progress (Foster, 1986).[23] On the initial part of the curve, a high degree of effort results in very limited performance gains, and delayed payoffs limit incentives to pursue the project. This is where public-sector support is most needed, because it addresses a clear market failure (see **Box 6**).

By comparison, projects with higher TRLs correspond to the final, flat part of the S-curve and so are closer to their maturity. Uncertainty about the commercial viability of the product or process involved is considerably lower. In this part of the curve, subsidies can only be justified if they address capital market imperfections.

BOX 6

Prerequisites for an effective industrial policy

1. Identification of the market failure so as to design the proper policy;

2. Use of independent high-level experts to select projects and recipients of public-sector funds;

3. Attention to the supply side (talent and infrastructure) and not just to the demand side (will there be the talented people who are going to make this happen?);

4. Adoption of a competitively neutral policy;

5. A humble approach of not prejudging the solution, but instead setting objectives (as illustrated by the Covid-19 vaccines: the vaccines could be based on several approaches, including the innovative but relatively untested mRNA technology);

6. Ex-post evaluation and dissemination of policy effectiveness, and the inclusion of a 'sunset clause' in the programme, forcing its closure in the event of a negative assessment;

7. Involvement of the private sector in risk taking, so as to avoid white elephants;

8. A process that is as expedient and hassle-free as possible.

For more detail, see chapter 13 of Tirole (2017).

Governance of EU innovation policy (EIC)

The EIC is not a self-standing body.[24] The EIC's core bodies are managed by an EU agency – the European Innovation Council and SMEs Executive Agency (EISMEA). This agency 'implements' and manages other EU programmes aimed at SME support. Thus, the management of the EIC programme was given to an existing body whose task is to

[23] The metric of technological progress depends on the technology considered, such as kilowatt-hour of electricity generated, or computational speed.

[24] In fact, while referred to as the 'Council', in reality no such council exists.

support SMEs (it used to be called the Executive Agency for Small and Medium-sized Enterprises, EASME). The fact that the EIC was simply added to the tasks of an agency for the promotion of SMEs already shows that, behind the creation of the EIC, the mission of encouraging innovation is at best competing with that of supporting SMEs.

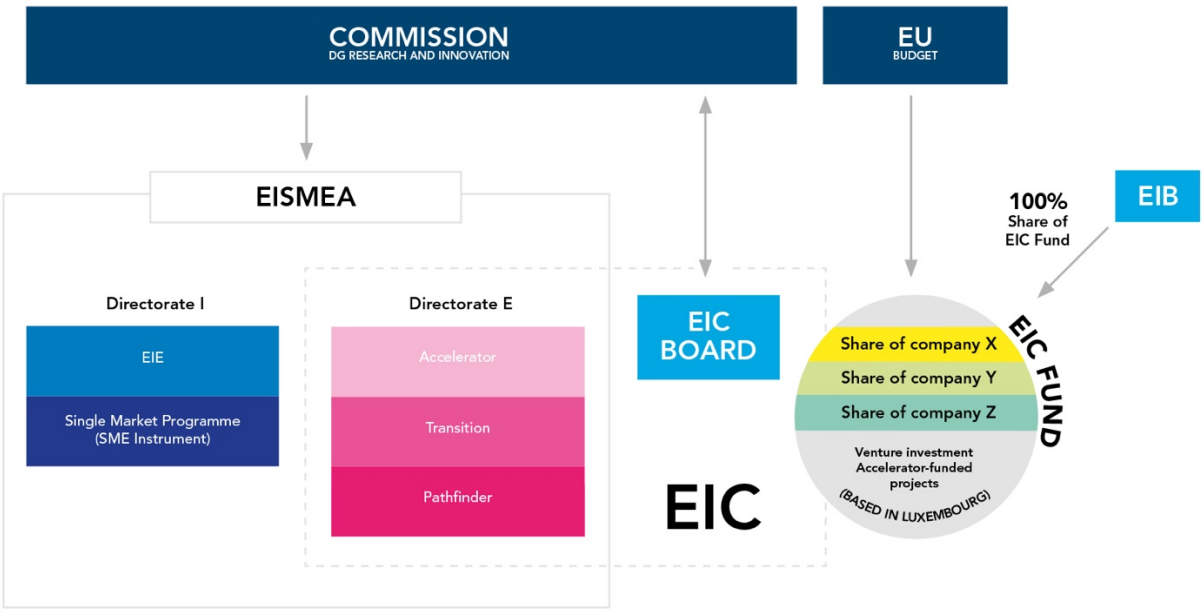
The EIC Board and its president advise the European Commission on the broad strategy of the EIC and on its work programme – a document specifying the various funding opportunities. More specifically, the EIC Board advises the European Commission on the thematic portfolios and the profiles of EIC programme managers, both key elements of the EIC as discussed below.

The EIC Board and its president are appointed by the European Commission and have an *advisory* role, thus leaving to the European Commission the bulk of the decision power. This compromises the independence of the EIC and sets it apart from the European Research Council (ERC), an EU-funded programme devoted to basic research that has acquired considerable prestige over the years.[25]

The governance structure of the EIC is summarised in **Figure 13**.

EIC Board members are not required to be leading scientists, and many have a business background. This echoes the EIC inclination towards bringing projects to market rather than developing new technologies.

Figure 13
Governance of the EIC



Only 4 of its 21 members are professors and fewer than half have a degree in science or engineering (see **Box 7**). Business 'insiders' might be better positioned to identify key global challenges and technology needs, but they appear unfit to specify the details of the work programme and identify the right people to manage scientific projects. Indeed,

[25] The ERC is discussed in more detail in Section 3.

research suggests that organizations with talented people are better at screening new employees, and therefore a temporary advantage can be self-sustaining (Board *et al.*, 2017).[26]

Of the 10 EIC Board members with a PhD, only 7 have a profile in the Web of Science, with an average of close to 2,700 citations and an h-index equal to 18. One can compare these numbers with the average citations and h-index of the ERC Scientific Council, respectively 18,000 and 58. The EIC Board thus has fewer scientists, and they are less prominent than those of the ERC.

More details on the comparison between the governance of EIC and ERC can be found in **Appendix Table 1**.

BOX 7

Can scientists be in charge of European funds

The reluctance to implement a non-political distribution of funds seems to stem from a strong risk-aversion, a concern that a non-political governance might generate a backlash in case of failure. A few remarks about this:

- The chosen alternative is, except for the ERC, a political process, whereby the European Commission has the final say on scientific choices. A most visible implication of political control is, in most of the European innovation policy, the requirement of large consortia, under the pretext of connecting multiple parts of Europe (as if professional scientists and managers did not know which potential partners would offer synergies!). There may of course be less visible, but no less important drawbacks, such as the choice of inferior programs or projects under (a) limited knowledge, or (b) the pressure of industrial lobbies, or else (c) electioneering.

- The ERC has existed since 2007 and, besides receiving acclaim from the scientific community, has been managed with integrity. In the US, DARPA, the National Science Foundation and the National Institutes of Health, agencies all managed by scientists, have been distributing much larger amounts of money for decades without substantial complaints. The presupposition that one must be a civil servant to behave with integrity seems groundless. And so is the idea that independent agencies are "out of control". As a matter of fact, it is precisely an integrity reasoning that took the judiciary system, central banking, and competition policy out of political reach.

- Of course, any agency, whether independent or under political control, must be monitored. The selection process of its leadership ex ante, and accountability ex post are central to obtaining a good performance.

[26] This has implications for projects' selection too, as we discuss further below.

Budget

The EIC has a total budget of €1.4 billion per annum and oversees three key funding schemes: *Pathfinder*, *Transition* and *Accelerator* (see **Figure 13** above). Only the first two of these programmes finance the types of low-TRL projects that are typical of the ARPA model and make use of highly-skilled programme managers. This implies that at best €470 million of the EIC budget is managed similarly to ARPAs. Given that the EIC should ideally cover all fields, this seems very small if compared with the combined annual budget of US ARPAs, which exceeds $7 billion.[27]

The other half of the EIC budget is allocated to the Accelerator programme, which finances projects close to commercialisation, i.e. projects with TRLs above 5. Therefore, the support from the Accelerator programme for the scaling of almost-mature technologies is unlikely to generate breakthrough innovation. Its purpose is more to remedy a perceived capital market imperfection. The question is then whether this use of EIC funds is the best way to address firms' limited access to capital and loans, if any.

Who receives support from EIC programmes?

In light of the technological path dependency afflicting the EU innovation ecosystem, new firms have a key role to play in boosting the development of high-tech industries. While the Accelerator programme's official aim is to support startups, i.e. firms no older than 4 years, much of the funding is directed towards projects by mature mid-tech companies.

First, the median age of Accelerator beneficiaries is 7 years, as revealed by a sample of EU-funded projects matched with the dataset of Crunchbase, a widely used database. Less than 20% of Accelerator beneficiaries are startups (**Figure 14**).[28] **Appendix Figure 10** shows that only 20% have revenue below €1 million but the vast majority have fewer than 50 employees.[29] This suggests that the EIC mostly targets mature SMEs.

Our evidence is consistent with the EIC's declared allocation of 70% of its budget to scale up *SMEs*. This is not the typical task of ARPAs. Available sources suggest that DARPA spends less than 2.5% of its budget ($100 million per year) on SBIR and STTR, the two US programmes devoted to SME support.[30] Other ARPAs can participate in these programmes, but they are unlikely to spend more than DARPA.[31]

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[27] Considering only three ARPA-style agencies in 2024, DARPA has an annual budget of more than $4 billion, ARPA-E $0.650 billion, and ARPA-H $2.5 billion.

[28] Pathfinder and Transition participants have a higher median age of 12-14 years, but that does not constitute an issue since their missions are not to create new companies.

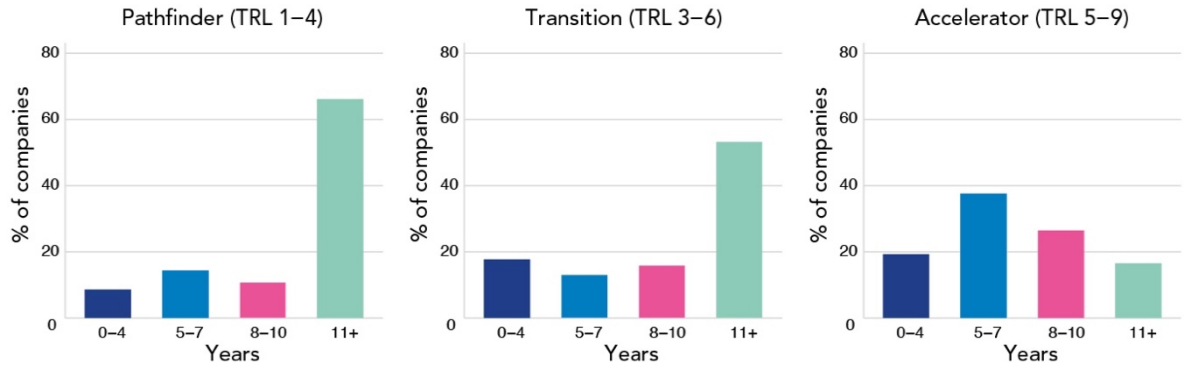
[29] Because Crunchbase is a database of companies, we have data only for the private companies that participate in the projects, but not for research institutions. Revenue and employment figures are estimates and need to be interpreted with caution. Age, however, is highly accurate.

[30] Each federal agency with an extramural R&D budget of $1 billion or more is required to allocate a portion of its R&D funding to conduct a multi-phase R&D grant programme for small businesses. The total EIC budget is not far from the $1.7 billion spent by the whole US Department of Defense in 2019 in favour of SMEs.

[31] In FY2019, US agencies awarded $3.3 billion in SBIR funding. The Department of Defense and the Department of Health and Human Services accounted for more than three-fourths of SBIR funding in FY2019.

It is an open question whether an innovation model so focused on SMEs will be successful (Box 8).[32] Taken together, these features suggest that the EIC is oriented at least partly toward remedying capital-market imperfections rather than primarily toward breakthrough innovation.

Figure 14 Age of Horizon Europe companies by programme



Sources: authors' calculations based on CORDIS and Crunchbase.

The second, broader issue is that the EIC seems to be underfinancing the sectors that could help the EU escape the middle technology trap. Specifically, Crunchbase lists the industries associated with companies whose projects are financed by the EU.[33] The detailed results are presented in Appendix Figure 11, which shows the number of financed projects by industry. The overall result is that the industries usually classified as high-tech, such as software and AI, appear relatively infrequently in the data. Biotech appears more often than software-related industries, but lies far behind the general categories of 'science and engineering' and 'healthcare', which are not necessarily high-tech although they have some advanced technological content.

Role of programme managers

The key role of ARPA project managers is to identify projects with high potential for breakthrough innovation. To accomplish this task in a broad set of scientific fields, ARPAs rely on *hundreds* of highly-qualified programme managers (or directors), who manage a portfolio with a limited number of projects and enjoy a high degree of discretion in project selection and management. These programme managers have an entrepreneurial mindset/background and a strong incentive to decide whether to put more means on functioning projects or stopping/abandoning them despite sunk costs.

[32] For instance, Akcigit and Kerr (2018) estimate and simulate a structural model in which small firms are more likely to innovate. Yet, Akcigit *et al.* (2022a) find that in a world of imperfect information, higher productivity firms have a comparative advantage at innovation and should be subsidised more than small firms. Santoleri *et al.* (2022) exploits a regression discontinuity design to provide evidence that R&D grants to small and young firms with relatively mature technology boost patenting and investment in intangibles; they do not find a significant impact of grants on early-stage projects. Bronzini and Iachini (2014) do find a positive impact of R&D grants to small firms on innovation, although these did not result in crowding in additional private investment.

[33] See the documentation from Crunchbase here.

Meanwhile, the EIC has only 9 programme managers, each managing projects worth around €200 million annually.[34] What is more constraining than the financial amount each EIC programme manager has to oversee is the sheer number of projects and the wide range each manager has to cover. The small number of programme managers severely limits the diversity of available expertise.

BOX 8

Administering R&D grants: timing and selection problems

Researchers have evaluated the impact of R&D grants, in particular the Small Business Innovation Research (SBIR) programme in the US. This programme has awarded grants (the government takes no stake in the project), on a competitive basis, to small high-tech firms since 1982. Applications are ranked by officers, and this rank is known only to the administration and not to the market, which observes only whether a grant application was successful. Howell (2017) compares the outcomes of projects that almost received a grant to those that just passed the bar (economists call this a Regression Discontinuity approach), that is projects that are assessed as very similar in merit. She does so for the two phases of the programme. The "phase 1 competition" awards small grants ($150,000). Phase 1 winners can 9 months later apply for a much bigger "Phase 2" grant ($1 million).

Sabrina Howell summarises her research in the following terms: "The Phase 1 award has powerful effects. First, it increases a firm's subsequent cite-weighted patents by at least 30 percent. Second, a Phase 1 grant increases a firm's chance of receiving venture capital (VC) investment from 10 percent to 19 percent, and also increases the amount of money raised and the number of deals. Within two years of the grant, the effects on cite-weighted patents and VC are just over one-half of their long-term effect. Third, a Phase 1 grant almost doubles the probability of positive revenue and, conditional on positive revenue, increases it by 30 percent. Finally, Phase 1 increases the probability of survival and successful exit (IPO or acquisition)."

In contrast, Phase 2 grants have little such effects, so the author concludes that it would be more efficient to reallocate that money to Phase 1. A few other observations are interesting. First, conditional on winning a Phase 1 grant, ranks are relatively uninformative about outcomes. This suggests unfortunately that officials struggle to analyse the quality of proposals, a fact consistent with the view that only a few experts have the ability to assess a project's potential. Second, the associated limited certification brought about by winning a Phase 1 grant raises the question of what explains the success of Phase 1; these small grants (to be compared with the $9 million average VC round in her data) are found to relax financial constraints of would-be innovators, allowing them to develop a proof-of-concept. Third, a likely explanation for the poor performance of Phase 2 grants is that officials face an adversely selected sample (see Lerner, 2000). Entrepreneurs prefer private money for a variety of reasons (Gans and Stern, 2003) and so those who receive favourable information in Phase 1 do not apply for a Phase 2 grant – or else cannot apply as they already have non-negligible private funding.

[34] Programme managers manage only Pathfinder and Transition projects, whose annual 2022-2023 budget was €0.47 billion. Roughly 40% of this budget (Challenges calls) is managed by the 9 programme managers.

Moreover, less than half of the €470 million devoted to breakthrough innovation is managed by ARPA-style programme managers. The majority of EIC funding (roughly 55%) is awarded through open calls with no predefined thematic priorities ('EIC Open') and without the involvement of programme managers. By contrast, ARPAs publicise funding opportunities primarily by soliciting proposals tied to programme-specific areas of research and development, set and managed by programme managers, with unsolicited proposals being allowed but generally discouraged.[35]

Eligibility requirements

Unlike ARPAs, but similar to other Horizon Europe funding schemes, two of the three EIC programmes require projects to be collaborative, meaning that applicants must form consortia of independent legal entities, with at least one established in a Member State, and at least two others in different Member States or Associated Countries.[36]

Almost all Pathfinder projects are run jointly by companies and research institutions. In Transition, 13% of projects are run solely by companies, and 6% solely by research institutions alone. Accelerator exclusively finances single companies and does not require collaboration. The average size of consortia is six members in Pathfinder and three in Transition. Accelerator does not have collaborative requirements. These statistics must be seen in conjunction with the average size of the grants disbursed: €3.2 million for Pathfinder, €2.3 million for Transition, and €2.3 million for Accelerator. This implies that each consortia member in the first two programmes receive on average just €0.5-0.75 million in grants. It is unlikely that these very small sums can generate breakthrough innovations.

The application success rate of EIC projects is quite low. The average success rate for all of Horizon Europe is 16%, but for the EIC it is less than 10% (with some variation across subprogrammes).[37] It would be a mistake, though, to conclude that, for a given budget, a low success rate jeopardizes innovation. The success rate may reflect the cost of writing proposals (a low cost inducing more applications). Another determinant of the success rate is the quality of screening. As Adda and Ottaviani (2023) show, the number of applications for a grant call increase with the imprecision of the grading; in a nutshell, the more random the allocation of grants, the more weak projects have a chance of being selected, and the more applications are received, increasing the rejection rate. So, it may be the case that a high rejection rate is a symptom of an insufficient quality of screening rather than of a size of grants that exceeds the optimum one given the fixed budget for the programme. Thus, a low application cost or an accurate screening, while desirable, may well decrease the success rate.

[35] Recent evidence from Howell *et al.* (2021), based on the US, suggests that projects selected through open calls involve younger and smaller firms, and that they are successful according to different metrics of innovation activity. However, these firms are less likely to win further funding competitions.

[36] This applies to Pathfinder Open, but not necessarily to Pathfinder Challenges. Collaboration applies only to part of Transition and it does not apply to Accelerator, which are targeted at individual legal entities (startups).

[37] The data are available here.

Furthermore, increasing the acceptance rate given a fixed budget would lead to sprinkling European money, with limited ability for Horizon Europe to have a real impact on the best projects. So, just increasing the acceptance rate for a fixed budget is unlikely to be a good idea.

The selection mechanism might be improved by being articulated in two phases. The first phase could be a streamlined version of the current screening process under the supervision of experts who would have the power to 'desk reject' proposals that are anyway unlikely to be approved. One reason for the success of the ERC is that its selection panels involve top scientists. But these individuals should not devote their attention to unpromising applications; instead, their valuable time should be used to select the best projects. It might thus be useful to associate several specialised scientific boards with the EIC, composed of top scientists and engineers. Their task would then be to make the final decision among the best applications that have survived the first screening process. In this way, they would not spend their time on projects whose rejection is a no-brainer, but rather on comparing marginal projects, i.e. projects for which the decision is complex.[38]

Funding delays

EIC funding of successful proposals is expected to take place in 8 months. In ARPAs, it can be as little as 3 months. This may be due to several factors. For instance, EIC officials evaluate proposals following complex guidelines requiring special briefings. Awardees are subject to a Commission-wide grant agreement contract (241 pages long) and additional provisions specific to the EIC programmes.[39] By contrast, proposals to ARPAs are required to follow the 'Heilmeier Catechism', a concise list of questions speeding up the evaluation process, without compromising clarity and informativeness.

A related issue is that ARPAs have the authority (typically delegated by their respective governmental agency) to enter into, and flexibly administer, contracts and grant agreements. By contrast, EIC funding has to follow standardised EU procedures that tend to be highly bureaucratic.[40] There has been progress in the speed of decisions and disbursement, but unless procedures and contracts are radically reformed, little further progress seems feasible.

[38] A more fundamental issue is that almost by definition, new fields of science will have only a limited number of experts working in them. This restricts the pool of potential funding awardees, creating a conflict of interest for the programme managers, who are likely to personally know them. International cooperation with non-EU scientists might help solve the problem.

[39] Different EIC stakeholders have complained about intellectual property issues with the current model.

[40] Most notably, ARPAs use 'Other Transactions', contracts designed to avoid burdensome regulations, complicated accounting rules, and extractive intellectual property terms that characterise federal contracts.

IV. ANATOMY OF HORIZON EUROPE

Horizon Europe has a budget of about €11 billion per annum. Increasing the EU's budget for innovation would be highly desirable but might be difficult for political reasons; therefore, our aim is to propose *budget-neutral* reforms. To that end, this section identifies which parts of Horizon Europe could be repurposed to finance breakthrough innovation.

Figure 15 presents the structure of Horizon Europe, which is organised around three 'pillars'. The figure provides the breakdown of the average 2021-2022 R&D grants paid by the EU through its various research and innovation programmes.[41]

Pillar I

The first pillar funds basic and applied research; it includes the well-known ERC. Due to data availability, the ERC is the most widely studied among EU funding programmes (e.g. Nagar *et al.*, 2023; Ghirelli *et al.*, 2023). The first pillar has a yearly budget of roughly €3 billion and accounts for the vast majority of basic research, around 30% of Horizon Europe.

The ERC accounts for about two thirds of the budget of Pillar I. It is characterised by its own government structure, which differs from other Horizon Europe programmes. Specifically, the ERC Scientific Council is composed of independent and internationally reputed scholars. Its president is appointed by the European Commission, which selects one among three names proposed by an independent commission, the Scientific Council having a veto right on these names. Unlike for other Horizon Europe programmes, the ERC work programme is set by the Scientific Council itself, without interference from European Commission officials.[42]

Likewise, the scientific panels of the ERC are made up of renowned scientists, who pick the laureates without any intervention from the European Commission (other than checking the conformity of applications and grant awards with the general rules). The award process establishes shortlists on which much of the skilled attention focuses, as it should.

It is therefore no surprise that, like its US counterparts the National Science Foundation (NSF) and the National Institutes of Health (NIH), the ERC functions with integrity and funds disruptive science. For example, Ugur Sahin, the BioNTech founder, received in 2018 a grant from the ERC to explore the mRNA technique in order to develop mRNA

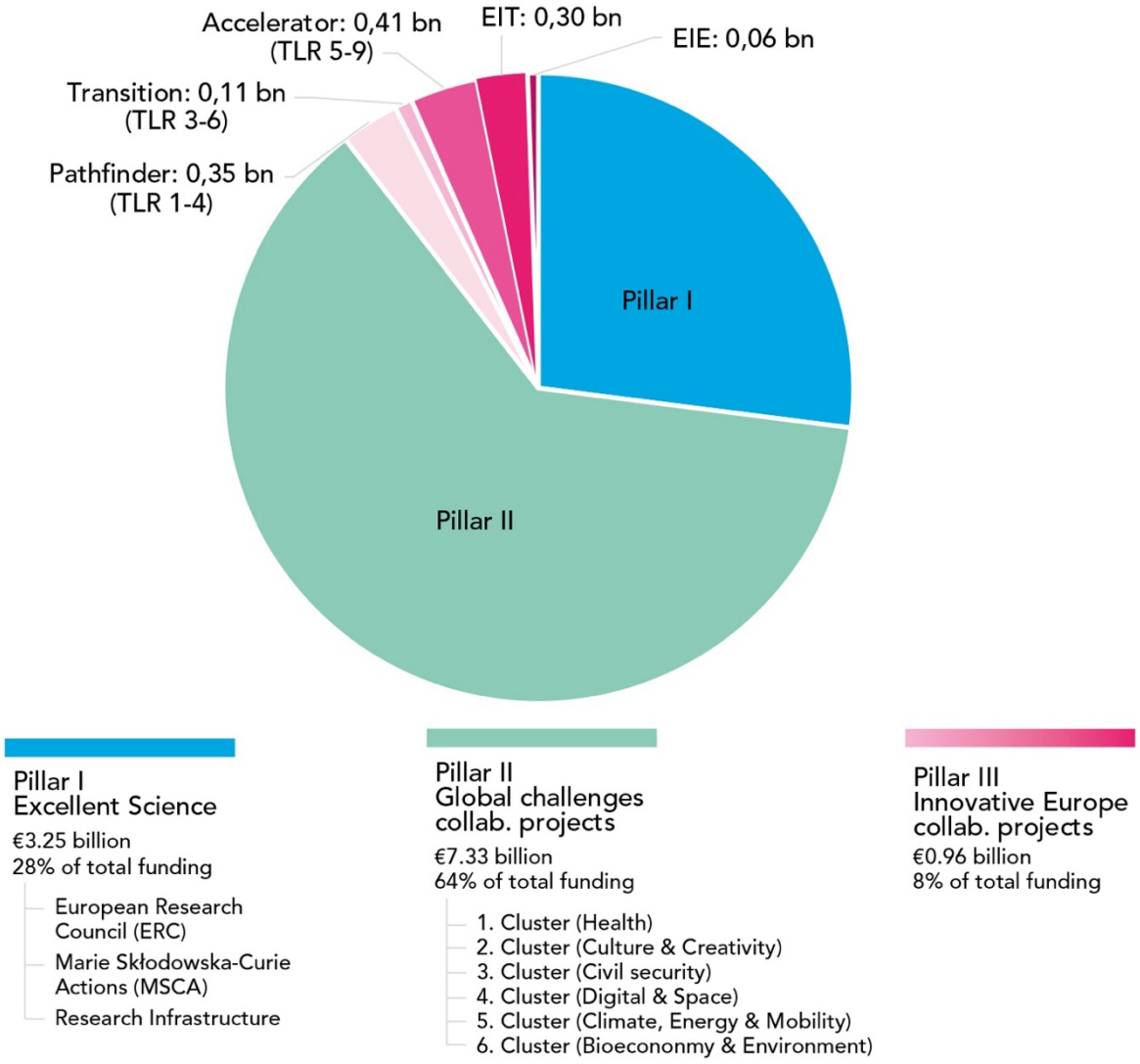
[41] The main source of data is the Community Research and Development Information Service (CORDIS), the European Commission's primary public repository on all EU-supported R&D activities. It should be noticed that the sums allocated from one year to another can vary to some extent. Also, they do not include venture capital investment, which is discussed further below.

[42] Anecdotal evidence of past conflicts between the Scientific Council of the ERC and the Commission suggests that the independence and academic excellence of the ERC cannot be taken for granted and must be safeguarded. In 2020, there was a clash between the newly nominated president and the other 20-members of the ERC scientific Council, who unanimously asked him to resign after only 3 months. The issue was his failure to represent properly the interests of the ERC and the priority he gave to personal activities, (strangely) authorised by the European Commission. More generally, there has been a political backlash against the independence of central banks, competition authorities and the judiciary, despite the fact that these institutions have served the general interest very well whenever competent and impartial leaderships were selected.

vaccines for various types of cancer. The scientist behind the AstraZeneca vaccine had also received an ERC grant.[43]

However, the ERC has a much smaller budget (about €2 billion) than its transatlantic counterparts. In 2023, the NSF had a budget of $9.5 billion, with $7.6 billion dedicated to research. The same year, the NIH had a budget of around $47 billion. It should be noticed that these sums do not include the budget of ARPA-H ($2.5 billion).

Figure 15 Horizon Europe by its pillar components and relative subprogrammes



Source: CORDIS.

[43] For more on the need for fundamental research and on European attitudes towards it, see 'The Future of European Science' by the former head of the ERC, Prof. Jean-Pierre Bourguignon.

Pillar II

The second pillar is the largest in terms of budget – over €7 billion annually or 64% of the Horizon Europe budget. The official title of Pillar II is 'Global Challenges and European Industrial Competitiveness'. It thus has a thematic focus. This pillar has two salient features.

The first is that it adopts a top-down approach by eliciting applications on specific topics decided by the European Commission.[44] It is organised around six main thematic clusters. These are: Cluster 1, Health; Cluster 2, Culture, Creativity and Inclusive Society; Cluster 3, Civil Security for Society; Cluster 4, Digital, Industry and Space; Cluster 5, Climate, Energy and Mobility; and Cluster 6, Food, Bioeconomy, Natural Resources, Agriculture and Environment. These themes reflect the judgement of the Commission of what constitute the main global challenges.

The second feature is that it funds *collaborative* projects by imposing consortia requirements, designed to strengthen EU country representativeness – a formal blending of EU cohesion policy and innovation policy. **Figure 16** shows the distribution of projects by number of consortium members in each pillar. Pillar II features many projects with a very large number of participants. It is an open question whether cross-country collaboration has a positive net impact, and the effects are likely to be case-specific.[45] At the same time, these patterns raise doubts about the effectiveness of mandatory top-down collaboration requirements. In practice, some collaborations may be formed primarily to satisfy funding criteria rather than because they create genuine research complementarities. Bottom-up collaborations are different in this respect. Our recommendation is therefore not to rule out collaborations, but rather not to make them mandatory. This would allow collaborations to emerge where they add value, since teams that expect genuine gains from an alliance would have an incentive to form one in order to strengthen their proposal.[46]

Appendix Figure 12 shows total and per-project funding by thematic cluster, distinguishing between basic and applied research, and product development. The expected TRL of the funded projects varies depending on the call, and a similar share of funding is devoted to research and development. Other than the collaborative aspect, however, Pillar II differs from the EIC in its mission of boosting "industrial

[44] Conclave Europe (2023) argues that 'R&D initiatives must be based on bottom-up projects, while top-down support should focus on a reduced number of strategic areas with enough continuity.

[45] On the one hand, this might be desirable given that there is literature suggesting that collaboration – research consortia in particular – generates positive outcomes, especially if involving basic research (e.g. Branstetter and Sakakibara, 2002). However, imposing collaboration across multiple entities in different countries might hamper innovation outcomes. This possibility is supported by a large body of literature studying the negative impact of coordination and communication frictions (e.g. Becker and Murphy, 1992), with some contributions arguing that small teams are better at developing radical innovation (e.g. Wu *et al.*, 2019).

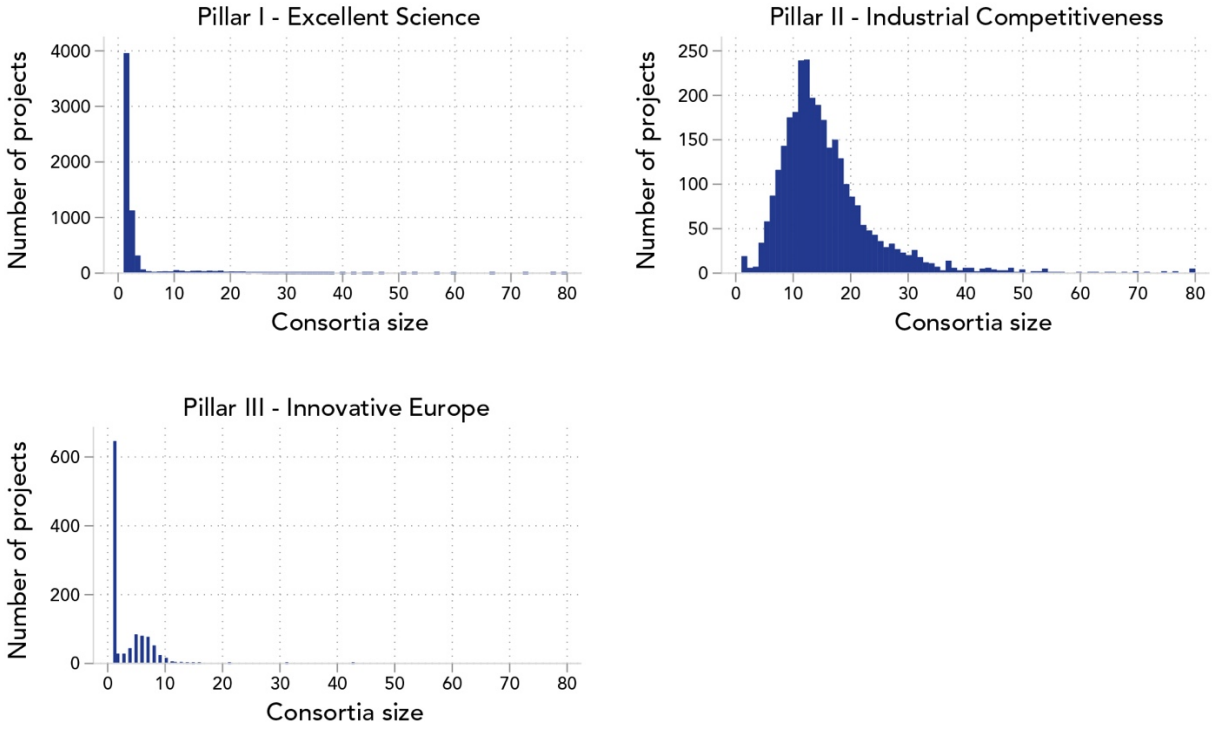
[46] In this we agree with Conclave Europe (2023) that 'Europe must eliminate the geo-return rule, which ties contract allocations to national contributions, prioritizing competitiveness and smart investment over political motives'. This rule used to plague the funding of fundamental research prior to the creation of the ERC, and still constrains some important agencies such as the European Space Agency.

competitiveness", rather than "supporting the development of disruptive and market-creating innovations", like the EIC.

The average Pillar II grant per project is around €6 million. Bearing in mind that the number of consortium members can easily be around 10-20, like for the EIC, one is left to wonder how impactful such fragmented funding can be.

Finally, the governance of Pillar II may be constrained by its more political decision-making process. Not having programme directors independently selecting and managing projects risks undermining their scientific value in favour of officials' preferences.

Figure 16 Number of consortium members by pillar



Source: authors' calculations based on CORDIS.

Pillar III

The objective of the third pillar is funding the development of ground-breaking technologies. It is composed of the EIC (the largest programme discussed in the previous section), the European Institute of Innovation & Technology (EIT) and the European Innovation Ecosystem (EIE). We argue that the EIT and the EIE do not have a clear mission and it is hard to understand what they do. Given that they absorb substantial resources, we review them below. We also describe the EIC Fund, the venture capital arm of the EIC.

European Institute of Innovation & Technology

The EIT, headquartered in Budapest, was created in 2008 and its mission has changed over time. At present it aims at encouraging the formation of 'networks'. Its mission is to connect education, research and business, not to finance innovation.

Yet, its declared budget is about €300 million per year, close to the budget of Pathfinder. Official data from the European Commission show that it financed eight projects, on average around €50 million, more than ten times the average grant from the EIC. The eight projects correspond to eight Knowledge and Innovation Communities (KICs) – whose categories are largely similar but somewhat more granular than the thematic clusters of Pillar II.

The EIT governing board selects the KICs and evaluates them every 3 years with the support of external experts.[47] The KICs typically receive financing for between 7 and 15 years, which implies that tens of million in grants are paid each year to the same entity, which in turn independently decides how to allocate the grant to the beneficiaries of its activities.[48] **Appendix Figure 13** shows the cumulative amount in grants paid to the KICs, some reaching over €700 million over their term.

KICs are supposed to create 'meeting hubs' around Europe for workshops, networking and incubator activities, but it is not clear how they operate or allocate the funding. Each KIC has its own governance and operational approach, implying reduced accountability and fragmentation of these funds. Moreover, it is not clear how the grants paid by the EIT differ from those awarded by the EIC or those in Pillar II, whether the eligibility requirements and contractual forms used by KICs differ from the rest of Horizon Europe, or how the EIT differs from other training-focused programmes such as Erasmus+.[49]

Finally, and more broadly, it is not clear why the EIT should be better placed than scientists and businesses to identify potential partners and synergies. For these reasons, it is natural to question the EU value added of the EIT and ask whether its budget could be more efficiently allocated elsewhere.

European Innovation Ecosystem

The smallest component of Pillar III is the EIE, a funding programme aimed at 'creating more connected and efficient innovation ecosystems' across the EU. The overall budget for the period from 2021 to 2027 is relatively small – roughly €60 million per year. Given that Pathfinder provides individual grants of up to €4 million, this implies that the funds of EIE would enable it to finance at least 15 potential breakthrough projects.

A key goal of the EIE is to overcome spatial issues of specialisation and integration in global value chains in less developed regions. However, it is not clear how the programme would achieve such a goal or how the funding it provides to SMEs differs from other existing programmes, which in this case also casts doubt on whether the programme serves any specific purpose.

EIC Accelerator and EIC Fund

The EIC Accelerator has the largest declared budget of the EIC, accounting for half to three-quarters of the total EIC budget depending on the year. It is implemented through

[47] See Appendix Table 2 for a comparison of the EIT's governance with that of the EIC and ERC.

[48] Financing data are available here. Some additional info is here.

[49] This has been recently argued also by Denmark's representatives. See this article here, this one here and another here.

an agency, the EISMEA. which collects and evaluates proposals by startups and SMEs through public calls, split roughly equally between 'EIC Open' and 'EIC Challenges'.

Following selection, and conditional on the rubberstamping of the decision by the European Commission, EISMEA can disburse a grant (up to €2.5 million). But while the Pathfinder and Transition programmes offer support exclusively through grants, selected Accelerator companies can receive much more financing (up to €15 million) in the form of equity.

Indeed, more than half the budget allocated to Accelerator takes the form of equity investment, around €400 million depending on the year.[50] The equity investment is delegated to the EIC Fund, the venture arm of the EIC. It is a capital fund subject to private law, with the European Commission as the unique investor and shareholder.[51] This implies that all risk, profits and losses are borne by Member States.

The EIC Fund decides on financing operations and does the monitoring, milestone disbursements, reporting and exit.[52] The external Fund Manager, AlterDomus Management Company S.A., is responsible for making investment decisions following the selection process designed by EISMEA and due diligence by the EIB.[53]

Despite the EIC's focus on funding 'unicorns', 55 of the top-100 startups in the world are from the US, while only 8 are EU companies.[54] Moreover, in a sample of 5,859 companies that received Horizon Europe funding, from Crunchbase, we find that less than 10% of funding rounds involved additional investors; for EIC-funded projects, it was less than 5%.[55] Some of these are private funds. This evidence suggests that EU-backed venture capital investment mobilises little private investment, possibly due to adverse selection. That is consistent with the literature, which casts doubt on the effectiveness of public-sector venture capital in boosting innovation.[56] In a nutshell, it is not obvious that a statist body, such as the Executive Agency for Small and Medium-sized Enterprises within the

[50] See Annex I here.

[51] Official EU sources state: 'In the future it is envisaged that the European Investment Bank (EIB) will take over this role under a mandate agreement.

[52] The EIC Fund Board is vested with the broadest powers of the EIC Fund. The Board oversees the investment strategy and makes the final decision on any single operation. The EIC Fund Manager is an external authority that manages the EIC Fund. It makes all the investment and divestment decisions on the selected companies. With the support of the EIB, it manages the EIC portfolio of invested companies.

[53] The EIC Fund Manager receives a commission fee of up to a 10%. Once the EIC Fund has approved the investment, the EIB, in its role of an investment adviser, guides the work of the lawyers for each specific transaction. This leads to an investment agreement, which is signed by the EIC Fund and the company.

[54] See the EIC Impact Report 2022. The full list from Crunchbase can be found here.

[55] According to Crunchbase, 30% of EU-funded companies never benefited from additional investors. However, we cannot observe whether the remaining 70% got funding from private sources, or whether the investments followed or arrived before the EU contribution.

[56] For instance, Breschi *et al.* (2021) find that government-backed venture capital underperforms its private counterpart, and that mixed public-private investment fails to attract additional private investment in later funding rounds. For these reasons, it might be better to use Accelerator funding solely for R&D grants, which are generally seen as an efficient policy instrument to boost innovation (Teichgraeber and Van Reenen, 2022).

Research and Technical Development framework, can emulate the best private equity funds.

These concerns are supported by data from the EU Innovation Scoreboard (Grassano *et al.*, 2022), which show that: (i) EU-based corporations provide about 22% of global corporate venture capital, but EU-based startups receive only 9% of the global total; and (ii) over 80% of venture capital investment by EU-based companies targets US-based companies **(Appendix Figure 14)**. This seems an indication of a lack of investment opportunities, casting doubt on the claim that developing its venture capital market would solve the EU's innovation problem.

Finally, and more broadly, it is unclear whether an EU venture capital market can be as developed as it is in the US.[57] Reasons include differences in fiscal regimes, corporate and labour laws, which in the EU are often inappropriate for the world of startups and innovation.[58] Cultural differences can also play a role. In the EU, universities – at which researchers, by lack of incentives or because of ideological reasons – are loath to participate in applied innovation. In the US, the general mindset emphasises advice, handholding, monitoring and relatively early termination – values that are not necessarily shared in the EU. And entrepreneurship is very rarely taught in the EU at the undergraduate level. Another often-mentioned hindrance is the absence of a single home market in a number of European tech markets (defence, AI, energy, healthcare...), complicating the emergence of sufficient scale technology champions.

Innovation Fund

The Innovation Fund is an EU fund for climate policy, independent from Horizon Europe, which invests in innovative Green-tech projects with the goal of reducing European emissions. It is entirely financed by the Emissions Trading System (EU ETS) and hence its overall funding depends on the carbon price. Given a carbon price of €70/tCO2, it might amount to annual funding of about €4 billion.

One might argue that, for a given climate objective, the higher the ETS carbon price, and therefore the stronger the European abatement ambition, the less need there is for green innovation support, all the more that a high carbon price already allows green innovators to monetize their technologies. While a high carbon price and high funding of green R&D are excellent news given the perilous climate situation, it is by no means clear that the financing mode as such is desirable. For certain it exposes green R&D funding to a populist backlash leading to a weak ETS price. In any case, even after the recent fall to about €60/tCO2, the result of higher ETS prices has been that a substantial amount of funding will be available to foster research on green energy solutions. It is thus important that this fund be effectively used.

[57] See Coatanlem (2024).

[58] Risky strategies mean a high probability of failure and a need to keep moving on, making slow and expensive layoff processes particularly cumbersome (see Bartelsman *et al.*, 2016). The corporate law literature points to substantial differences between the flexible US legislative system – largely deferring contractual choices to private parties – and the EU, where regulatory rigidities might prevent the development of an efficient venture capital market (see Enriques *et al.*, 2024).

The Innovation Fund is managed by the European Commission through delegation to the European Climate, Infrastructure and Environment Executive Agency (CINEA), led by four heads of department, who are responsible for more than seven other programmes, including Cluster 5 of Pillar II in Horizon Europe.

The Innovation Fund is actually not about innovation, but rather finances large-scale demonstration projects (with TRLs above 5). A large portion of these projects is related to hydrogen, which exposes the fund to the risk involved in a scarcely diversified portfolio.

The fund mostly awards grants through calls for proposals, and in some part through competitive bidding (auctions). Specifically, projects need to be *sufficiently mature* in terms of planning, business model and financial and legal structure, which sets the Innovation Fund apart from the kind of breakthrough innovation the EU needs.[59]

[59] The financed projects might use advanced technologies that are produced in high-tech industries, but they are not aimed at developing high-tech itself.

V. A BUDGET-NEUTRAL POLICY PROPOSAL TO BOOST EUROPEAN DEEP-TECH

This section formulates a concrete policy proposal to boost the EU's capability for breakthrough innovation.

Reallocation towards disruptive innovation

Panel (a) of **Figure 17** depicts the status quo by illustrating the declared 2024 budget of key components of the EU ecosystem for innovation.

Our proposal is articulated in five steps:

1. Reform the governance of the EIC, hiring more independent and highly qualified programme managers and giving them greater discretion over project selection and management. Streamline management practices and simplify the application process. Design a procedure that allows prominent and busy scientists to cast the decisive vote on the best proposals.

2. Scale down progressively the European Institute of Technology (EIT) and the European Innovation Ecosystem (EIE). The current projects (KICs) of the EIT are anyway expected to become financially independent in 7 to 15 years. Over time, this could free up to €0.51 billion per annum.

3. Replace the financing of equity stakes by the Accelerator budget with other sources whose mission is investment, rather than innovation. For example, the EIC could be merged with the European Investment Fund (EIF, which does not rely on EU budgetary resources) or the proposed Sovereignty Fund. This would free up €0.41 billion per annum.

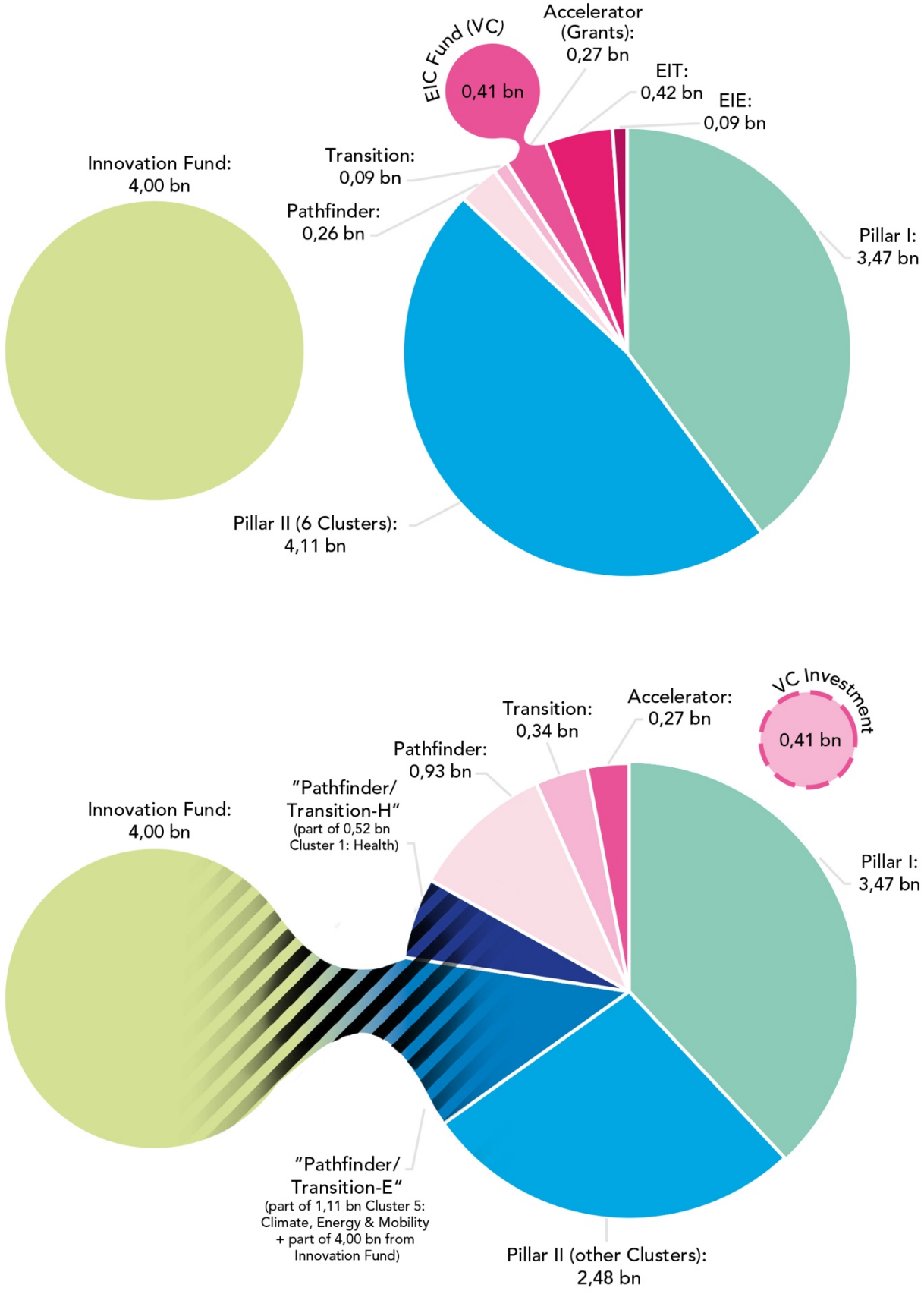
4. Use the resulting €0.92 billion for grants to increase the budget for ARPA-style programmes, through Pathfinder and Transition.

5. Pool a share of resources from Pillar II clusters, as well as part of the Innovation Fund, to finance Pathfinder-type programmes (or create two thematic agencies on energy and health, with the same reformed ARPA-style governance of the EIC).

Panel (b) of **Figure 17** depicts Horizon Europe after the reform. The dark colouring of the new EIC represents an ARPA-style governance, which extends to two new agencies through the dark bands. These are *Pathfinder/Transition-E* and *Pathfinder/Transition-H*.

Pathfinder/Transition-E would would focus on energy, climate and transportation matters, and pool resources from Cluster 5 of Pillar II and the Innovation Fund. The Innovation Fund has a much larger budget than the EIC, so devoting only a small portion, say 10-20%, of its budget to breakthrough innovation would free up resources equivalent to what is currently available to the EIC.

Figure 17 Before and after our policy proposal (in € billion)



Source: authors' representation.

Pathfinder/Transition-H would deal with health issues, and pool resources from Cluster 1 of Pillar II.[60] Resources from the original, 'general' Pathfinder and Transition programmes could also be used to finance the new agencies.

More broadly, we argue that through the EIC, the ARPA-style governance model could be extended to other components of the EU innovation landscape. A natural candidate is the European Defence Fund, which represents a long-overdue effort to foster cooperation in defence-related R&D. Currently, the fund devotes only 4-8% of its budget to disruptive innovation.

The amounts on the table for promoting disruptive innovation are very small in the EU (see **Box 9**). It is therefore important to find a solution for bringing more money to this end. Yet, il is also interesting to note that we could get "more bang for the buck". Our proposed reform is therefore EU budget-neutral (except for the minor cost of hiring programme managers).

About €400 million would be needed to finance the equity stakes that currently use up to 60% of the EIC Accelerator programme. Buying equity stakes in startups represents a financial operation that does not need to be funded by budgetary resources. Alternative funding could potentially come from an EU sovereign fund, or the existing European Investment Fund – part of the European Investment Bank group – whose remit could be enlarged to take over the equity stakes from the Accelerator programme in its portfolio.

Monitoring, evaluation and data sharing

In line with its current focus on remedying capital market imperfections, the key performance indicators (KPIs) set by the EIC Board are mostly related to *investment* performance, rather than innovation.[61] This should change in favour of more appropriate indicators.

Given the diversity of projects funded, it is unlikely that a one-fits-all approach to monitoring and evaluation can be successfully applied. For this reason, each individual project should be evaluated on the basis of milestones established by the programme manager before starting the programme, and possibly adjusted during its course.

Nonetheless, there are two general principles that can be borrowed from the transatlantic agencies. First, ARPA-funded projects are meant to have the *potential of being transformational*. **Box 10** presents a version of the "Heilmeier" questions used by ARPAs to assess whether a project fulfils this criterion.

The second criterion is that a project should fill technological white space, namely address a perceived gap or opportunity in the technological landscape. Importantly, the latter should be evaluated in terms of other EU funding schemes and private companies to avoid duplication and redundancies. To that extent, the EIC should carefully monitor the emergence of new science and technology, and then issue calls for projects on specific themes it deems promising. However, such a scientific and technological watch requires

[60] As shown in Appendix Figure 10, most of the funding of Pillar II already goes to basic and applied research.
[61] See the annex of the EIC impact report 2023.

the involvement of top scientists, which again raises the issue of their role in the overall funding scheme.[62]

The qualitative approach outlined above should be complemented by an analysis of key metrics, such as: i) scientific publications and their forward citations; ii) patents and their forward citations; iii) follow-on funding, and iv) new firm foundation.

BOX 9

EU vs national funding to innovation

A closer look at the data shows that the EIC represents an important part of the overall (national and EU-level) funding of breakthrough innovations. This box also argues that an EU-wide selection mechanism has important advantages over national initiatives.

Public spending on R&D in the European Union is dominated by Member States. The EU level (mostly through its Horizon Europe programme with an annual budget of about €11 billion) accounts for roughly 1/10 of the combined public R&D expenditure by Member states. However, Horizon Europe – and the EIC in particular – are much more important in the area of funding breakthrough research.

The budgets of some of the most important national agencies with the official goal of funding transformative innovation appear quite modest. We focus on the three biggest Member States. Examples include in Germany SPRIN-D and the Agency for Innovation and Cyber Security (Cyberagentur), with respective budgets of €150 million and €70 million per year. In France, the Defense Innovation Agency (AID) has a yearly budget of around €1 billion, but little of this seems to be spent on DARPA-style projects. In Italy, ENEA has a yearly budget of roughly €150 millions, which is spent mostly on energy efficiency. The Franco-German Joint European Disruptive Initiative (JEDI) acts as a network, but does not have its own funding sources as shown by its balance sheet. The combined total available from national sources for low-TRL projects is thus of a similar order of magnitude as the EIC. The EIC, especially Pathfinder and Transition are thus an important part of the overall funding for breakthrough research in Europe.

There are a number of advantages with funding breakthrough research at the European, rather than national level: First, it expands the pool and diversity of applicants and evaluators. Second, the fact that ambitious R&D is bound to fail with non-negligible probability means that it is hard to conduct advanced research without risking a mediatic backlash if only few projects can be funded and several of them fail. The law of large numbers at the EU level makes this occurrence less likely. Finally, and most importantly, a European-level funding increases the physical, cultural, and social distance between the reviewers and those who originate the projects. This reduces the danger of cronyism and political influence in the selection process.

[62] In the United States, the "Fast Track Action Subcommittee on Critical and Emerging Technologies" is tasked with identifying critical and emerging technologies. See the report here.

BOX 10

Is the project potentially transformational?

- Does the programme/project hold potential to create "forks" in the technology roadmap that could change the conventional understanding of what is possible, practical, and profitable in applications with large potential impact?
- Does it reach for impacts that may be very far off but that may eventually result in faster learning curves and potentially disruptive entitlements?
- Does it bridge gaps in technological development that might otherwise prevent a particular research pathway from being advanced?
- Does it challenge a community to tackle barriers seen as too risky for rate of return–based investment decision metrics?
- Does it empower a community to challenge conventional wisdom regarding feasibility?
- Does it shake up "group think" and political or industrial establishments?
- Does it set aggressive targets that, if attained, could result in high impact?
- Does it create a stakeholder or technical constituency?
- Does it revisit a failed approach in the context of related supporting advances or changes in economic or other external factors?
- Does it fuse disparate technologies in novel ways?

Clearly, these metrics are not always a good measure of success. For instance, publications might be more suitable to evaluate funding to academic institutions; (quality-weighted) patents might be better measures for small companies than large ones, which might use results internally, and not all projects might result in startup formation. Moreover, a sufficiently long amount of time might be needed to properly evaluate the results of a project. Nevertheless, making available a dashboard with such measures can help forming a holistic view on the progress of a funded project.

Importantly, project-specific metrics should be compared against other similar projects – possibly from other EU financing schemes. This would allow to evaluate the effectiveness of ARPA-style programme management relative to more traditional programmes.

Case studies can complement the evaluation. One possible way, inspired by ARPA-E, is to form a portfolio of projects representing a mix of different recipients (e.g. academia vs private companies) and financing mode (open calls vs thematic calls). Beneficiaries can be asked about the status of their research before receiving funding, so to be able to form a "pre-post" type of analysis.

Appendix Figure 15 shows an example based on ARPA-E independent evaluation from the National Academies of Sciences (2017). In that example, Harvard University received an ARPA-E award of $2.750 million in 2013. A year and a half into the project, it raised $3 million in venture capital and in October 2014, the start-up company "SLIPS Technologies, Inc." was founded.

Data Sharing and Transparency

Finally, data on EU funded projects, as well as rejected applications, should be openly available to researchers interested in conducting evaluation exercises. The European Commission has already undertaken important steps in this direction by publishing the CORDIS dataset. However, the information provided is not always consistent across datasets and more granular information could be provided without undermining privacy concerns.

SUMMARY AND CONCLUSIONS

The first part of the report documents the sources of the transatlantic difference in business R&D. We show that European industry is skewed towards mid-tech sectors, which appears—alongside other possible explanations such as market fragmentation, weaker risk-finance, and differences in firm size distributions—to be an important proximate feature of the transatlantic R&D gap. This specialisation in mid-tech has persisted for decades, even increasing over the recent past, whereas the weight of different sectors has profoundly changed in the US. Possibly due to path dependency, the EU is thus failing to catch up in high-tech industries and with the AI and biotech revolutions. Moving away from the status quo requires public-sector intervention to encourage research in new technologies and to promote the development of EU high-tech industries.

The second part of the report examines the main body set up by the EU to boost breakthrough innovation: the European Innovation Council (EIC). We argue that in order for the EIC to be more effective and compete with its benchmark models on the other side of the Atlantic, it needs, first of all, a substantial restructuring of its governance. Specifically, the EIC needs less political decision-making, more highly qualified scientists and engineers on the EIC Board, and more programme managers who are experts in the fields of projects they manage. Programme managers should also be given more decision-making power. Top scientists and engineers could become involved in a redesigned, two-stage evaluation process.

Moreover, a large part of the EIC's budget currently goes to high-TRL activities and therefore does not support breakthrough research, but rather the upscaling of technologies by SMEs. In principle, the EIC was meant to support startups (i.e. firms no older than 4 years), but few of them are beneficiaries. This applies in particular to the equity investments by the Accelerator programme, which tend to support mature enterprises instead of breakthrough innovation.

The third part of the report illustrates the plethora of funding instruments in Horizon Europe, the flagship EU programme for R&D, and two formally independent initiatives, the European Innovation Fund and the European Defence Fund. We argue that while there are a number of funding sources nominally devoted to innovation, *de facto* most of this funding is earmarked for projects that are close to being commercially viable. These resources, including those currently allocated to the European Institute of Technology and European Innovation Ecosystem, could have a greater impact on innovation if they were transferred to the (reformed) EIC, or at least reassigned to the task of supporting ground-breaking innovation and managed accordingly.

Finally, the last part of the report formulates our policy proposal for a budget-neutral but radical restructuring of the EU ecosystem for innovation. If successful, the reform could improve the EU's innovation capacity and thereby help Europe move beyond its middle-technology trap, creating the basis for private investment in new sectors with higher growth potential. The aim is not to channel more resources into specific areas, but rather to create more space for innovation and economic dynamism across the board.

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THE EU INVESTMENT GAP IS REALLY AN R&D GAP

Journal of Industrial and Business Economics
Published: 12 July 2025
Volume 52, pages 667–682, (2025)

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ABSTRACT

This paper examines the prevalent notion of an "investment gap" in Europe. By using data from different sources, we come to three conclusion. First, as a share of GDP, overall investment is higher in Europe than in the US. Second, where Europe significantly lags is in intangible investments, especially in R&D and software. Third, this is due mainly to a composition effect, since European industry is concentrated in mid-tech sectors with low research intensity. We conclude that the current public financing initiatives at the national and EU level that focus mainly on tangible low-risk and thus low-return projects do not foster high-tech industries and innovation, and thus ultimately do little to increase long-term growth in Europe.

KEYWORDS: Investment Gap, Middle-Technology Trap, European Union, Industrial Composition, Tangible Investment, Intangible Investment

JEL Classification: L5 , O3

INTRODUCTION

A popular thesis in policy circles is that there is an "investment gap" that Europe needs to fill to face the great challenges of our times, such as the digital and green transitions (Draghi, 2024; Letta, 2024; Noyer, 2024; Schnabel, 2024). However, the notion of an "investment gap" used by policymakers is often vague and therefore it risks to legitimate a wasteful allocation of public resources.

Shedding light on the issue is important, especially in the context of the new *Political Guidelines* of the European Commission (von der Leyen, 2024), which see boosting investment as an important priority.

This paper examines investment data from different sources at varying levels of aggregation and reaches three main conclusions. First, as a portion of GDP, investment is higher in the EU than in the US. This is true for aggregate investment, as well as for three of its four components: dwellings, buildings & structures, and industrial machinery. The only category where the EU lags behind the US is in intangibles, mostly R&D and software development, where the gap is very large.

Second, this holds as well when focusing on investment *levels* in the business sector. Firms headquartered in the EU and in the US spend about the same on tangible capital. However, EU firms spend only 1/3 as much on R&D relative to firms in the US.

Third, the "R&D gap" is due to the high-tech industry in the EU being small compared to the US. The EU corporate sector specializes in mid-tech industries, such as automotive, with a lower propensity to invest in R&D (Fuest, Gros, Mengel, Presidente, & Tirole, 2024).

Public guarantee programs like the 2014 *Juncker Plan*, or more recently *InvestEU*, finance mostly large-scale tangible investment of the sort Europe already does abundantly. Instead, more support for intangible investment is what Europe needs to compete strategically with other geopolitical blocks.

If the objective of EU policymakers is technological leadership in digital and clean technology, then it should find ways to boost private R&D spending, which is much lower in the EU than in the US. This cannot simply be done by spending more on publicly-funded R&D, which is similar on both sides of the Atlantic.

What the EU needs is structural change, i.e. the development of high-tech industries. To do so, policymakers should create incentives for companies to invest in high-risk, high-reward projects outside of their current areas of specialization. There are a number of concrete, well-known areas for improvement in fiscal, corporate, labour law and the education system. The creation of a capital markets union—in particular reducing disincentives to invest in equity and start-up—combined with structural reform, would be much more effective in boosting innovation and long-run growth in the EU (Fuest *et al.*, 2024) than increased spending on infrastructure.

The rest of the paper is organized as follows. Section 2 presents the evidence against the notion of an EU investment gap; Section 3 links the R&D gap to industrial composition; Section 4 discusses potential underlying frictions. Finally, Section 5 concludes.

EXAMINING THE EU INVESTMENT GAP

To start with, it is useful to clarify which gap needs to be filled and to what purpose. Investment is defined in national accounts as expenditure that creates tangible or intangible assets yielding returns for more than one year. In official statistics this is called "gross fixed capital formation" (GFCF). Panel A of **Figure 18** presents data from Fund (2024b) on total investment—defined as gross fixed capital formation (GFCF) plus inventories—as a share of GDP for the EU27 and the US. Panel B displays AMECO data on GFCF excluding inventories (Commission, 2024). Both series include projections—up to 2029 for the IMF data and up to 2026 for the AMECO data.[1] A limitation of the IMF data is that it does not allow for the removal of inventories from total investment. However, GFCF data from AMECO (Panel B) and the OECD (available until 2022) show a very similar trend. Investment in the EU has closely tracked that of the US up to 2024—and even exceeds it in the case of the IMF's GFCF data.

Clearly, the investment rate fluctuates over time and the two series follow similar cycles. In the EU, investment dropped after the dotcom bubble and the Great Financial Crisis, to reach 23% in the years preceding the pandemic. After the COVID-19 crisis, investment in Europe spikes to 25% and in 2023—the last year for which actual observations are available—goes back to 23%, remaining stable thereafter according to the projections. Thus, IMF data say that today, investment in the EU is in line with its long-run average value, and even above the US.

AMECO projections, available until 2026, suggest that the US maintains a slightly higher GFCF-to-GDP ratio in recent years, roughly one percentage point difference. This can hardly be considered a significant long-term investment gap between the EU and the US.

2.1 Estimating the Returns on Investment in Europe

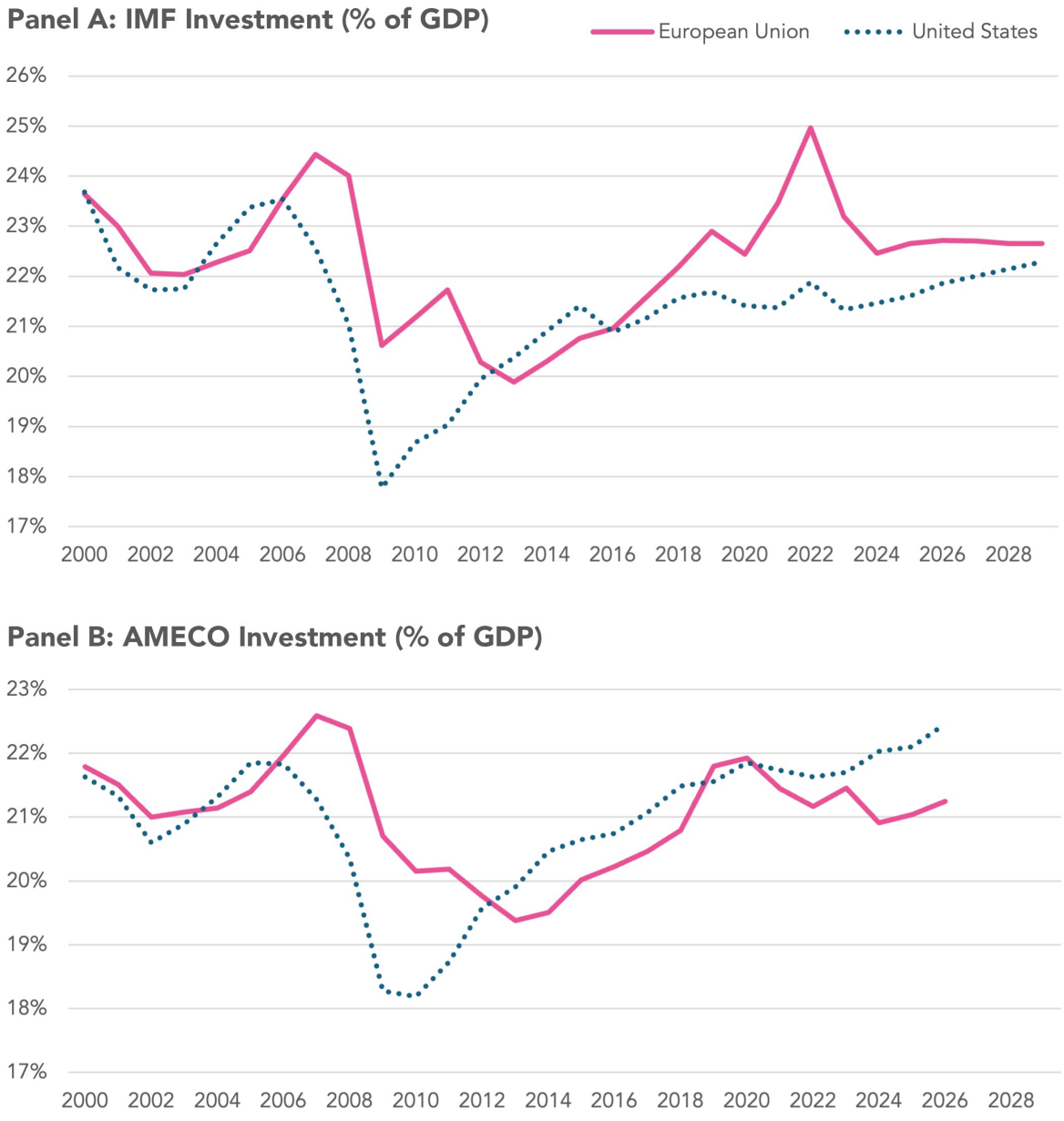
A common argument is that more investment is always better because it increases the capital stock and thus output. However, this view is incorrect. Basic economic principles, such as to invest more when the returns to investment are high, suggest that the optimal level of (domestic) investment is at the point in which the marginal product of additions to the domestic capital equals the rate of return on the global market.

Taking the US as the global benchmark, one can assess how the EU compares. A marginal product on domestic investment higher than the global benchmark would imply that there is an investment gap relative to the optimum, while a lower one would imply that investment in the EU is too high.[2]

[1] Our primary reference is the IMF data, as it provides five-year projections. The data are available at https://www.imf.org/en/Publications/WEO/Issues/2024/04/16/world-economic-outlook-april-2024

[2] We implicitly assume diminishing returns to capital, implying that the marginal product of capital declines with additional investment.

Figure 18 Investment (in % of GDP)



Source: Fund (2024b) & Commission (2024).

At the macroeconomic level, one can measure the return on investment by dividing the change in GDP divided by the change in capital stock:

$$MPK \approx \left(\frac{\Delta K}{\Delta Y}\right)^{-1} \quad (1)$$

where $\Delta X = X_t - X_{t-1}$ denotes yearly changes of a variable X.

We estimate the US and EU aggregate capital stocks using IMF data on GDP and Investment.[3]

[3] Consistent with common practice in the literature, we assume a depreciation rate of 0.06 and use the perpetual inventory method. To compute the initial capital stock, we follow Caselli and Feyrer (2007) and calculate $K_0 = I_0/(g + \delta)$, where I_0 is the value of

Based on Equation (1), Panel A of **Figure 19** shows the estimated returns on investment for the EU and the US (the global market benchmark) between 2004 and 2029, averaged over 5-year intervals to remove the influence of cyclical fluctuations. Specifically, we divide the GDP change between years t and $t+5$ by the average value of the change in capital between years t and $t-5$.[4]

With the exception of a short period from 2003 to 2006, the return on domestic investment tends to be much lower in the EU than in the US. Over the years of the sample, the average returns are 9% in the US and 6% in Europe. Thus, contrary to the narrative that there is an investment gap, the evidence suggests that investment in the EU is already too high. Moreover, the rate of return of additional investment is very unlikely to be higher than the rate of return on existing investment, because investment projects that have not been undertaken so far are likely to have lower returns than those already currently undertaken.

We conduct two robustness checks. First, we replicate the analysis using AMECO data (see Panel B of **Figure 19**). Although the AMECO series yields a slightly higher investment-to-GDP ratio, the estimated marginal returns on investment remain unchanged. Second, we compute the inverse ICOR based on the capital *stock* rather than on the *flow* of investment (see Panel C of **Figure 19**). Specifically, we employ a standard measure of the capital stock derived via the perpetual inventory method. Overall, the results remain robust, as the return on investment is consistently higher in the US than in the EU. Notably, only during the initial years—from 1999 to 2006—does the stock-based measure suggest a higher inverse ICOR for the EU.

Although none of these estimates have a causal interpretation, the evidence suggests that it is doubtful that additional investment incentivized through public guarantees programs would increase growth.

2.2 Are EU Savings Wasted?

An important corollary is that the notion of EU savings being somehow "wasted" because they are invested abroad, as suggested in Letta (2024), is mistaken.

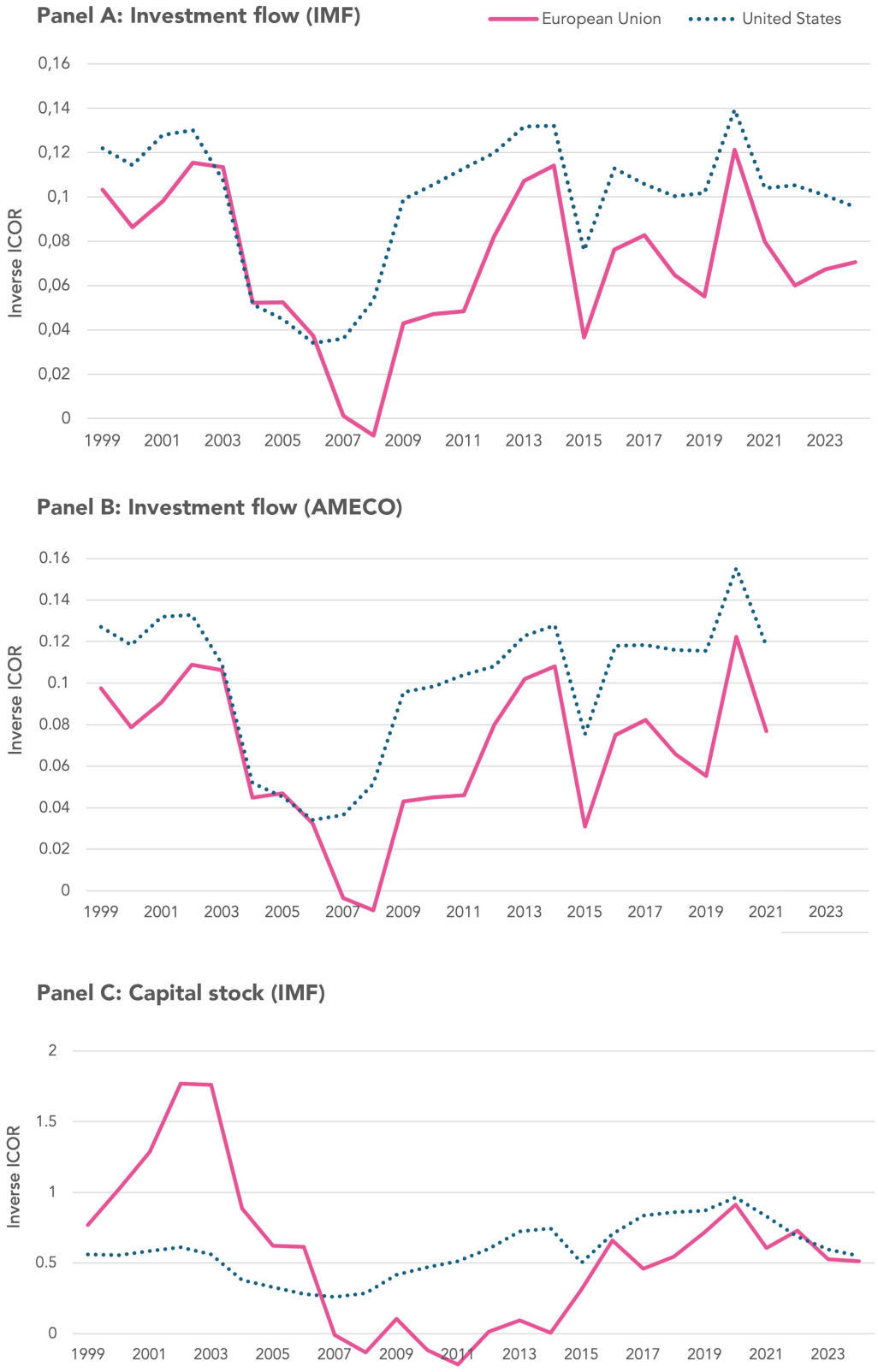
Figure 20 shows that domestic savings in the EU are higher than domestic investments, by about 2-3% of GDP. These "excess savings" are reflected in the EU external current account running at about 300 billion euros annually.[5] But it does not follow that EU growth would increase if only these 300 billion euros were invested in the EU, because as shown in the previous section, investment is already inefficiently high. If these 300 billion euros were invested domestically, instead of abroad, EU GDP would increase marginally (as pointed out above) but EU GNP would be lower (the loss in income from abroad would be higher than the gain in GDP). The different rates of return on investment estimated

investment in the first year with available data, g is the average geometric growth rate of investment between that year and 1970, and δ is the depreciation rate.

[4] We assume that actual GDP approximates potential GDP over the years of the sample.

[5] Inventories might be relevant for a comparison of investment to savings. Therefore, this figure uses GFCF data from OECD, which is limited to 2022.

Figure 19 Estimated return on investment (5-years rolling average)

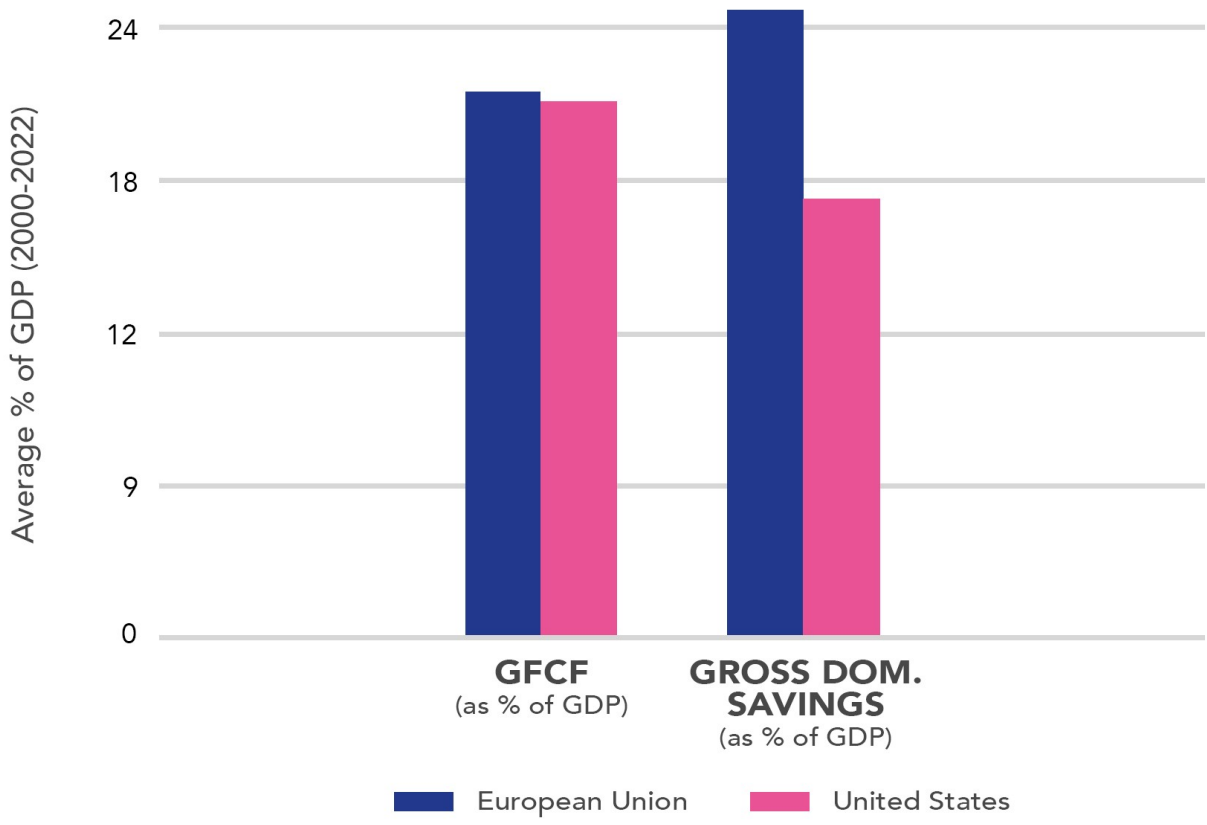


Notes: Panel A & B present the inverse of the Incremental Capital Output Ratio (ICOR), calculated as average GDP growth between years *t* and *t* + 5, divided by the average value of investment-to-GDP ratio between years *t* and *t*– 5. Panel C calculates the inverse ICOR as the average change in GDP growth between years *t* and *t* + 5, divided by the average change in capital stock—computed by the perpetual inventory method.

Source: Author's calculations based on Fund (2024b) & Commission (2024).

above—roughly 3 percentage points—imply an opportunity cost of investing EU savings at home of (300 × 0.03) 9 billion euros annually. If European savings are bottled up like this for ten years, the annual loss would increase to 90 billion euros—about the same amount the EU will spend on imports of natural gas this year.

Figure 20 Investment & savings as percent of GDP (2000-2022)



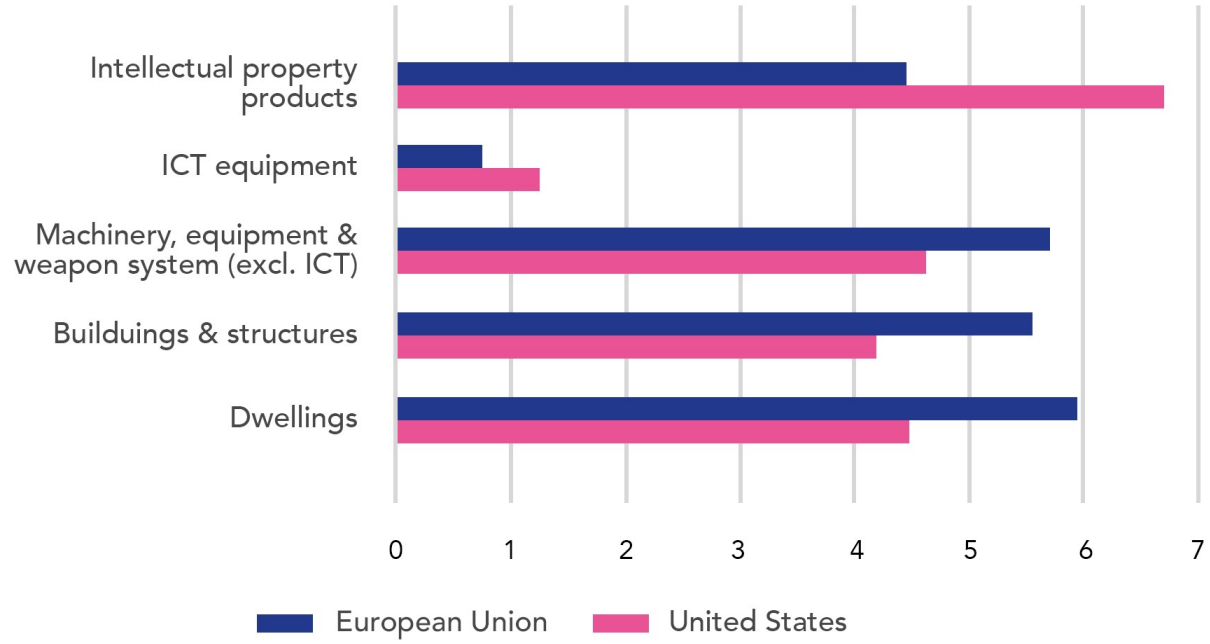
Notes: Data extracted on 16 May 2024 17:15 UTC (GMT). *Source:* OECD (2024)

2.3 A Rather Intangible Investment Gap

The aggregate investment figures on investment discussed so far might mask important sectoral differences. In **Figure 21**, we break down GFCF into its main components: dwellings, building & structures, industrial machinery and its subcategory ICT equipment, and intellectual property products (all figures are expressed in percent of GDP). The main message is that the EU invests a larger fraction of its GDP in all sectors, except ICT equipment and intellectual property products, where the US level is roughly one-half higher.

The assets included in these sectors are subject to strong complementarities, such as between R&D, software development and ICT infrastructure. This kind of investment is mostly private, and it receives little public support because the kind of investment that the EU intends to mobilize with its public guarantee programs— e.g. the *Juncker Plan* or the more recent *InvestEU*—is mostly devoted to large-scale infrastructures.

Figure 21 Breakdown of GFCF main components



Notes: Data extracted on 16 May 2024 17:15 UTC (GMT).
Source: OECD (2024)

2.4 Investment Gap or R&D Gap?

To analyse in more detail the composition of business investment, we turn to the EU Industrial R&D Scoreboard, which unlike the national accounts data used above, provides a reasonably granular industry breakdown.[6]

Figure 22 presents business capital expenditure (CAPEX) and business R&D spending (BERD) by EU-headquartered companies. In absolute terms one finds a gap in CAPEX—mostly tangible assets—of less than 100 billion euros. Considering that the US is roughly 50% larger in terms the GDP, one cannot really claim that there is a gap in private capital investment, which is only 30% higher in the US. On the contrary, relative to the size of the EU economy, business CAPEX is somewhat higher in the EU than in the US.

The real gap is in R&D, where the amount invested by private companies in the EU amounts to only 200 billion euros—1/3 of the amount invested by US companies. The investment gap turns out to be really a R&D gap.

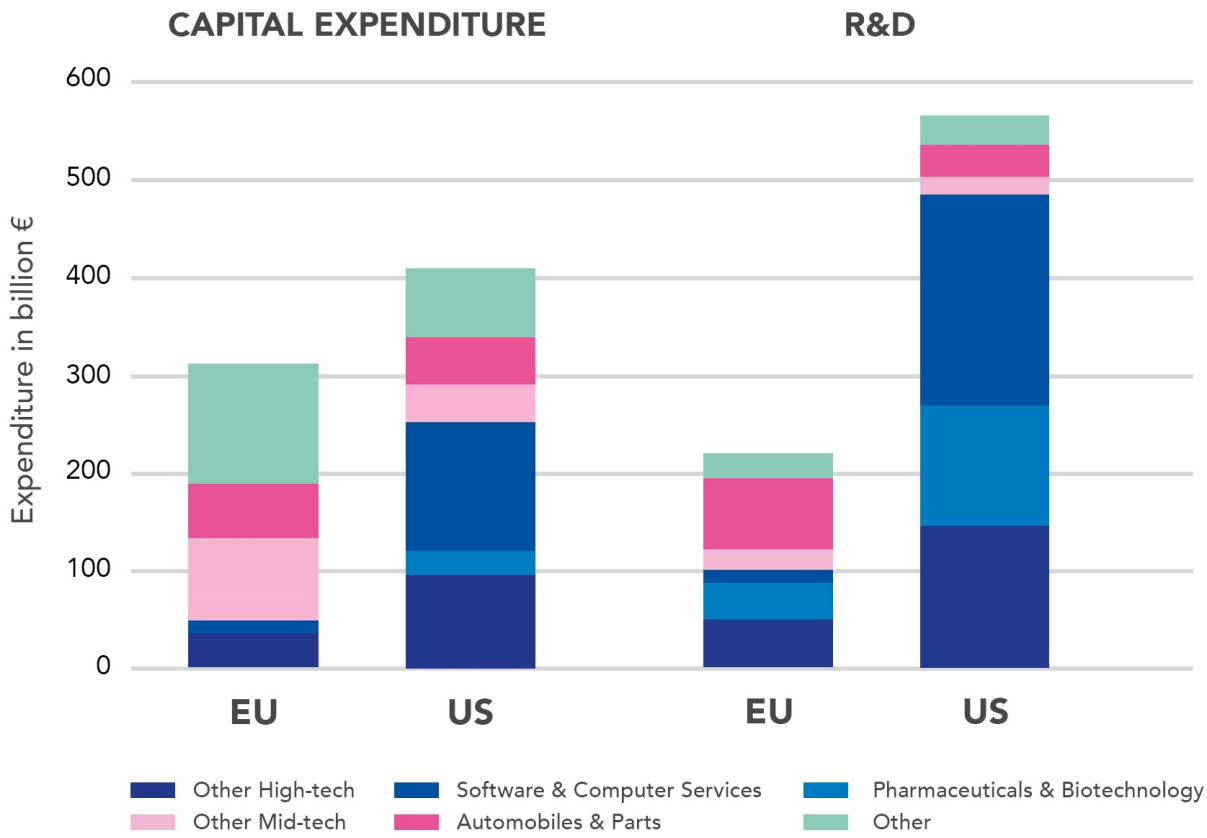
The Middle-Technology Trap

Section 2.4 shows that the transatlantic investment gap can be mainly explained by lower aggregate R&D expenditure from the business sector in Europe compared to the US. Looking more closely, much of this R&D gap is due to structural differences in industry *composition*. **Figure 22** shows the sectoral composition of BERD in Europe versus the US and illustrates how the European corporate sector specializes in mid-tech industries—

[6] The data are based on the accounts of the 2,500 largest global companies in terms of R&D spending. A cross-check with the OECD data shows that these 2,500 companies account for 80 to 90% of the total, making the data broadly representative. The data can be found at: https://iri.jrc.ec.europa.eu/scoreboard/ 2022-eu-industrial-rd-investment-scoreboard.

mostly automotive.[7] Fuest *et al.* (2024) call this the "middle technology trap". Companies in mid-tech industries make up almost 50% of European BERD (34% alone from the automotive industry), which compares to only 10% in the US.

Figure 22 CAPEX and BERD by industry sector



Source: Author's calculations based on EU Industrial R&D Scoreboard (2023). The analysis considers the global top 2,500 companies.

The preponderance of mid-tech companies raises a number of concerns. First, these companies are substantially less R&D-intensive than companies in high-tech sectors, such as software and biotech, where the US is the undisputed leader. If one starts from the premise that high-tech industries are inherently more R&D intensive than mid-tech or low-tech industries, one can distinguish two effects that drive the transatlantic R&D gap: an

[7] In order to distinguish high- and mid-tech industries, we use a classification similar to the one adopted by Eurostat and the OECD:

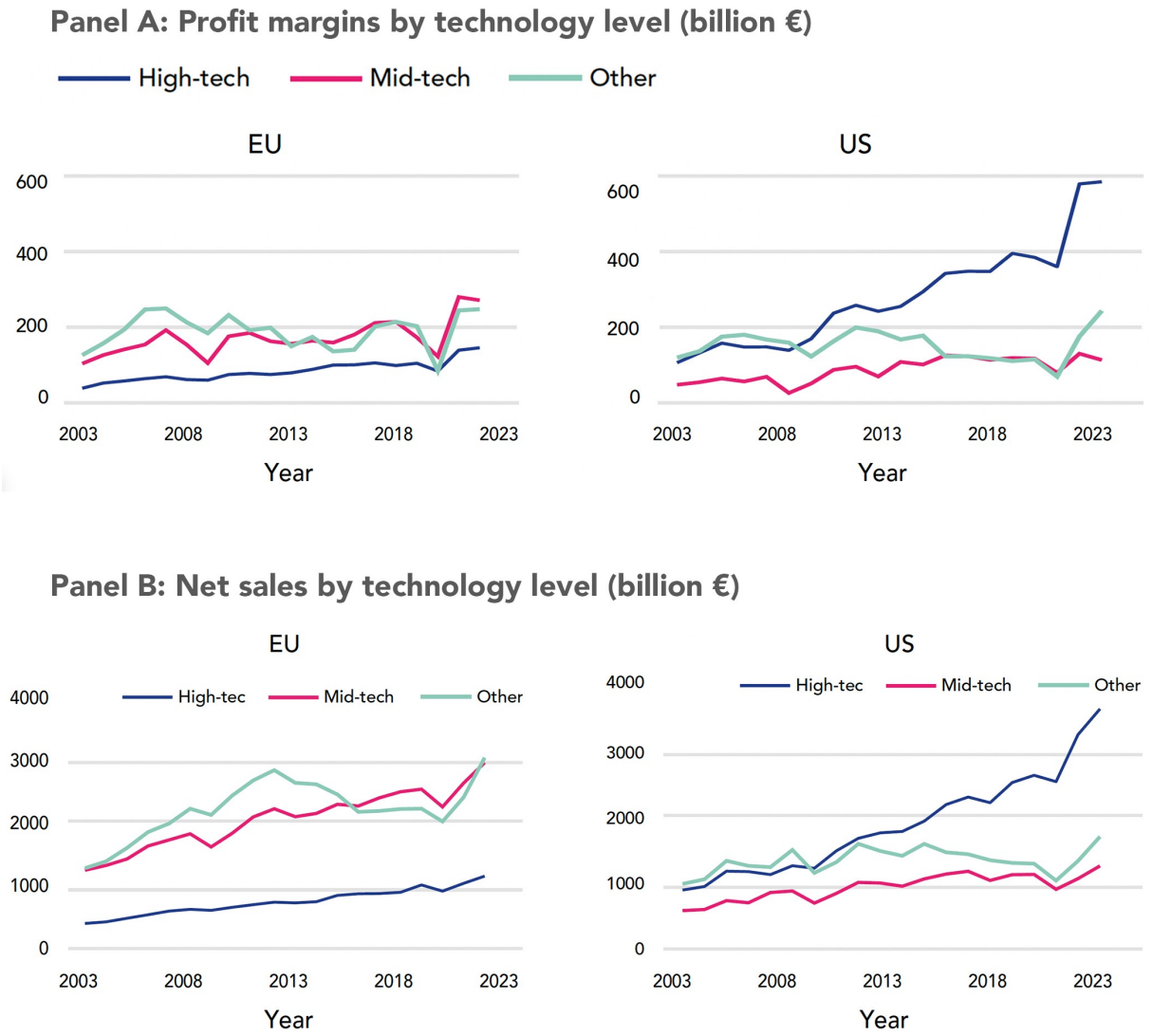
- **High-tech** includes aerospace & defence, alternative energy, electronic & electrical equipment, health care equipment & services, pharmaceuticals & biotechnology, software & computer services, and technology hardware & equipment.
- **Mid-tech** includes automobiles & parts, chemicals, financial services, fixed line telecommunications, industrial engineering, industrial metals & mining, industrial transportation, leisure goods, mobile telecommunications, and personal goods.
- **Other** includes banks, beverages, construction & materials, electricity, food & drug retailers, food producers, forestry & paper, gas, water & multiutilities, general industrials, general retailers, household goods & home construction, life insurance, media, mining, nonlife insurance, oil & gas producers, oil equipment, services & distribution, real estate investment & services, support services, tobacco, and travel & leisure.

industry composition effects and an R&D underinvestment effect. Fuest *et al.* (2024) find that in 2022, 60% of the gap could be attributed to differences in composition (since the R&D-intensive high-tech industry is larger in the US), while 40% can be explained by a generally higher R&D intensity in the US across all industries.

Data from the EU Industrial R&D Scoreboard suggest that companies in high-tech spend 1.5 euros on innovation funding for each euro of capital investment, while only 0.5 euros is spent in mid-tech sectors. Therefore, a policy-induced injection of the kind of tangible investment "mobilized" by the usual public guarantee programs is unlikely to generate much private R&D spending, which is what it would take to fill the investment gap documented in the previous sections.

Furthermore, firms in high-tech industries tend to grow substantially faster in terms of both profits and revenues, as illustrated in **Figure 23**. This dynamic may help explain why Europe has struggled to cultivate global tech champions on a scale comparable to that of the US.

Figure 23 Profit margins and net sales over time



Source: Author's calculations based on EU Industrial R&D Scoreboard (2023). The analysis considers the global top 2,500 companies.

Finally, a few large mid-tech companies in Europe can shape the rest of the endemic value chain. For example, the German economy is largely influenced by hidden champions—medium-sized automotive suppliers that focus on mid-tech niche products that are compatible to the production of automobiles. And even the domestic chip industry (e.g. Infineon) produces mostly automotive-compatible semiconductors rather than smaller cutting edge logic chips.

3.1 Public R&D Funding and the Missing Crowding-in

The R&D gap can hardly be attributed to differences in public funding. In 2020, for instance, government-funded R&D spending (GERD) amounted to 110 billion euros in the EU and 150 billion in the US, accounting for a very similar percentage of GDP, around 0.7-0.8%. Moreover, there are no substantial differences in government tax support for BERD either, since, according to the OECD this amounts to about 0.1% of GDP for the EU and 0.12% of GDP for the US.[8] Instead, the key reason is the low business sector engagement with R&D. In the EU, the ratio of private to public GERD spending is 1.8, while in the US it is over 3. Once again, this is not surprising given the industrial composition of the EU, where the incidence of mid-tech industries that are not R&D-intensive is very large.

3.2 Why is High-Tech so Small in the EU?

A popular argument is that EU financial markets are fragmented and so there are binding financial constraints. According to this line of arguments, EU companies might struggle finding capital, as a large fraction of European household savings are

diverted from European markets towards the US. However, as documented by the above analysis, the EU corporate sector as a whole invests as much as the US one.

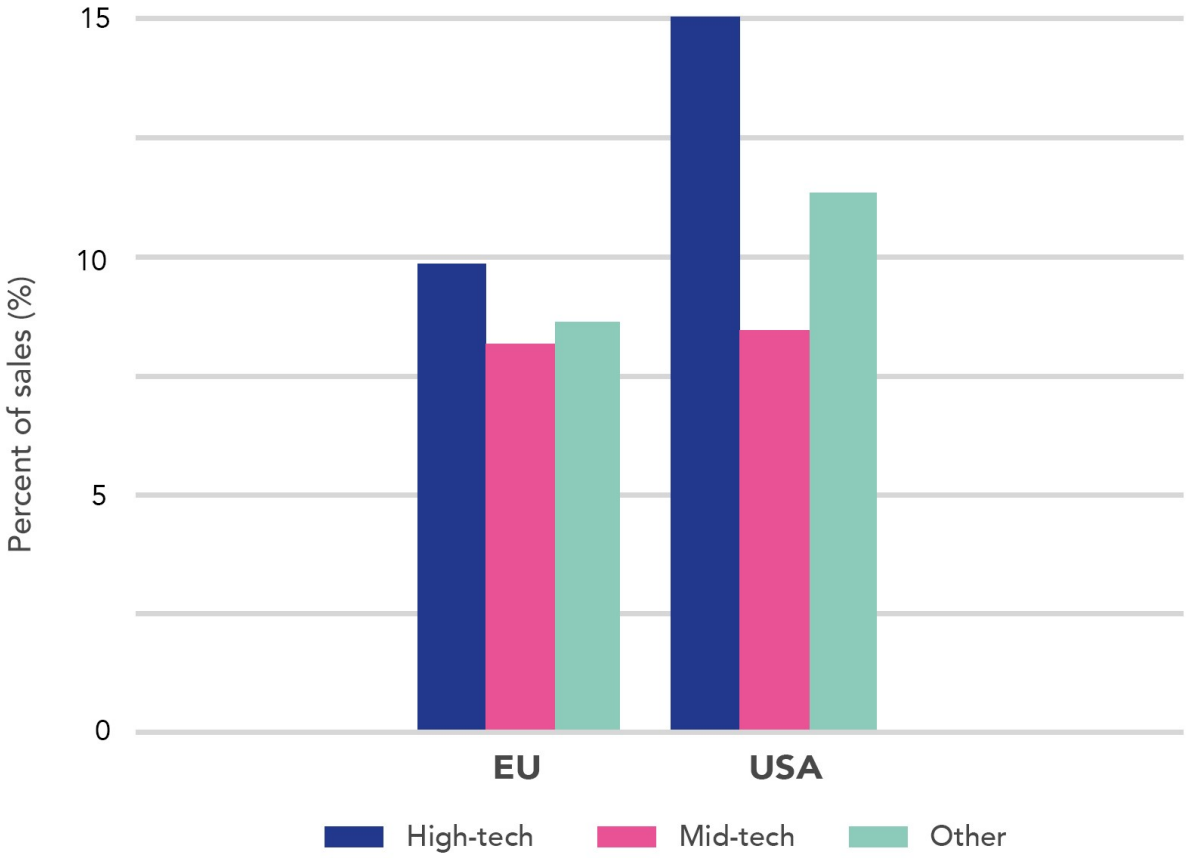
The real problem is that the EU ecosystem does not provide the right incentives to invest in the high-risk, high-reward projects that are typically pursued in high-tech industries. We provide two key pieces of evidence. First, data from Grassano *et al.* (2022) suggests that over 80% of venture capital investment by EU-based large companies—which are unlikely to be financially constrained—finance US-based startups. In light of the fact that EU companies specialize in industries such as automotive, which have a limited technological content and growth prospects, it seems thus unsurprising that EU investors interested in high-growth potential industries would find more interesting opportunities in the US.

The second piece of evidence is presented in **Figure 24**. On average over the last twenty years, the profit margin of high-tech industries was about 2 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. The small difference in profitability is likely to hamper the incentives to invest outside of the safer mid-tech industries in the EU.

The issue thus appears to be not only on the supply-side, but also on the demand side of capital markets, an issue of missing opportunities.

[8] See the OECD INNOTAX portal.

Figure 24 Average profit margin by sector (2003-2022)



Notes: Profit margin is defined as profits divided by net sales.

Source: Author's calculations based on EU Industrial R&D Scoreboard (2023). The analysis considers the global top 2,500 companies.

DISCUSSION: POTENTIAL UNDERLYING FRICTIONS

Clearly, the root causes of the more abundant investment opportunities for venture capital in the US are to be found at a more granular level. In this section, we review the existing literature to identify some underlying frictions that help explain why the return on domestic investment in the EU—as measured by the ICOR—tends to be much lower than in the US.

One argument brought forward by Coatanlem (2024) is that inefficient fiscal, corporate, and labour laws in the EU often hinder start-up formation and innovation. The argument goes as follows: even if one assumes that the probability of failure is similar for start-ups in Europe and the US, venture capital funds might be more reluctant to invest in Europe if the foreseeable losses in the event of failure are significantly higher. This is mainly due to restructuring costs which are up to ten times higher for companies in most European countries compared to the US (Coste & Coatanlem, 2023). Since the profitability of venture capital funds is mainly determined upon the exit of a start-up—e.g. an IPO to the stock market—there exists an a-priori transatlantic valuation gap which directs venture capital away from Europe.

Another root cause stems from the university system. While many European universities are front-runners in basic research, they often fail to translate scientific and technological breakthroughs into commercial applications (Office, 2024). This might be due to the fact that the European university system often fails to provide incentives for researchers to participate in applied innovation, but also because entrepreneurship is very rarely taught at the undergraduate-level (Fuest *et al.*, 2024). Strengthening collaborations with the industry, facilitating patent applications, promoting spin-offs into new firms, and offering general entrepreneurial training could facilitate the conversion of ideas and help universities becoming more entrepreneurial entities—an idea which is not new in the academic literature (Slaughter & Leslie, 1997). The much-lauded German dual system—that combines vocational university education with apprenticeships in a company—might serve as a blueprint for that.

The absence of a single EU market for key high-tech technologies—such as defense, AI, energy, and healthcare—could also play an important role (Letta, 2024). For example, the aerospace & defence industry constitutes one of the few sectors where European business expenditure on R&D is nearly as high as in the US (8.7 billion euros versus 9.4 billion euros). However, looking at the overall market size, the European aerospace & defence industry reports only half as many net sales (140 billion euros) compared to the US (260 billion euros). This suggest that even for industries where Europe possesses a comparative advantage, market fragmentation within the EU (and the limited role of joint procurement) still constitutes the biggest obstacle to keep up with foreign competitors.

Moreover, the bank-centric structure of Europe's capital market favours investment in tangible and less-risky assets, especially structures, that can serve as guarantees for bank credit (IMF, 2024a). By contrast, the equity market—which participates in both losses and gains from entrepreneurship—is more likely to fund high-risk, high-return projects involving intangibles and cutting-edge technologies. The US equity market is a case in point.

The importance of unifying Europe's splintered capital markets has been known for a long time. However, little has been done due to the fact that policymakers in individual Members States prefer to maintain their local capital market, which gives them some influence, rather than agree to reforms that would favour the creation of a unified market (Smaghi, 2024). Thus, we join Letta (2024), Schnabel (2024) and Noyer (2024) in calling for implementation of the so-called "capital markets union". While not a panacea for the structural issues the EU faces (Fuest *et al.*, 2024), without any reform of the European capital market, additional investment would yield the same low returns observed over the last decades.

Finally, it is not only the splintered nature of the European capital market that limits investment in higher yielding projects, but also the widespread preference of European savers for fixed income securities and bank accounts. These deep-rooted preferences cannot be changed by official action. But it would be possible to lessen the existing disincentives for professional investors like pension funds and insurance companies to

invest in equity in general and in start-ups in particular.[9] One way to do this would be to allow pensions funds and insurance companies to invest at least a small part of their overall funds in venture capital and private equity. This was done in the US when the supervisors of retirement plans recognised that a "prudent person" could invest at least a small part of the portfolio in risky assets, like venture capital. Something similar should be done in Europe. By enabling EU pension funds and insurance companies to allocate even a modest share of their assets to venture capital, the currently limited supply of start-up capital could be substantially enhanced.[10]

CONCLUSION

In a recent speech, former European Central Bank President Mario Draghi said that the European Union needs to invest an "enormous amount of money in a relatively short time" to deal with the deep challenges the bloc is facing (Strauss, Fleming, Romei, & Arnold, 2024). Our analysis suggests that the key issue for the EU is not how to find an "enormous amount of money", but rather how to re-direct the enormous domestic savings that are available towards more productive investment.

A recent proposal suggests to extend public guarantees to European private debt funds (Letta, 2024). But guarantee programs such as in *InvestEU* are unlikely to yield large returns. The problem with this approach is that public guarantee programs mobilize investment in infrastructure and industrial equipment of which the EU has at least as much as the US, while the important investment gap is mostly in intangibles and R&D. To fill this gap, what is needed is creating incentives to invest in highrisk, high-return projects, incentives currently hampered by a number of institutional frictions.

For this reason, "more of the same", i.e. just more investment without radical changes in capital markets and economic structures that hold back innovative firms, will only lead to more of the same result, i.e. low growth.[11] Additional resources devoted to innovation would certainly be welcome, but there is little prospect that Member States or the EU are likely to find room in their budgets for more more funding for research. Funding tangible industrial and infrastructure projects is politically more attractive, but, without structural change, unlikely to boost long-run growth in the EU and improve its geopolitical relevance.

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[9] While European households hold 34% of their assets in deposits and currency, in the US it is only 14% (Christie, McCaffrey, & Pinkus, 2024). Furthermore, looking at the composition of household portfolios, countries like Denmark, the Netherlands and Sweden exhibit a similar distribution of financial assets compared to US households all countries with large mandatory pension funds.

[10] See, for example, Scott Marcus (2024), "Europe can produce its own tech giants–here's how", available at https://www.ceps.eu/europe-can-produce-its-own-tech-giants-heres-how/.

[11] This does not imply that demand-side policies should be discarded, nor that public investment is ineffective. In fact, a substantial literature documents the positive growth effects of public investment and the dynamic role of fiscal policy in shaping private-sector behaviour (see, e.g., Zezza and Guarascio [2024] and Ciaffi, Deleidi, and Mazzucato [2024]). Assuming a complementarity between demand- and supply-side measures, our evidence suggests that alleviating the EU frictions discussed in the previous section would enable public investment to more effectively stimulate private investment.

We are not the first to notice that the notion of an investment gap is elusive (Sandbu, 2024), and that policymakers should focus on the composition of investment, rather than simply on its level (Letta, 2024). We hope to reinforce these messages. The risk is that, as one of us noticed ten years ago in different circumstances (Gros, 2014), public spending will have a temporary boost on demand today, but at the expense of demand tomorrow.

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II.

THE EFFECTIVENESS OF R&D GRANTS

THE TYRANNY OF CORPORATE CONTROL

Ownership Structure and The Effectiveness of R&D Grants to Small Firms

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ABSTRACT

This paper provides causal estimates of the long-run impact of European R&D grants to small and medium-sized enterprises and shows that the effects are mediated by recipients' ownership structure. We exploit a quality label awarded by the European Commission to high-scoring R&D grant proposals that could not be funded due to budget constraints and find that subsidies have a positive and significant long-run impact on productivity when the recipient has no corporate shareholder or is owned by individuals. In contrast, the effect is at best muted for controlled subsidiaries owned by other corporations. The mediating role of the ownership structure is not driven by firm size, and the results are robust across a battery of alternative performance measures.

INTRODUCTION

Over the past decade, the fiscal cost of research and development (R&D) subsidies has approached €1 trillion in the European Union. During the same period, the United States—where publicly funded R&D represents a similar share of GDP—spent at least as much.

The existing causal evidence suggests that R&D subsidies can be effective in boosting recipients' performance (Bloom *et al.*, 2019; Howell, 2017; Howell *et al.*, 2021; Santoleri *et al.*, 2022), especially among young and small companies. In light of its immediate policy application, teasing out size-related heterogeneity is a major contribution of this literature.

The aim of this paper is extending the empirical evidence to another policy-relevant and targetable dimension of heterogeneity: ownership structure. Specifically, we ask whether the impact of R&D grants vary depending on whether the recipient is a controlled subsidiary or an independent company.

Ownership structure may affect the additionality of a subsidy through several channels. Unlike independent firms, subsidiaries of corporate groups can rely on internal capital markets and may therefore face weaker financing constraints (Gertner *et al.*, 1994; Shin and Stulz, 1998). Firms embedded in corporate networks might be in a better position to "game" the system, securing support without meaningfully changing their operations (Criscuolo *et al.*, 2019). More broadly, controlled subsidiaries and independent companies differ markedly in shareholder composition and governance (Demsetz and Lehn, 1985; Bertrand and Mullainathan, 2003; Shleifer and Vishny, 1986), which can have an impact on the allocation of subsidy-funded resources.

To study the issue empirically, we build a novel dataset linking the universe of R&D grants disbursed by the European Commission since 2014, to rich firm-level data on recipient companies, including detailed information on ownership structure and shareholder characteristics.

We focus on a specific program that supports small and medium-sized enterprises (SMEs), for which we have a list of companies awarded the *Seal of Excellence*—a quality label granted to high-ranking project proposals that ultimately did not receive funding due to budget constraints.[1] This institutional feature provides a credible comparison group and enables us to estimate the causal effects of receiving a grant.

Crucially, for each beneficiary firm we observe ownership and shareholders' characteristics. This allows us to assess how the causal impact of the grant on firm performance varies with ownership structure.

Our baseline metric of performance is Total Factor Productivity (TFP), which we measure using revenue-based data. In our context, the advantage of revenue-based TFP is that it compactly captures efficiency, product quality, variety and price/markup effects more

[1] See also https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/ seal-excellence_en

broadly. R&D grants can plausibly affect all these dimensions through innovation-related activities, which are otherwise difficult to measure independently.

Based on this setup, we study the causal impact of R&D grants on productivity.

We make three main contributions. The main contribution is providing causal evidence that impact of R&D grants on performance is mediated by ownership structure: grants have a positive and significant long-run impact on productivity for independent companies, but not for controlled subsidiaries. The result is robust across a battery of alternative TFP and performance measures, such as patents and revenue growth.

The second contribution is extending the causal evidence on R&D grants to the European context, as most existing papers focus on the United States (Bloom *et al.*, 2019; Howell, 2017; Howell *et al.*, 2021). One exception is Santoleri *et al.* (2022), which studies the same SME support program examined in this paper. However, we have access to longer time series. Consequently, the third contribution of this paper is provide long-run causal estimates of the grant.

The rest of the paper is organized as follows: Section 2 presents the institutional setting; Section 3 and 4 describe the data and ownership structure respectively; Section 5 presents the empirical approach; Section 6 presents the results, and Section 7 concludes.

INSTITUTIONAL SETTING

The Framework Programmes are the European Union's multi-year funding cycles for research and innovation. Beginning with Horizon 2020 (2014–2020), the EU introduced dedicated instruments to support SMEs more directly.[2]

The main programs supporting SMEs are the *SME Instrument* (2014–2020) and the *EIC Accelerator* (2021–present), both providing EU support for innovation-driven SMEs.[3]

There are close similarities between the two programs. In both cases, the objective is developing a product, process, or service that can be readily commercialized.

The programs are endowed with a similar budget of approximately €3-4 billion over seven years. SME Instrument was rolled out by the Executive Agency for SMEs (EASME), which evolved into the European Innovation Council and SMEs Executive Agency (EISMEA) now administrating the EIC Accelerator.

Under both SME Instrument and EIC Accelerator, firms can access grants up to €2.5 million. Eligible R&D activities covered a broad set of late-stage innovation tasks,

[2] Before Horizon 2020, SME support was fragmented and largely embedded within other programs rather than a consolidated accelerator-like scheme.

[3] Another program, Fast Track to Innovation (2015–2020) provided grants to consortia of at least three entities–often including SMEs–supporting close-to-market technologies through collaborative development rather than single-firm acceleration. Because funding is awarded to multi-beneficiary consortia, it is difficult to isolate the causal impact of the grant on any single firm, so we exclude this program from our analysis.

including prototyping, testing, design, performance evaluation, demonstration, piloting, validation for market replication, scale-up, and application development.

One notable difference is that previously under the SME Instrument, applicants could receive limited grant support for preparatory activities of €50,000 (Phase 1), while full proposals could be awarded grants of up to €2.5 million to fund activities such as demonstration, piloting, validation, and scale-up (Phase 2). Phase 1 grants have been discontinued under the EIC Accelerator, which only provides grants after a successful full proposal and interview stage.

The program duration is typically between six and a maximum of twenty-four months, although there is no minimum program duration for the EIC Accelerator.

Under the SME Instrument, firms applied to specific calls by submitting a thirty-page proposal containing a business plan and a description of the planned activities; proposals were then evaluated remotely by four independent experts appointed by EASME. The EIC Accelerator follows a broadly similar logic—supporting high-impact innovations close to market—but uses a multi-stage evaluation process. Applicants first submit a short proposal (including a pitch deck and video), which is screened remotely by expert evaluators. Successful applicants are invited to submit a full proposal with a detailed business plan and work plan, evaluated again by independent experts. Projects that pass this stage proceed to an interview with an EIC Jury before funding decisions are made. Unlike the SME Instrument's fixed calls, the EIC Accelerator operates a continuous submission system with periodic cut-off dates.

Submissions are deemed eligible when three criteria are met: (i) the applicant must be a profit-oriented SME, (ii) it must be legally based in an EU Member State or a Horizon-associated country, and (iii) it cannot be simultaneously submitting or carrying out another project under the SME Instrument.

For our framework, it is important to focus on the definition of SME as part of criterion (i). The European Commission defines SMEs as firms with fewer than 250 persons employed and either an annual turnover of up to €50 million or a balance-sheet total of no more than €43 million. Under the EU's SME definition, ownership structure is a key determinant of SME status, distinguishing between autonomous, partner, and linked enterprises. An enterprise is considered autonomous if no other enterprise holds 25% or more of its capital or voting rights; holdings at or above this threshold generally create a partner relationship, requiring proportional aggregation of financials and employment. Full linkage arises when there is control—such as majority voting rights, the power to appoint management, or dominant influence through contractual arrangements—in which case 100% of the linked entities' data must be consolidated. Importantly, certain investors (e.g. venture capital firms, business angels below a specified investment ceiling, universities, and regional development funds) may exceed the 25% threshold without compromising autonomy, provided they do not exercise control. By contrast, enterprises that are 25% or more owned by public bodies are excluded from SME status altogether. This ownership-based framework is designed to ensure that only genuinely independent and economically constrained firms benefit from SME-targeted policies.

DATA

The analysis is based on a novel dataset that links information on European Commission funding—extracted from CORDIS, the official repository covering all grants awarded between 2014 and 2024—to balance sheet data on recipient firms, sourced from Bureau van Dijk's ORBIS IP database (ORBIS henceforth). Online Appendix C presents the details of the matching procedure between CORDIS and ORBIS. We clean balance sheet data from ORBIS by following the standard procedure of Kalemli-Özcan *et al.* (2024).

We focus our analysis on the SME instruments, i.e. EU programs funding SMEs. As mentioned in Section 2, there are two main instruments devoted to SMEs funded by the European Commission. We combine these into a single consolidated program spanning 2014 through the last year of our sample.[4] To ensure that our sample includes only beneficiaries that received a single grant, we drop the 587 firms that obtained both Phase 1 and Phase 2 funding under the SME Instrument (10% of the sample).

Ownership and Shareholder Data

We rely on two sources of ownership information provided by ORBIS. First, each company is assigned a single "entity type", a categorical variable distinguishing between "independent company" and "controlled subsidiary". The labels of controlled subsidiary is assigned by Bureau van Dijk depending on whether there is an identified shareholder with over 50% direct ownership, or the company is identified as a branch or foreign. Independent companies are those with no identified shareholder with over 25% ownership share.

We complement the data with ORBIS' ownership module, which provides information on beneficiaries' complete shareholder structure and their corresponding ownership shares, distinguishing by shareholder type. Details on the shareholder data cleaning process can be found in Appendix C.

Appendix Table 5 presents ownership shares by type of shareholder. The most frequent shareholder types are "Corporate" and "One or more individuals or families". We focus on contrasting these two types of ownership because individual shareholders such as founders, entrepreneurs, or family owners typically reflect a form of entrepreneurship that differs fundamentally from the structured innovation processes typical of large corporate R&D labs. Individuals usually operate with fewer resources, face higher personal and financial risks, and rely more on tacit knowledge and experimentation, whereas corporate shareholders channel innovation through formal R&D departments embedded in broader strategic and organizational frameworks.

[4] In this paper, *SME Instrument* (singular) refers exclusively to the specific programme implemented in 2014–2020. By contrast, SME instruments (plural) denotes the broader set of EU support instruments targeting SMEs, including the EIC Accelerator.

Descriptive Statistics

Our sample consists of an unbalanced panel of 1,940 companies observed for 9 years on average, operating in 17 NACE 1-digit industries and 35 EU27 and non-EU27 countries.[5]

Appendix Table 2 presents the sample distribution by industry. It shows that the vast majority of companies in the sample belongs to Professional, technical & support services (34%), Manufacturing (31%) and Information and Communication (22%).

Appendix Table 3 presents statistics by country. The sample includes EU27 and non-EU27 companies. The largest number of companies in the sample is found in Italy (18%), Spain (13%), United Kingdom (10%), and Germany (6%).

Table 5 presents summary statistics of the beneficiaries for the overall sample and distinguishing by type of entity. Panel A presents statistics for the full sample. The average revenue is €4 million, and the median is €560,000—indicating that the size distribution is skewed by a few larger companies. The maximum revenue is above €65 million, which is above the threshold allowed to be qualified as SME by the Commission. This is due to the fact that companies can grow over the years of our sample. In terms of employees, the companies tend to be small. The average number of employees is 21 and the median is 8.

The companies in our sample received a total of approximately €1 billion in R&D grants, evenly distributed between controlled subsidiaries and independent companies. Table 1 shows that on average firms receive €500,000 in grants, while the median grant is €50,000. In line with the program design described in Section 2, the maximum grant received in the sample is €2.5 million, while the minimum is €50,000.

The average program duration is 10 months, while the median duration is 5 months. We notice that some companies participate in the program for as long as 44 months.

Panel A1 and A2 present statistics for controlled subsidiaries and independent companies separately. The average revenue is more than €5 million for controlled subsidiaries and slightly less than €2 million for independent companies. Also in this case, the size distribution is skewed, with median revenue being lower than the mean in both cases. This can be also observed in **Appendix Figure 17**, which plots the distribution of log-revenue for the two entity types.

Despite the significant differences in size, controlled subsidiaries and independent companies receive similar grants and stay in the program for the same amount of time.

[5] In addition to EU Member States, Horizon programs include non-EU Associated Countries that have concluded an association agreement with the EU. Legal entities established in these countries may generally participate under conditions equivalent to those for Member-State entities, including eligibility for EU funding.

Table 5 Summary Statistics

Variable†	Obs	Firms	Mean	Median	Std. Dev.	Min	Max
Panel A: All firms							
Revenue ('000)	11,205	1,459	4,003	559	9,401	0	65,969
Employees	12,487	1,799	21	8	36	0	220
Grant ('000)	1,634	1,634	472	50	804	50	2,500
Duration (months)	1,635	1,635	10	5	11	2	44
Breakdown of Panel A by entity type:							
A.1 Controlled subsidiaries							
Revenue ('000)	6,793	855	5,476	935	11,231	0	65,969
Employees	7,551	1,043	26	10	41	0	220
Grant ('000)	984	984	409	50	750	50	2,500
Duration (months)	984	984	9	5	10	2	44
A.2 Independent companies							
Revenue ('000)	4,412	604	1,736	350	4,665	0	65,969
Employees	4,936	756	14	6	25	0	220
Grant ('000)	650	650	566	50	873	50	2,500
Duration (months)	651	651	11	5	11	2	44

Source: IEP-COMPET (Gros *et al.*, 2025).
Note: All variables are winsorised at the 1st and 99th percentiles. Monetary values are in euros unless stated otherwise.

OWNERSHIP STRUCTURE

Before examining the causal impact of R&D grants on the beneficiaries, we examine the differences between controlled subsidiaries and independent companies using shareholder information. Since the shareholder data are time-varying, we use the ownership information corresponding to the year in which the companies in our sample receive the grant.

Figure 25 presents the distribution of ownership shares for each entity. The key message of this figure is that controlled subsidiaries are more likely to be run by other companies. Almost all controlled subsidiaries have more than 80% corporate shares.

The ownership share distributed for independent companies is skewed on the left. The bulk of independent companies has less than 50% shareholding by corporation, in line with the definition provided by ORBIS. There is still a positive mass on the right, which could be because ORBIS assigns a time-invariant entity type, while ownership status can change over time.

To characterize further differences in ownership structure between controlled subsidiaries and independent companies, we turn to logit regressions of a dummy equal to 1 if a company is a controlled subsidiary on the ownership share of corporations, individuals, and other two aggregate shareholder categories: financial institutions, and public and research entities. Appendix C presents details about the shareholder type aggregation used to construct the broad groups.

We include in the logit regression log-revenue as a proxy of firm size, and an index of ownership concentration to account for the different shapes of the distributions in **Figure 25**.[6] We also add industry and country fixed effects in order to absorb characteristics that can systematically shape firms' ownership structures.[7]

The results are presented in **Figure 26**, which presents the average marginal effects of each variable, normalized to have zero mean and unitary standard deviation in the sample. Relative to independent companies (the reference group), controlled subsidiaries are less likely to be owned by individuals but more likely to be owned by other firms, or public or research entities. They are also larger and have more concentrated ownership, with an average concentration index double the magnitude of independent companies. We do not find any significant difference in terms of ownership by financial institutions.

EMPIRICAL APPROACH

We base our causal analysis on the following event study regression:

$$Y_{ist} = a_i + \gamma_{st} + \sum_{k=-T}^{T} \beta_k D_{ik} + \epsilon_{ist} \,, \qquad (1)$$

where Y_{ist} is the outcome variable of firm i in industry s at time t. The indicator function D_{ik} captures the time to/from the grant and β_k is the associated coefficient. ϵ_{ist} denotes the error term.

In (1), α_i is firm-fixed effect and γ_{st} denotes industry-year fixed effects. The inclusions of γ_{st} allows to purge the estimates from the impact of unobserved sector-specific shocks.

The parameter T denotes the length of the pre/post treatment period and is chosen to be the largest possible depending on data availability. In order to avoid picking T arbitrarily, we set the earliest pre-treatment such that at least 500 observations are available. This results in the event windows [-5,6].

[6] Specifically, we construct a Herfindahl–Hirschman Index based on the ownership shares of all shareholders.

[7] For instance, firms in industries with high capital requirements, or countries with stronger investor protection or more developed capital markets might be more more likely to host controlled subsidiaries.

Figure 25 Ownership shares by shareholder and entity type

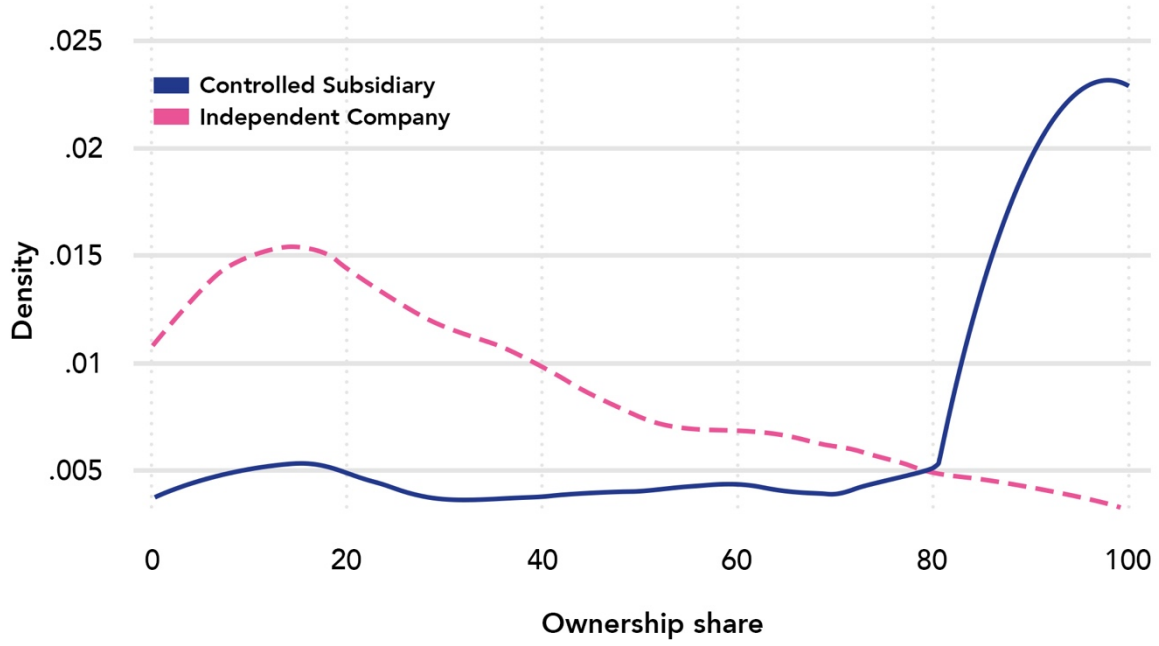
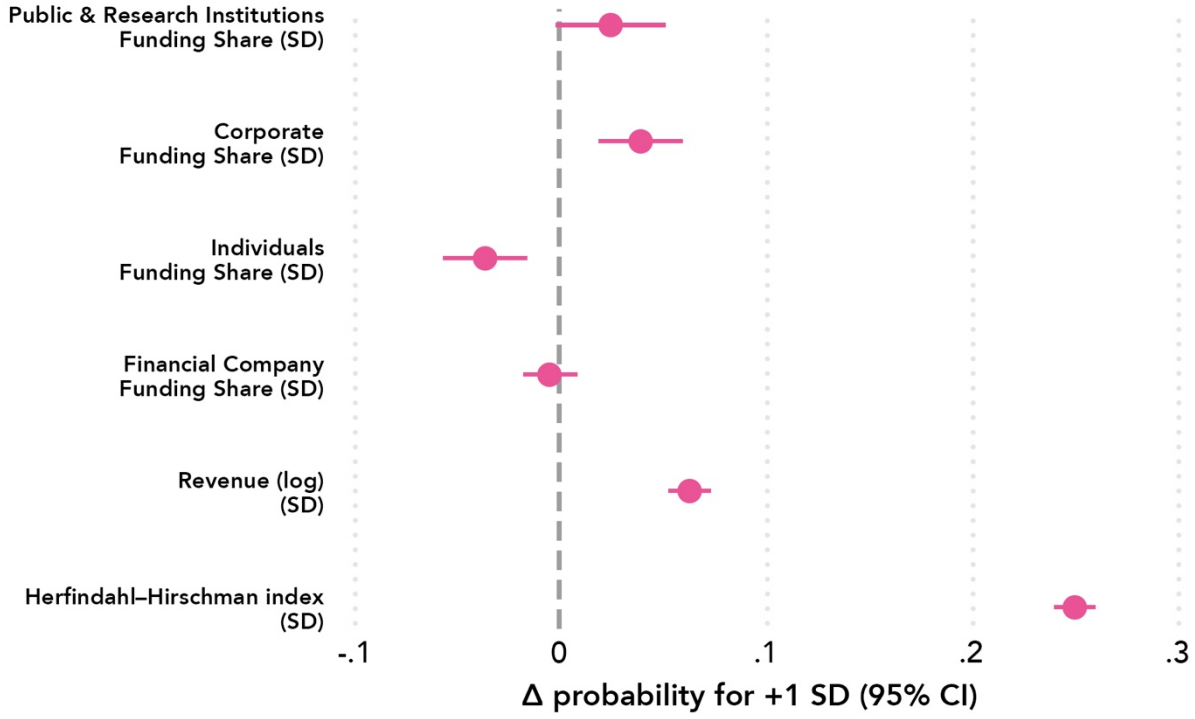


Figure 26 Logit: Predictors of Being a Controlled Subsidiary

(vs. Independent Firm)



Endogeneity Concerns

The primary identification issue facing Equation (1) is that treatment—i.e., receiving a grant—is not randomly assigned across firms. For example, the European Commission might intentionally target companies based on their performance, potentially biasing the estimates. Firms treated last could be systematically different from those treated earlier, as well as from those never treated, compromising comparability. All such issues might result in a violation of the parallel trend assumption.

Some of these issues can be partially mitigated by including firm fixed effects, which control for firm-specific, time-invariant characteristics. However, fixed effects alone cannot address biases stemming from time-varying firm characteristics. Therefore, we adopt a strategy leveraging a sample of firms that applied to specific funding programs, were considered eligible by the evaluators, but ended up not receiving the funding due to budgetary reasons. Such firms are awarded by the Commission a quality label named *Seal of Excellence* (SoE).[8]

Unfortunately, the European Commission does not disclose the complete list of SoEs. Therefore we compile a non-exhaustive list of 530 SoEs from Bpifrance (2025) and Demolin *et al.* (2025), which we manually match through their company name to ORBIS' balance sheet and ownership data.[9] Of these SoE firms, 368 are either controlled subsidiaries or independent companies, and we use them as the control group.

The validity of our identification strategy hinges on grant recipients and SoEs to be comparable, ideally differing only in whether they received a grant. Therefore, **Table 6** presents a comparison of key observable characteristics of SoEs and treated firm.

The table shows that controlled subsidiaries receiving the grant have an average revenue of €5.4 million, average employment of 27 and average age of 18 years. The SoEs counterparts have an average revenue of €6.5 million, 26 employment and age 14. Despite being somewhat younger on average, SoEs that are controlled subsidiaries are thus comparable to the treated firms.

For independent companies, grant recipients have average revenue of €1.8 million, employment 14 and age 16; the SoEs counterparts have average revenue of €1.1 million, 12 employment and age 14. Therefore, on average the treated have larger revenue, but they are comparable in the other observable dimensions.

Table 6 also shows that the size of the control group tends to be smaller than the treatment group. For controlled subsidiaries, the control group is 11% of the total; for independent companies, the control group accounts for 22% of the sample.

A final concern with our strategy is that since the list of SoEs is incomplete and gathered from public sources, there might be some sample selection. In particular, there might be unobserved factors correlated to being publicly disclosed as a SoE and company

[8] See https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/ seal-excellence_en.

[9] A few SoE firms in our list are also in CORDIS. This suggests that they first applied unsuccessfully, but then obtained a grant in later funding rounds. We drop such firms from the dataset.

characteristics. For this reason, we implement an Inverse Probability Weighting (IPW) procedure assigning each firm a weight equal to the inverse of its probability of receiving the grant, conditional on observed characteristics: revenue, employment, total assets, NACE 1-digit sector classification, and year of grant receipt. To estimate such probabilities, we use a logit regression.

Table 6 Comparison of grant recipients and SoEs

Entity type	Obs	Firms	Avg. Revenue ('000)	Avg. Employees	Avg. Age
Panel A: Full sample (excl. SoE)					
ContrSubs	8,829	984	5,386	26.5	17.5
IndepCo	5,372	650	1,833	14.1	16.2
Panel B: Seal of Excellence (SoE) control firms					
ContrSubs	866	126	6,501	25.8	13.9
IndepCo	1,068	180	1,115	11.9	14.1

Source: IEP-COMPET (Gros *et al.*, 2025).
Note: All variables are winsorised at the 1st and 99th percentiles. Monetary values are in euros unless stated otherwise.

Productivity Measurement

Our main metric of performance is Revenue-Total Factor Productivity (TFP). To obtain TFP measures while addressing transmission bias (Griliches and Mairesse, 1995), we apply the two-stage proxy variable estimator of Ackerberg *et al.* (2015), and the dynamic panel method of Blundell and Bond (2000). In both cases, we estimate translog production functions separately for six 1-digit industries based on industry-deflated revenue/value added, capital, employment, and materials.[10] Appendix C presents the details.

An advantage of using revenue-based measures of TFP is that they capture the combined impact of several channels related to the performance of the grant recipient. This includes process and product innovation, but also more broadly the firm's ability to appropriate returns through higher markups or expanded market reach. An R&D grant may influence all these dimensions simultaneously, and while they are individually difficult to disentangle empirically, their joint contribution is precisely what matters for assessing the overall effectiveness of the grant. Revenue-based TFP therefore provides a compact, informative indicator of performance that aggregates these channels in a meaningful way.

THE CAUSAL IMPACT OF R&D GRANTS

Given that firms receive grants at different times, we estimate Equation (1) using the estimator of Sun and Abraham (2021), which is designed for situations in which the treatment time is staggered across units. The treatment group is composed by grant

[10] We do not observe firm-level prices, a common issue in the literature (De Loecker and Warzynski, 2012; Klette and Griliches, 1996; Foster *et al.*, 2008; De Loecker *et al.*, 2016). For this reason, in our analysis we employ a battery of alternative performance indicators.

recipients, while the control group is composed by SoE firms, which never receive the grant.

Figure 27 depicts the estimated impact of the grant on recipients' TFP. The figure presents point estimates and 95% confidence intervals from Equation (1), distinguishing between controlled subsidiaries and independent companies. There is no evidence of significant pre-trends, which reassures us on the validity of the parallel trend assumption required for a causal interpretation of the estimates. This suggests that *Seal of Excellence* awardees form a reasonable control group.

We find a positive, statistically significant and persistent impact of the grant on independent companies, but not on controlled subsidiaries. The grant increases TFP of independent companies by 25% during the first two years of the program, and then by 50% three-to-six years later. Controlled subsidiaries exhibit a milder increase in productivity, roughly 25%, but the effect dies out three years after the grant reception.

Figure 28 presents the estimated impact on log-revenue, which closely resemble the TFP estimates. The estimates show a positive and significant +50% impact of the grants on recipients' revenue, but only for independent companies. For controlled subsidiaries, the estimates are again hump-shaped, with a positive and significant +25% impact for the first two years after the reception of the grant. However, the estimates become small and not statistically significant thereafter.

We compare our estimates with the existing evidence from Santoleri *et al.* (2022). They find that winning an SME grant leads to a large and statistically significant increase in firm revenues *one year* after the award. Using a regression discontinuity design, the estimated impact on log revenues ranges from about 37% to 66%, depending on specification. The magnitude of our estimates is thus in line with the existing evidence, but they shed light on two important differences. The first is that the average effect masks heterogeneity in effects depending on ownership structure. The second is that the effect of the grant can change over longer time horizons, and therefore measuring the short-run impact might be misleading.

Robustness

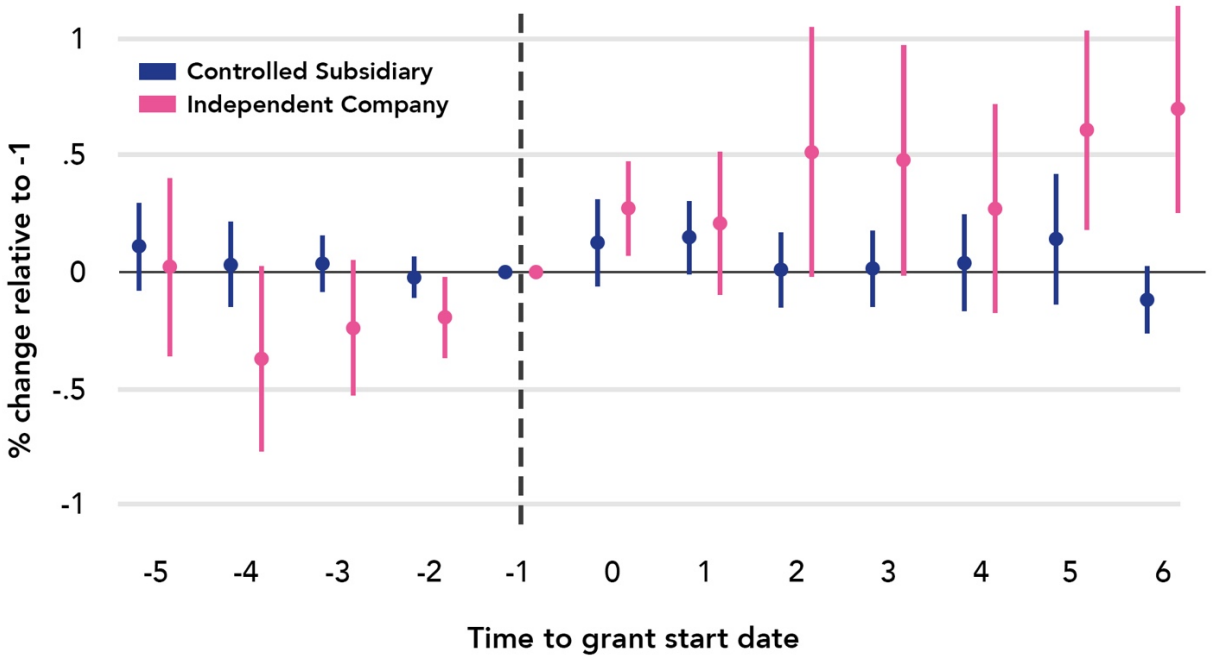
To check the robustness of our main findings, we examine the causal impact of the grant using alternative outcome variables.

The evidence strongly suggests that the pattern of **Figure 27** and **Figure 28** is genuine, as it carries over to several other variables arguably related to research and innovation. **Appendix Figure 18** shows the estimated impact of a grant on: (a) patents, (b) value-added per employee, and (c) a TFP measure based on different estimation assumptions. In all cases, the point estimates for independent companies are larger and more precisely estimated.

Panel (a) presents the impact of R&D on patents. The post-treatment estimates for independent companies are large and statistically significant, suggesting that the grant increases the number of patents filed per year by about two. The base value of the patent count variable is roughly three (for both entity types). Although the estimates must be

interpreted with caution due to the marginally significant pre-trend coefficients, the estimated impact of the grant on patents is quite large. Grants have a positive and significant impact on controlled subsidiaries, but the size of the coefficients is roughly one-fourth to those for independent companies, and it becomes precisely zero after six years.

Figure 27 The causal impact of R&D grants on TFP
Dynamic Panel Estimator



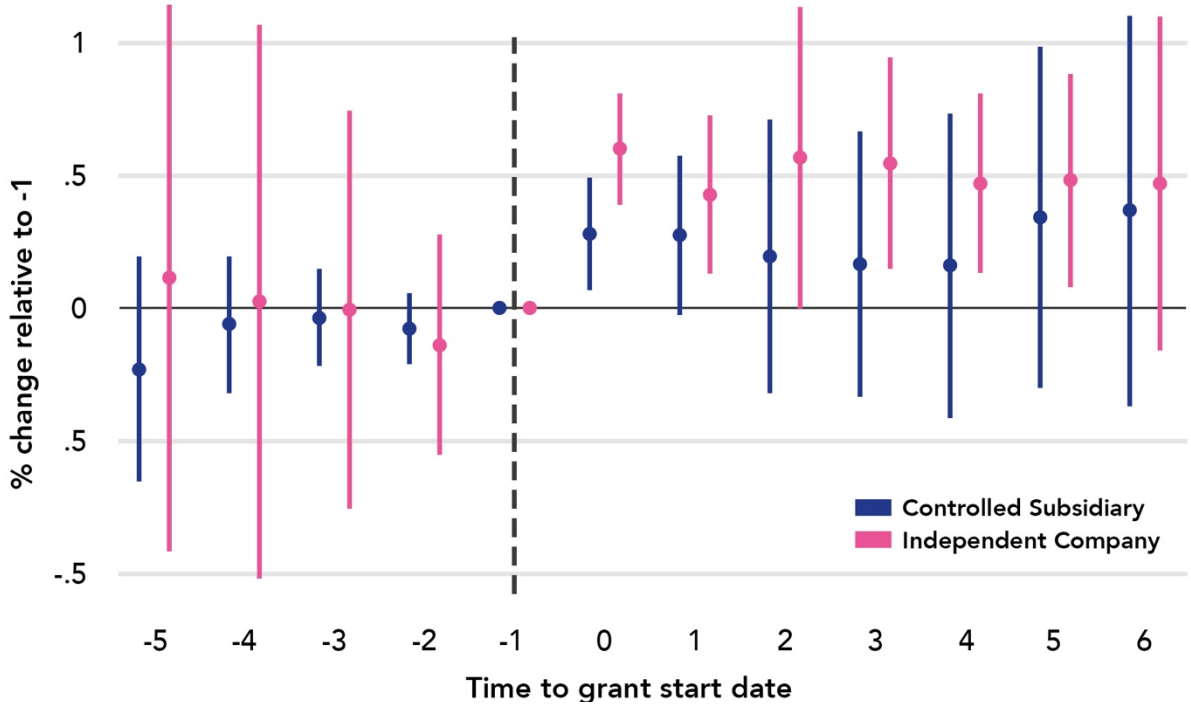
Source: this figure shows point estimates and 95% confidence intervals of the impact of R&D grants on TFP. Blue estimates correspond to controlled subsidiaries and red estimates concern independent companies. The treated group is composed by firms receiving a grant in some year of the sample, while the controlled group is composed by firms that received the Seal of Excellence certification but never got a grant. Estimates are based on the estimator by Sun and Abraham (2021). All regressions include firm fixed effect and 2-digit industry-year fixed effects. Standard errors are clustered at the firm level.

Panel (b) presents the estimates for value-added per worker, which is an important variable especially for manufacturing firms, constituting 30% of the sample **(Appendix Table 2)**. Also in this case, the grant has a positive and significant impact on controlled subsidiaries, but the impact on independent companies is much larger.

Panel (c) presents the results for an alternative TFP measures based on the Proxy Variable Estimator. The estimates are fully consistent with the main productivity estimates.

Finally we check that the differential impact for the two entity types is not simply driven by systematic differences in size between controlled subsidiaries and independent companies. **Appendix Figure 19** presents results based on a split sample of companies above and below the median value of log-revenue. If size was driving the result, we should also see the pattern reflected in **Figure 28**. However, this is not the case, as we do not find significant effects for both categories.

Figure 28 The causal impact of R&D grants on revenue



Source: this figure shows point estimates and 95% confidence intervals of the impact of R&D grants on log-deflated revenue. Blue estimates correspond to controlled subsidiaries and red estimates concern independent companies. The treated group is composed by firms receiving a grant in some year of the sample, while the controlled group is composed by firms that received the Seal of Excellence certification but never got a grant. Estimates are based on the estimator by Sun and Abraham (2021). All regressions include firm fixed effect and 2-digit industry-year fixed effects. Standard errors are clustered at the firm level.

CONCLUSIONS

This paper provides causal estimates of the impact of R&D grants to SMEs and documents that it is mediated by recipients' ownership structure. Grants increase long-run productivity and performance more broadly, but only for independent companies. The effect is at best muted for controlled subsidiaries.

We characterize ownership in terms of the size of shareholders' ownership shares and their characteristics. Controlled subsidiaries tend to have highly concentrated ownership by corporations, while independent companies are more likely to have no shareholders or be owed by individuals. These differences can shape the impact of a subsidy over and above the impact of firm size, which is extensively documented in the literature.

Pinpointing the specific mechanism behind our causal effects goes beyond the scope of this paper. Nonetheless, our evidence suggests that giving more weight to ownership characteristics in program requirements might substantially improve the efficiency of support schemes for research and innovation.

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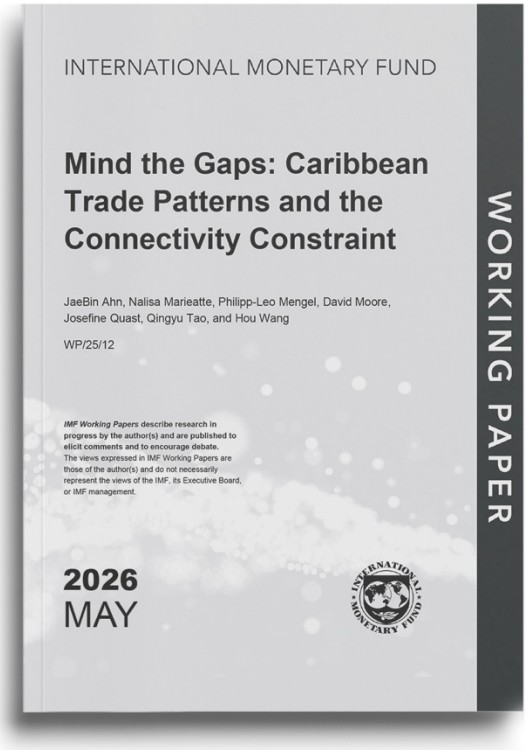
III.

TRADE, CONNECTIVITY, & DIVERSIFICATION

MIND THE GAPS

Caribbean Trade Patterns and the Connectivity Constraint

IMF WORKING PAPER
WITH J. AHN, N. MARIEATTE, D. MOORE, J. QUAST, Q. TAO, AND H. WANG



ABSTRACT

This paper analyzes trade patterns across the Caribbean Community (CARICOM)—15 Caribbean countries—and makes three main contributions. First, it provides a unified empirical assessment of Caribbean external connectivity by jointly analyzing goods trade, tourism flows, and cross-border banking linkages within a consistent gravity-model framework. Second, it presents new evidence on the role of physical connectivity—shipping and air transport—in shaping both import source concentration and tourism inflows, drawing on granular bilateral trade, tourism, and flight capacity data. Third, it shows that, while financial connectivity matters in a global context, it is not the primary binding constraint for Caribbean economies; instead, limited physical connectivity emerges as the more decisive factor shaping trade patterns and external vulnerabilities.

PERSONAL CONTRIBUTION:

I developed the gravity model that underpins the entire working paper. In particular, I am the sole author of Chapter 1, which focuses on goods trade.

INTRODUCTION

Amid intensifying geoeconomic fragmentation and rising geopolitical tensions, Caribbean economies face heightened exposure to external shocks.[1] Evidence suggests a broad-based decline in potential growth in the Caribbean over the past two decades due to declining contributions of total factor productivity and human capital as well as to resource misallocation (Amundsen *et al.*, 2025). Shifting global trade policies and uncertain geopolitical dynamics further pose risks to traditional sources of growth, including through goods and services trade. Against this backdrop, strengthening the economic resilience of Caribbean countries takes on increasing importance.

Understanding Caribbean goods and services trade patterns—and their implications for Caribbean countries' resilience to external shocks—is essential for designing strategies that can mitigate risks and sustain growth. On the one hand, goods exports account for only a small share of GDP in most Caribbean countries, with the important exception of oil exporters. But Caribbean countries rely heavily on goods imports—notably for food—implying vulnerability to external shocks, particularly those stemming from foreign exporter supply disruptions. On the services side, travel exports dominate foreign exchange earnings for many Caribbean countries.[2] Thus, it is highly relevant to explore the impact of supply-side constraints on tourism inflows, which could in turn inform potential efforts to diversify tourism sources and thereby reduce vulnerabilities to shocks originating in particular source countries.

Caribbean countries remain heavily concentrated in their sources of imported goods and tourism demand, which represents a source of vulnerability across these two critical channels.[3] Stylized facts from the goods trade data reveal that Caribbean countries rely significantly on a narrow set of exporter partner countries. Likewise, the concentration of tourism source markets for the region ranks among the highest in the world. In both cases, the exposure to a limited set of countries implies elevated risks from potential spillovers. Identifying the drivers of these concentration patterns in both goods and services trade can help inform options for diversifying trading partners and strengthening resilience.

A gravity-model based analysis of the goods trade shows that Caribbean countries trade relatively less with countries outside the Caribbean region than predicted by fundamentals, while trading more within the region than the model suggests. Our estimation results indicate that this pattern is driven largely by the disproportionate effect

[1] This paper's references to "Caribbean countries" are the 15 Caribbean Community (CARICOM) member countries: Antigua and Barbuda; The Bahamas; Barbados; Belize; Dominica; Grenada; Guyana; Haiti; Jamaica; Montserrat; St. Kitts and Nevis; St. Lucia; St. Vincent and the Grenadines; Suriname; Trinidad and Tobago. The regional integration movement in the Caribbean was formalized in 1973 with the Treaty of Chaguaramas, whose primary objective was to promote regional integration and development among its member countries through functional cooperation. The treaty was revised in 2002 to allow for the establishment of a CARICOM Single Market and Economy (CSME), facilitating the free movement of goods, services, skilled labor and capital in pursuit of a unified regional economic space.

[2] For this reason, we focus our analysis of services trade on tourism exports.

[3] Efforts in the region to pursue trade diversification, to build economic resilience and to address the high cost of living are under way (for example, for The Bahamas, see Acalin [2026] and IMF [2025]).

of geographical distance, as well as by re-exports, which together account for most of the discrepancy between actual and model-predicted trade values.

The evidence underscores the role of weak connectivity—and the associated high shipping costs—in contributing to the high concentration of import sources in nearby countries. Bilateral-level shipping connectivity data from UNCTAD show that, after controlling for pair-wise geographic fundamentals as well as origin-country specific factors, Caribbean countries as destinations have relatively weak shipping connectivity compared with other regions. This limited connectivity raises reliance on re-exports through central hubs within the region, resulting in greater intra-regional trade than would otherwise occur. Moreover, weak connectivity amplifies the trade barriers associated with geographical distance, particularly for countries located farther outside the region.

Turning to tourism exports, the lifeline of many Caribbean economies, this study investigates the extent to which tourist arrivals are sensitive to shocks in air connectivity—in particular, passenger flight capacity. The Caribbean region's relative geographic isolation and limited domestic markets make air connectivity a critical precondition for international stayover arrivals, as stayover tourists in the region depend almost exclusively on air travel. While tourist arrivals tend to be driven primarily by demand, the question remains whether supply-side factors—such as air connectivity, airport capacity, and carrier networks—also play a role. Consistent with the literature highlighting the critical role of connectivity in facilitating trade and travel, we find that air connectivity plays a quantitatively important role in shaping tourism flows.

We further examine a third dimension of connectivity: financial connectivity through cross-border banking relationships. While limited shipping and air connectivity represent physical constraints to trade, weaknesses in the supporting financial infrastructure itself may act as a binding constraint. However, while we find that banking relationships positively affect trade globally, the effect is substantially weaker for CARICOM goods trade and muted for tourism. This suggests that the region's primary trade constraints lie in physical rather than financial connectivity.

Overall, these findings suggest potentially important roles for policies aimed at strengthening shipping and air connectivity, which could play a key role in facilitating the diversification of goods and services trade partners.

LITERATURE

Goods Trade

Recent studies show a marked decline in growth and a weakening of medium-term prospects in the Caribbean region. Amundsen *et al.* (2025) attribute this mainly to productivity slowdowns and resource misallocation, mirroring broader global trends (IMF, 2024). A growing literature seeks to identify the key constraints to goods and services trade in the region (Amundsen *et al.*, 2025; Parente and Moreau, 2024; Hassan *et al.*, 2020; Beaton *et al.*, 2017; Bhattacharya and Pienknagura, 2024), noting that the openness of an economy can drive productivity by forcing firms to compete in world markets through "learning by exporting" (De Loecker, 2007) and "learning by importing" (Amiti

and Konings, 2007; Goldberg *et al.*, 2010; Halpern *et al.*, 2015), while trade and FDI foster aggregate productivity through reallocation, firm upgrading, creative destruction, and structural transformation (Iacovone *et al.*, 2025).

Using a standard gravity model, we contribute to the literature on intra-Caribbean trade integration by quantifying the extent to which CARICOM countries under-trade relative to fundamentals and how well they are embedded in the wider regional trade network.[4] The structure of our gravity model is similar to Bhattacharya and Pienknagura (2024) and Parente and Moreau (2024). But in contrast to these, we focus on the Caribbean and explicitly incorporate the growing role of re-exporting hubs in global value chains (Jones *et al.*, 2020), highlighting how trade connectivity shapes observed trade patterns within and beyond the region.

We also contribute to the literature on how limited diversification and structural bottlenecks heighten exposure to external shocks (Ahn and Brandon, 2025). At a time of intensifying geoeconomic fragmentation (Aiyar *et al.*, 2023), our systematic assessment of the geographical sources of goods imports and tourism exports in the Caribbean's hub structure is, to our knowledge, the first of its type.

Tourism

A large body of literature documents the central role of tourism in the Caribbean and structural factors that affect the tourism sector in the region. Tourism has been found to support income growth and employment. Real income in source countries, relative prices, and competitor destination prices have been identified as the dominant determinants of tourism flows. Moreover, the number of airlines has a statistically positive impact on arrivals and expenditure, and airlift plays an important role in affecting U.S. tourist arrivals to the Caribbean (Laframboise *et al.*, 2014; Acevedo *et al.*, 2017).

The gravity framework has become the dominant empirical workhorse for analyzing bilateral tourism flows. Rosselló-Nadal and Santana-Gallego (2022) survey the literature, which consistently finds a geographical distance decay effect.[5] Caribbean-specific applications confirm the role of economic mass, distance, source-country income, and prices, while also highlighting the relevance of marketing activity and high operating costs (Lorde *et al.*, 2014; Martin and Abraham, 2017; Ghazanchyan *et al.*, 2019).

Our paper contributes to the literature by explicitly integrating air connectivity into the gravity framework for Caribbean tourism demand. While existing studies have established the importance of income, prices, distance, and connectivity in shaping tourism flows,

[4] Several closely related studies explore this topic. Beaton *et al.* (2017) find that trade liberalization in Latin America and the Caribbean (LAC) can promote growth but has heterogeneous effects on inequality, highlighting the importance of complementary policies to ensure inclusive benefits. Hassan *et al.* (2020) find that strengthening Caribbean regional integration could yield significant economic gains by improving trade, investment, and policy coordination, although these benefits depend on deeper cooperation across multiple policy areas. Bhattacharya and Pienknagura (2024) identify persistent trade constraints in LAC countries, including infrastructure, regulatory, and logistical bottlenecks, which limit the region's ability to fully leverage global trade opportunities.

[5] In subsequent work, Rosselló-Nadal and Santana-Gallego (2024) adopt a global bilateral gravity framework, finding that geographical distance remains a strong determinant of tourism flows.

they treat accessibility only indirectly and rarely address potential endogeneity between flight connectivity and tourism demand. We combine bilateral tourism arrivals with granular flight-level data and adopt an instrumental variable approach to isolate exogenous "push" factors originating from source markets, which allows us to quantify the extent to which these translate into tourism flows. In doing so, our paper directly links the structural gravity perspective to ongoing policy debates on air connectivity, open skies agreements, and regional integration in the Caribbean.

Connectivity

Caribbean Small Island Developing States (SIDS) face structural connectivity challenges beyond geography.[6] Liner shipping connectivity and port infrastructure quality are important determinants of freight rates, with poorly connected ports facing substantially higher costs (Limão and Venables, 2001; Clart el al., 2004; Wilmsmeier and Hoffmann, 2008). While regional hubs like the Dominican Republic or Jamaica are well connected, maritime connectivity for SIDS remains substantially lower and has declined further over the past decade (UNCTAD, 2024), with port handling charges and freight costs two to three times the global average **(Figure 32)**. Elevated costs are driven by trade imbalances, limited shipping competition, inefficient customs and port administration processes, and dependence on transshipment through regional hubs (UNCTAD, 2024). Consistently, Shepherd, Briceno-Garmendia, Arroyo, Hoffmann, and Palsson (forthcoming) construct new data sets on maritime connectivity to find the causal impact of direct maritime connectivity on trade in the Caribbean, while documenting a widening connectivity gap in the region as recent transformations have not been equally shared across the region.

For Caribbean SIDS, these connectivity constraints impose binding constraints on trade competitiveness that compound the effects of limited access to trade finance. High transport costs and limited economic size reduce trade volumes, which could diminish the profitability of maintaining correspondent banking relationships, impeding the region's integration into global markets, production, and financial networks. We explore these potential interactions below.

Bank flows and trade–finance linkages

Banks mitigate trade risks through various financial instruments, and disruptions to these relationships can significantly reduce trade flows. The health of financial institutions affects firm-level exports during crises (Ahn *et al.*, 2011; Amiti and Weinstein, 2011), with credit conditions particularly binding for sectors with extensive external financing needs (Chor and Manova, 2012). Small markets with few active banks, like those in the Caribbean, are particularly exposed as adverse shocks to the letters-of-credit supply reduce export growth in such markets (Niepmann and Schmidt-Eisenlohr, 2017).[7]

Beyond direct trade finance, deepening financial linkages through syndicated lending networks increases bilateral trade flows between countries, particularly in industries subject to export risk (Caballero *et al.* 2018). Exporters tend to rely on banks specializing

[6] See, for instance, Briceno-Garmendia, Bofinger, Cubas, and Millan-Placci (2014) for previous discussion.
[7] Ahn and Sarmiento (2019) illustrate this for Colombian importer-exporter pairs.

in their export destinations (Paravisini *et al.*, 2023), and exports are larger when a foreign bank from the destination is present (Claessens and van Horen, 2021). Our study complements the approach of Caballero *et al.* (2018), capturing the extensive margin through relationship formation and information transmission between financial institutions, by exploring the intensive margin of outstanding cross-border banking linkages using claims and liabilities data. By doing so we complement existing approaches by capturing the actual capacity to finance trade and settle payments.

Correspondent banking networks are integral to the global payment infrastructure, particularly for smaller states, through enabling importers and exporters to settle cross-border trade transactions. Post-Global Financial Crisis (GFC) de-risking led to a withdrawal of correspondent banking relationships, with Caribbean economies disproportionally affected (World Bank, 2015; Erbenova, 2016; Alleyne *et al.*, 2017). Borchert *et al.* (2024) show that this matters for trade: declining correspondent banking services reduce not only overall exports but also firm's likelihood of continuing to export.[8]

DATA

Goods Trade

For the goods-trade analysis, we assemble data from multiple standard sources. Our main dependent variable—bilateral merchandise exports—comes from CEPII's BACI database, which provides information on bilateral annual trade flows measured on an FOB basis (i.e., net of transport costs) (Gaulier and Zignago, 2010). We assess robustness using export series from the IMF's Direction of Trade Statistics (DOTS; IMF, 2024), as well as from UN Comtrade that separately reports re-exports (United Nations, 2024).[9] Standard control variables at the dyad (i.e., country pair) level—great-circle distance, contiguity, common language, and colonial ties—are taken from CEPII's Gravity database (Conte, Cotterlaz, and Mayer, 2022). The presence of preferential trade agreements is sourced from Mario Larch's Regional Trade Agreements Database—updated from Egger and Larch (2008)—which covers all multilateral and bilateral regional trade agreements as notified to the World Trade Organization.[10] We also control for effective bilateral tariff rates (Teti, 2024; Ahn and Tan, 2025). In additional robustness specifications, we incorporate various kinds of relevant measures, including geopolitical distance (Aiyar, Malacrino, and Presbitero, 2024; Bailey, Strezhnev, and Voeten, 2017), a common-currency indicator (de Sousa,

[8] Borchert *et al.* (2024) base their analysis on four emerging European economies: Bosnia and Herzegovina, Croatia, Hungary, and Turkey.

[9] According to the UN definition of general trade flows (United Nations, 1998), re-exports take place when goods enter a customs territory from one country and are shipped to another country without being transformed. The presence of re-exports is most likely in those countries and regions with favorable geographical positions from a perspective of intercontinental transportation.

[10] CARICOM's preferential trade agreements include the CARICOM Single Market and Economy (CSME, 2002); the CARIFORUM-EU Economic Partnership Agreement (EPA, 2008); trade arrangements with the United States under the Caribbean Basin Initiative, including the Caribbean Basin Economic Recovery Act (1983) and the Caribbean Basin Trade Partnership Act (2000); the CARICOM–Canada CARIBCAN program (1986–1998; 2015–2023); and free trade agreements with the Dominican Republic (1998; entered into force 2000), Venezuela (signed 1992; ratified 2006), Colombia (signed 1994; ratified 2006), Cuba (signed 2000; Second Protocol signed 2017), and Costa Rica (signed 2004; ratified 2006), as well as the energy cooperation arrangement PetroCaribe (2005).

2012), and a bilateral export-similarity index computed based on Finger and Kreinin (1979).

Tourism

For the tourism analysis, we employ the bilateral country-level tourism dataset from the United Nations World Tourism Organization (UNWTO). The dataset provides detailed information on international tourism flows across countries, such as the number of arrivals and departures by origin–destination pair, allowing us to explore the direction and intensity of cross-country tourism linkages. Coverage spans more than 200 countries over multiple decades, offering a consistent basis for studying the evolution of global tourism patterns, the role of geopolitical barriers in tourism flows, and the sensitivity of tourism flows to economic shocks (UNWTO 2022).

This dataset has been widely used in the tourism literature (e.g., Rosselló-Nadal and Santana-Gallego, 2024). It can be further disaggregated by tourist residency and nationality, distinguishing between different measures of international tourism, including arrivals of non-resident tourists at national borders, arrivals of non-resident tourists staying in all types of accommodation establishments, and arrivals of non-resident tourists staying in hotels and similar establishments. Each measure is further broken down by country of residence and by nationality. In this study, we use arrivals of non-resident tourists at national borders by country of residence as the baseline measure of international tourism. For destination countries with missing information, we instead rely on arrivals of non-resident tourists at national borders by nationality.

We complement the global annual frequency tourism analysis with the monthly regional analysis using the monthly information on tourism for 23 destinations in the region provided by the Caribbean Tourism Organization (CTO). The CTO primarily relies on member countries for reporting data, although it also uses non-resident hotel registrations or non-resident air arrivals as alternatives for a few countries when official source is unavailable. In this study, we use total tourist arrivals or equivalently stop-over arrivals as our dependent variable. The tourist arrivals data excludes cruise ship passengers, making it suitable for analyzing air travel. However, we cannot exclude other forms of sea travel that are presumed to be minor and unlikely to affect the results.

Connectivity

The Liner Shipping Connectivity Index (LSCI) from the United Nations Conference on Trade and Development (UNCTAD) provides a measure of a country's integration level into global liner shipping networks. The LSCI, ranging from 0 to 1, is constructed on a quarterly basis by taking simple averages of six normalized components deemed to reflect bilateral connectivity between a pair of countries.[11] The dataset covers over 150 countries for the past two decades.

[11] According to the UNCTAD, the LSCI is generated from the following six components: (1) the number of scheduled ship calls per week (i.e., weekly average of annual schedule) in the country; (2) total scheduled annual deployed capacity, in Twenty-foot-Equivalent Units (TEU), offered in the country; (3) the number or regular liner shipping services from and to the country; (4) the

The freight cost measures are drawn from the UNCTAD Experimental Transport and Trade Dataset and capture the average transport expenditure per kilogram of traded goods. Transport costs are defined as expenditures invoiced for services required to deliver internationally traded goods from the border of the exporting economy to the border of the importing economy and are measured as the difference between CIF and FOB values. It covers 237 economies of origin and 170 economies of destination over the period from 2016 to 2021 and was developed jointly by UNCTAD and the World Bank, using UN Comtrade data as the main source and applying a transport network model based on geographic information systems developed by Equitable Maritime Consulting (Halim *et al.*, 2018).

Total flight-based passenger capacity data are constructed through two main steps. Our approach follows Sozzi and O'Hanlon (2021). First, we obtain global direct flight data from *FlightRadar24*, which provides real-time, unique information on aircraft type, airline operator, departure/arrival date, and origin/destination country. Commercial passenger flights are further differentiated in the database using a list of passenger airlines extracted online. Several other online databases also provide complementary information on aircraft characteristics, including the official seat capacity or payload of different aircraft models. In the next step, we use the information on seat capacity to derive an average total capacity for each flight model identified in the database. This measure of passenger capacity accounts for the different configurations of seat classes. We compute total passenger capacity by multiplying the number of flights by the average capacity per aircraft type and then aggregate the results bilaterally by month and year for each destination country. The final dataset is limited to global flights since November 2018 and covers 264 origin-destination country pairs.

Bank flows

Our analysis of banking-trade linkages uses the Bank of International Settlements' (BIS) Locational Banking Statistics (LBS). These data capture outstanding claims and liabilities of internationally active banks and cover around 95 percent of all cross-border banking activity.[12] To date, banking offices located in 44 countries, including many offshore financial centers, report the LBS vis-à-vis more than 200 countries. Using data on outstanding stocks, we construct our claims and liabilities variable from the borrower's perspective, measuring an import country's liabilities to an export country. Doing so suits our focus on Caribbean economies, which are predominantly importers. Specifically, we consider claims from the origin countries' perspective and liabilities from the destination countries' perspective. Compared to other data sources, the BIS LBS capture financial

number of liner shipping companies that provide services from and to the country; (5) the size, in TEU, of the largest ship deployed on services from and to the country; and (6) the number of other countries that are connected to the country through direct liner shipping services (where a direct service is defined as a regular service between two countries – it may include other stops in between, but usually no transshipment, as this is not required in the transport of a container).

[12] The LBS are compiled following principles that are consistent with balance of payments statistics. Changes in the LBS reflect movements in outstanding positions, capturing capital flows and valuation effects. Banking linkages are measured using changes in bilateral positions in the LBS.

relationships that are relevant for smaller economies, such as correspondent banking relationships and reflect ongoing financing capacity, including for trade financing.

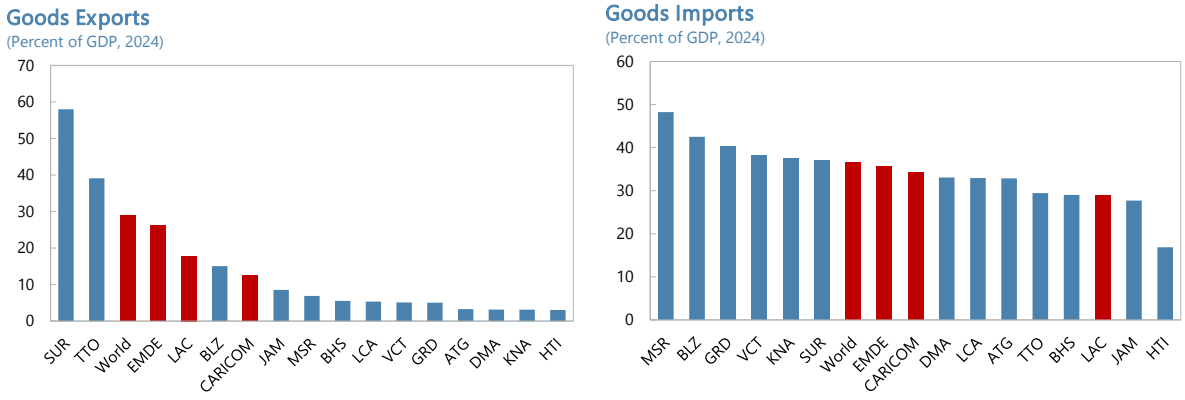
Despite the detailed information available on cross-border banking linkages, important gaps remain in understanding how trade is financed in the Caribbean. While banks intermediate some trade financing instruments such as letters-of-credit or documentary collection, which are covered in our study, large fractions of trade financing occurs on cash-in-advance or open-account terms that do not require bank intermediation (Antràs and Foley, 2015) and are, thus, not covered by the BIS LBS data.[13] Due to a lack of systematic, bilateral data on cross-border cash-in-advance or open-account flows, the question of whether alternative financial mechanisms can substitute for interbank relationships remains unanswered. Addressing these data gaps will be critical for assessing the resilience of trade financing in the region and for identifying policy measures that could mitigate the effects of weak banking–trade linkages.

GOODS TRADE AND CONNECTIVITY

Background

In many Caribbean economies, goods exports represent only a small share of GDP—with the notable exception of oil-exporting countries. Nevertheless, understanding goods trade patterns in the Caribbean is crucial, not only to identify opportunities to expand exports and GDP, but also to assess economic resilience given the region's heavy reliance on imports **(Figure 29)**.

Figure 29 Goods Exports and Imports, 2024



Source: IMF Balance of Payment Database and authors' calculations.
Note: Group aggregate values are simple averages. "EMDE" = Emerging and Developing Economies; "LAC" = Latin America and the Caribbean.

[13] Yet, as trade relationships solidify via repeated interaction, using cash-in-advance terms becomes less likely (Antràs and Foley, 2015).

Concentration

Caribbean countries' imports are highly concentrated. We construct a measure of import source concentration by calculating the Herfindahl-Hirschman Index (HHI) for each importer country in each year:

$$HHI_{jt} = \sum_{i}^{N_{jt}} (S_{ijt})^2,$$

where S_{ijt} denotes the share of imports from country i in total imports of country j in year t and the total number of trading partners for country j in year t is denoted by N_{jt}. As such, this measure is bounded between 0 and 1, where 1 corresponds to complete concentration, with a single country occupying the entire market. **Figure 30** illustrates relatively highly concentrated sources for the Caribbean imports, as 13 out of 14 CARICOM countries covered in the data rank well above the 50th percentile globally in terms of import source concentration. **Table 7** further confirms that Caribbean countries stand out as importers with concentrated sources, even after controlling for importers' income levels and geographic remoteness. Similar to Wei (1996), we measure remoteness as the GDP-weighted distance from a country to all its trading partners, so countries with no nearby large economies tend to have a higher remoteness index.

This high concentration may increase countries' vulnerability to external shocks. As small open economies that rely on imported consumption and production inputs, high import concentration could make them more vulnerable to external shocks. Borrowing concepts from portfolio theory, the variance of the exporter-supply shocks (i.e., risk measure) for each importer can be calculated as:

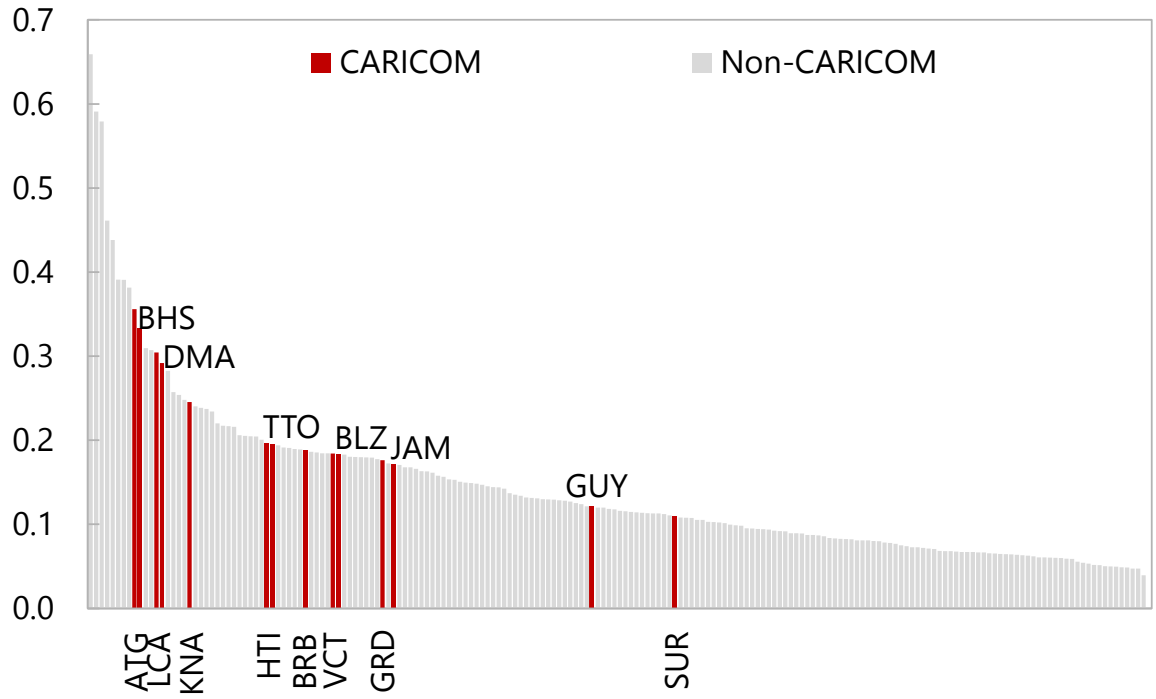
$$\sigma_j^2 = W \times C \times W',$$

where W is the row vector of country-level (time-average) market shares and C is the covariance matrix of country-level trade cost shocks that are measured as the exporter-year fixed effect term from the gravity-type estimation of the global bilateral country-level trade flows.[14] Relating the concentration measure to the risk measure, **Figure 31** illustrates a strong correlation between the two. In this context of highly concentrated import sources, shocks—such as idiosyncratic disturbances in source countries or shifts in global trade policies—can have amplified effects.

[14] A similar approach from the U.S. perspective is employed at the product level in Ahn and Brandon (2025).

Figure 30 Import Source Concentration by Destination, 2022

Herfindahl-Hirschman Index



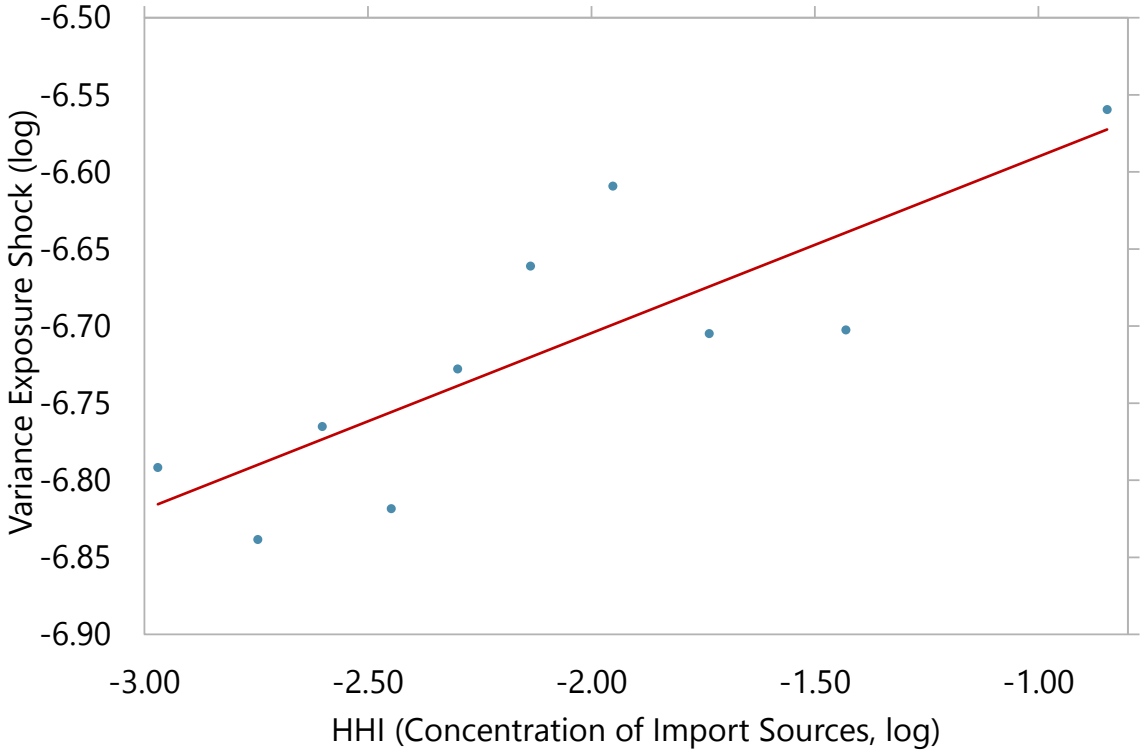
Source: BACI database and authors' calculations.
Note: 2019 data is used for St. Lucia due to incomplete data for 2022. Import concentration is the concentration of the source of the imports, measured by Herfindahl-Hirschman Index (HHI) with scale 0-1, with one reflects the highest concentration.

Table 7 OLS Regression of Import Concentration Index

Dependent variable: country-level HHI	(1)	(2)	(3)
GDP per capita	0.011	-0.006 ***	-0.004 ***
	(0.008)	(0.001)	(0.002)
Remoteness index	0.114 ***	0.109 ***	0.062 ***
	(0.038)	(0.007)	(0.007)
CARICOM dummy		0.047 ***	0.059 ***
		(0.008)	(0.009)
Latin America dummy			0.012 ***
			(0.004)
Sub-Saharan Africa dummy			0.011 ***
			(0.004)
Middle East and North Africa dummy			-0.028 ***
			(0.004)
Emerging and Developing Asia dummy			0.049 ***
			(0.002)
Emerging and Developing Europe dummy			-0.007 ***
			(0.002)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	No	No
Observations	3,078	3,078	3,078
Adj. R-squared	0.795	0.180	0.206

Source: BACI database, IMF staff calculations.
Note: This table reports the OLS estimation results from the importer country-level panel regression of Herfindahl-Hirschman Index of import sources. Robust standard errors clustered at origin-destination country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

Figure 31 Correlation between Import Source Concentration and External Shock Volatility, 2007-2022



Source: BACI database and authors' calculations.
Note: This figure plots binned scatter plots for the relationship between geographic concentration of import sources and exporter supply shock risk at the importer level. The degree of geographic concentration of import sources is measured using the Herfindahl-Hirschman Index (HHI), based on the share of imports from each source country. Exporter supply shock risk is measured as the import-share-weighted variance- covariance of supply shocks across exporters.

Connectivity

Connectivity constraints may contribute to the high concentration of import sources in the Caribbean. Limited shipping connectivity restricts direct links with a broad set of trading partners, forcing countries to rely on a smaller number of accessible suppliers (Fugazza and Hoffmann, 2017). Even along existing routes, weak connectivity raises freight costs and transit times, reinforcing incentives to source imports from fewer origins. Infrequent or unreliable services further increase supply chain uncertainty, strengthening reliance on established trading relationships and entrenching existing trade patterns.

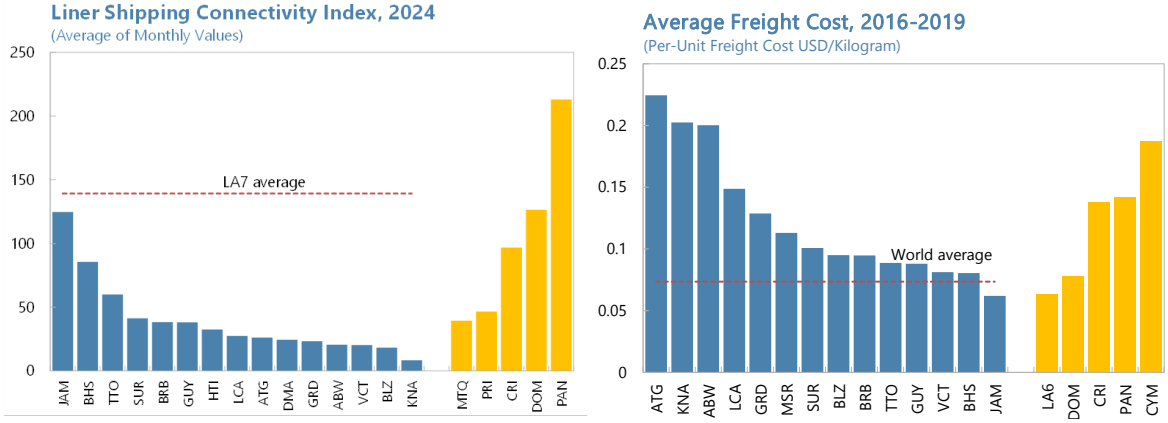
Cross-country connectivity data suggests that Caribbean countries face particularly high maritime connectivity constraints. UNCTAD's Liner Shipping Connectivity Index, which measures a country's integration into global liner shipping networks, highlights that connectivity is a significant challenge for CARICOM countries compared to peer countries (Panel A of **Figure 32**). This is consistent with country-level aggregate average freight cost measures, indicating that Caribbean countries face some of the highest shipping costs in the world (Panel B of **Figure 32**). All CARICOM countries, except for Jamaica, incur shipping costs above the global average, with Antigua and Barbuda notably experiencing

rates that are three times higher than the world average. These elevated costs likely stem from multiple factors, including geographic location, small market size, reliance on transshipment hubs, among others.

Simple OLS regressions using time-varying bilateral-level connectivity analysis corroborate these patterns.[15] Even after controlling for key economic fundamentals such as geographic distance, CARICOM countries as destinations exhibit significantly lower shipping connectivity than other regions **(Table 8)**. Similarly, bilateral shipping costs remain systematically higher for CARICOM destinations **(Table 9)**. Together, these conditional differences point to persistent challenges in the region's integration into global shipping networks.

A closer examination of shipping routes highlights the limited availability of direct cargo connections in the Caribbean and the region's heavy reliance on hub ports. **Figure 33** maps direct cargo shipping routes in the Caribbean basin based on data from major logistics providers. A striking feature is the prominence of distribution hubs—most notably Jamaica and The Bahamas for the wider CARICOM region, and Antigua and Barbuda for the ECCU—through which cargo is consolidated and re-exported to other CARICOM island states. This hub-and-spoke structure is consistent with weak connectivity at the level of individual CARICOM countries, which often lack sufficient scale to sustain direct links with source countries and instead rely on regional hubs for consolidation and onward distribution. As a result, a significant share of CARICOM exports likely reflects transshipment or light processing rather than domestically generated value added. Consistent with this interpretation, **Figure 34** shows that three CARICOM members rank among the world's top 15 re-exporting hubs, measured as re-exports relative to total exports using UN Comtrade (2025) data.

Figure 32 Maritime Connectivity and Average Freight Cost in the Caribbean



Source: UNCTAD Experimental Transport and Trade Dataset and authors' calculations.
Note: Liner shipping connectivity index is rescaled so that the average across all countries is 100 in February 2023. LA7 average reflects the average across Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Uruguay. Freight cost measures the average transport expenditure per kilogram of traded goods. LAC6 reflects the average across Argentina, Brazil, Chile, Colombia, Peru, and Uruguay.

[15] While both are constructed at the bilateral level, the connectivity index is non-directional and symmetric between country pairs, whereas shipping costs are directional and asymmetric.

Table 8 OLS Regression of Connectivity Index

Dependent variable: bilateral connectivity index	(1)	(2)	(3)
Regional Trade Agreement	-0.009 ***	0.049 ***	0.027 ***
	(0.003)	(0.003)	(0.003)
Distance	-0.118 ***	-0.093 ***	-0.094 ***
	(0.002)	(0.002)	(0.002)
Border	-0.026 ***	0.0119	0.022
	(0.009)	(0.013)	(0.013)
Language	0.004	0.040 ***	0.040 ***
	(0.003)	(0.004)	(0.004)
Colonial ties	0.011 ***	-0.032 ***	-0.005 ***
	(0.004)	(0.005)	(0.005)
CARICOM destination dummy		-0.103 ***	-0.178 ***
		(0.004)	(0.052)
Latin America destination dummy			-0.027 ***
			(0.005)
Sub-Saharan Africa destination dummy			-0.114 ***
			(0.004)
Middle East and North Africa destination dummy			-0.100 ***
			(0.005)
Emerging and Developing Asia destination dummy			-0.110 ***
			(0.005)
Emerging and Developing Europe destination dummy			-0.116 ***
			(0.007)
Origin-year fixed effects	Yes	Yes	Yes
Destination-year fixed effects	Yes	No	No
Observations	330,795	291,900	291,900
Adj. R-squared	0.626	0.366	0.390

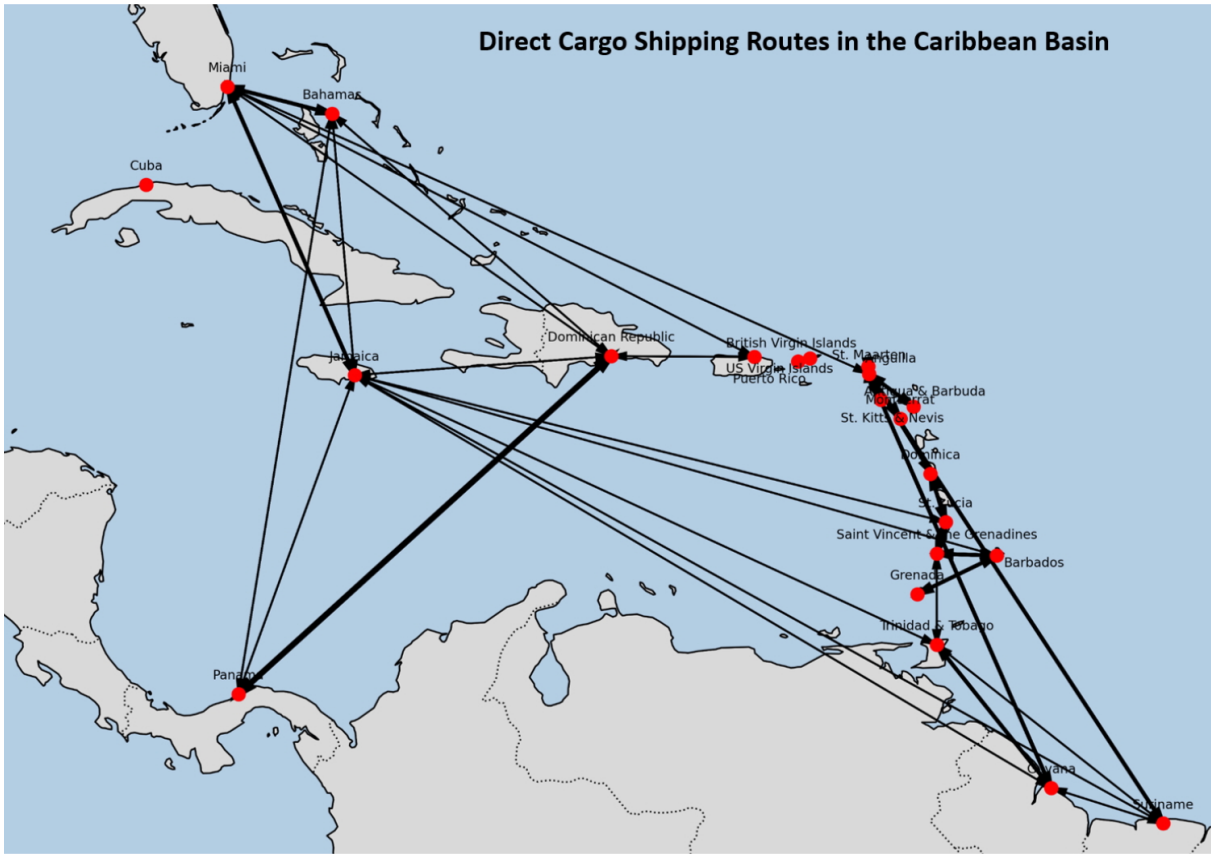
Source: UNCTAD database, IMF staff calculations.
Note: This table reports the OLS estimation results from the bilateral country panel regression of connectivity index on gravity-type variables. Robust standard errors clustered at origin-destination country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

Table 9 OLS Regression of Shipping Cost

Dependent variable: bilateral shipping cost	(1)	(2)	(3)
Regional Trade Agreement	-0.094 ***	-0.241 ***	-0.237 ***
	(0.019)	(0.018)	(0.019)
Distance	0.530 ***	0.454 ***	0.449 ***
	(0.012)	(0.011)	(0.012)
Border	-0.178 ***	-0.227 ***	-0.257 ***
	(0.048)	(0.046)	(0.047)
Language	-0.065 ***	-0.091 ***	-0.109 ***
	(0.025)	(0.025)	(0.025)
Colonial ties	-0.179 ***	-0.102 ***	-0.079 ***
	(0.030)	(0.030)	(0.030)
CARICOM destination dummy		0.296 ***	0.340 ***
		(0.030)	(0.032)
Latin America destination dummy			0.191 ***
			(0.026)
Sub-Saharan Africa destination dummy			0.178 ***
			(0.022)
Middle East and North Africa destination dummy			-0.128 ***
			(0.027)
Emerging and Developing Asia destination dummy			-0.118 ***
			(0.029)
Emerging and Developing Europe destination dummy			0.146 ***
			(0.028)
Origin-year fixed effects	Yes	Yes	Yes
Destination-year fixed effects	Yes	No	No
Observations	136,762	136,762	136,762
Adj. R-squared	0.317	0.222	0.227

Source: UNCTAD database, IMF staff calculations.
Note: This table reports the OLS estimation results from the bilateral country panel regression of shipping cost index on gravity-type variables. Robust standard errors clustered at origin-destination country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

Figure 33 Direct Cargo Shipping Routes in the Caribbean Basin

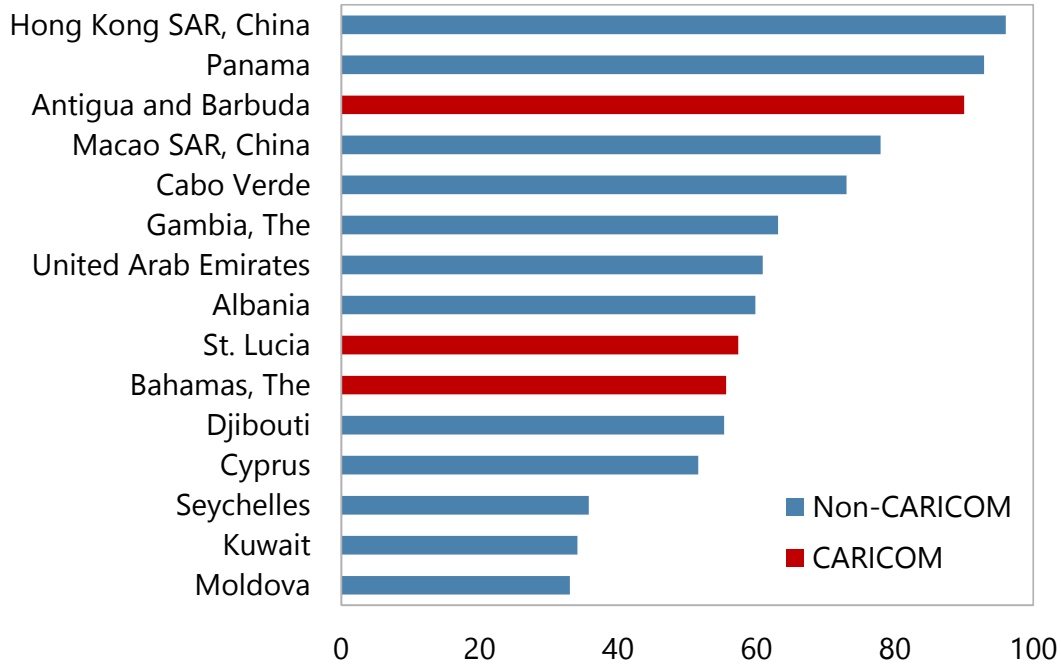


Source: ECCB staff

Note: The routes provided are as advertised by shipping companies operating in the region namely - MSC, Maersk, Tropical Shipping, King Ocean and Zim Integrated. These are scheduled routes which operate either weekly or biweekly or other as of August 2025. Companies also offer chartered routes and rates upon request.

Figure 34 Top 20 Re-export Hubs in the World

Percent of total exports, annual average



Source: UN Comtrade and authors' calculations.

Gravity-based approach

A gravity-type model provides a useful framework for assessing how connectivity constraints shape trade patterns. Such constraints are expected to have disproportionately large adverse effects on trade between more distant country pairs relative to nearby ones. If connectivity is not adequately accounted for, the model will result in biased predictions: overestimating trade with distant partners and underestimating trade with closer ones.

We estimate the gravity model using a standard Poisson Pseudo Maximum Likelihood (PPML) specification. This approach has the advantage that the PPML estimator accommodates zero trade flows without *ad hoc* transformations and delivers consistent estimates under heteroskedasticity (Silva and Tenreyro, 2006). To proxy for multilateral resistance, we include two-way fixed effects—exporter–year and importer–year—and cluster standard errors at the country-pair level.[16] With this specification, only bilaterally varying covariates are identified, while all country-specific factors are absorbed by the fixed effects. Using coefficients estimated on the global sample, we then plug country-pair characteristics into the model to predict what country i would export to country j if country i were in line with the sample countries' overall trend. Any gap between predicted and actual exports indicates whether country i is exporting above or below this benchmark to partner j.

We begin by estimating the following specification, using bilateral goods trade data from the BACI (CEPII) database:

$$Export_{ijt} = \exp(\beta X_{ijt})\, \eta_{ijt} \ ,$$

where $Export_{ijt}$ stands for exports of country i to j in year t. The set of control variables can be expressed as:

$$X_{ijt} = FE_{it},\ FE_{jt},\ \ln\ Dist_{ij},\ Geo_{ij},\ RTA_{ijt},\ \ln Tariff_{ijt} \ ,$$

which includes exporter-year fixed effects (FE_{it}); importer-year fixed effects (FE_{jt}); geographical distance in log ($\ln Dist_{ijt}$); other geographical dummy variables (e.g., common language, common continent, common colony, etc.); a regional trade agreement dummy variable (RTA_{ijt}); and applied average bilateral tariff rates in log ($\ln Tariff_{ijt}$). The estimation is done in a pooled panel at the country-aggregate level.

[16] Inward and outward multilateral resistance terms are unobservable, theoretical artifacts capturing the extent to which bilateral trade is influenced by each country's relative trade costs with all other trading partners. At least since Olivero and Yotov (2012), they have been accounted for by exporter-time and importer-time fixed effects in a dynamic gravity estimation framework with panel data. Moreover, in addition to accounting for the unobservable multilateral resistance terms, the exporter-time and importer-time fixed effects also effectively absorb all other observable and unobservable country-specific characteristics, including various national policies, institutions, and exchange rates (Yotov, Piermartini, Monteiro, and Larch, 2016).

The model allows analysis of relative under- or over-trading for a given country or region vis-à-vis its trading partners.[17] Specifically, the predicted bilateral trade flow from country *i* to country *j* at time *t* is computed as:

$$\widehat{Export}_{\text{ijt}} = \exp(\hat{\beta} X_{ijt}),$$

while the excess/missing bilateral trade flow is captured as:

$$Excess_{ijt} = Export_{\text{ijt}} - \widehat{Export}_{\text{ijt}},$$

where $Excess_{ijt} > 0$ implies trade flows in excess of those predicted by the model and $Excess_{ijt} < 0$ corresponds to missing trade flows relative to predicted flows.

With all the *bilateral* excess/missing trade flows, we can then aggregate them in various ways to study trade patterns both between countries/regions and within a region itself. For instance, one can aggregate up the excess/missing exports of all the exporting countries *i*'s within a region *R* (i.e., $i \in R$) to a given destination country *j* and obtain the excess/missing export of region *R* as a whole to country *j* as:

$$Excess_{jt}^{R} = \sum_{i \in R} \left(Export_{\text{ijt}} - \widehat{Export}_{\text{ijt}}\right)$$

Similarly, one can also aggregate the excess/missing exports of a given exporting country *i* to all the countries *j*'s in a region *S* (i.e., $j \in S$) and obtain the excess/missing export of country *i* to region S as:

$$Excess_{it}^{S} = \sum_{j \in S} \left(Export_{\text{ijt}} - \widehat{Export}_{\text{ijt}}\right)$$

The degree of trade integration within a region, relative to the level implied by the model, can be assessed by imposing *R* equal to *S* and aggregating it up all excess/missing exports within all the bilateral pairs with the region:

$$Excess_{t}^{R} = \sum_{j \in R} \sum_{i \in R} \left(Export_{\text{ijt}} - \widehat{Export}_{\text{ijt}}\right).$$

Our baseline gravity model estimates confirm key factors influencing global trade. Column (1) in **Table 10** reports PPML estimates for our baseline model with the full sample over 2007-2022. The estimated coefficients line up with the gravity literature in sign and order of magnitude: having a regional trade agreement, sharing a border, speaking a common language, or having colonial ties are all associated with higher trade, while geographic distance and higher bilateral tariffs are associated with lower trade flows. We note that gross exports in regional hubs may primarily reflect transshipment rather than domestic value added, which could bias the gravity estimates. In Column (2), we therefore account for the fact that several CARICOM economies are among the most re-export-

[17] For any country or region, the "adding-up" constraint ensures that the under- or over-trading with all its trading partners will sum to zero. Specifically, a well-known implication of PPML with exporter–year and importer–year fixed effects is: for each exporter–year (and analogously for each importer–year), the sum of predicted bilateral flows exactly matches the observed total (e.g., Fally 2015). Hence, by construction of the model, any overprediction for some partners must be offset by underprediction for others. While this prevents identifying aggregate over- or under-exporting for a country in a given year, the framework is well suited to pinpoint partner markets with untapped export potential.

oriented countries in the world by re-estimating the gravity model using our measure of domestic exports (that is, excluding re-exports) as the dependent variable.[18] The main results are essentially unchanged.

The estimates suggest that distance has a stronger adverse effect on trade for Caribbean destination countries. To assess whether trade determinants differ systematically for CARICOM destination countries relative to the rest of the world, Column (3) introduces interaction terms between the CARICOM destination dummy and the key gravity variables. The negative and statistically significant coefficient on the distance interaction indicates that trade involving CARICOM destination countries declines more sharply with distance than the global average. Tariffs and common language also show larger effects in the region, while regional trade agreements appear to be less trade-enhancing for CARICOM. By contrast, the interaction terms for colonial ties and shared borders are not statistically significant. Results are broadly similar when using domestic exports as the dependent variable (Column [4]).

Table 10 PPML Estimation of the Gravity Model

Dependent variable:	Gross Exports	Net Exports	Gross Exports	Net Exports
Regional Trade Agreement	0.625 ***	0.621 ***	0.631 ***	0.627 ***
	(0.072)	(0.074)	(0.073)	(0.074)
Distance	-0.304 ***	-0.306 ***	-0.301 ***	-0.303 ***
	(0.062)	(0.062)	(0.063)	(0.062)
Border	0.797 ***	0.788 ***	0.799 ***	0.790 ***
	(0.103)	(0.103)	(0.103)	(0.103)
Language	0.387 ***	0.362 ***	0.385 ***	0.360 ***
	(0.110)	(0.107)	(0.110)	(0.107)
Colonial ties	0.915 ***	0.897 ***	0.922 ***	0.902 ***
	(0.130)	(0.133)	(0.131)	(0.134)
Bilateral tariff rate	-1.944 *	-2.032 *	-1.850	-1.937 *
	(1.147)	(1.168)	(1.133)	(1.154)
Regional Trade Agreement x Region dummy			-0.884 ***	-0.910 ***
			(0.183)	(0.185)
Distance x Region dummy			-0.583 ***	-0.571 ***
			(0.114)	(0.114)
Border x Region dummy			0.950	0.988
			(0.762)	(0.773)
Language x Region dummy			0.365 **	0.419
			(0.183)	(0.187)
Colonial ties x Region dummy			-0.159	-0.158
			(0.247)	(0.253)
Bilateral tariff rate X Region dummy			-9.330 ***	-9.181 ***
			(2.439)	(2.490)
Exporter-Year FE	Yes	Yes	Yes	Yes
Importer-Year FE	Yes	Yes	Yes	Yes
Observations	663,821	663,821	663,821	663,821
Pseudo R-squared	0.914	0.914	0.914	0.914

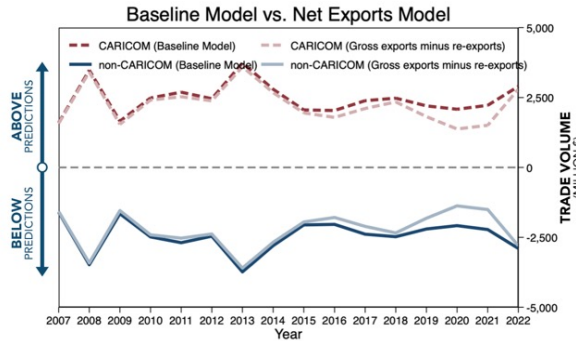
Source: UNCTAD database, IMF staff calculations.
Note: This table reports the PPML estimation results from the bilateral country panel regression of trade flows on gravity-type variables. Robust standard errors clustered at exporter-importer country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

[18] Examples of such CARICOM economies include Antigua and Barbuda, St. Lucia, and The Bahamas, where re-exports account for more than half of total exports. We measure domestic exports by taking out re-exports from total exports.

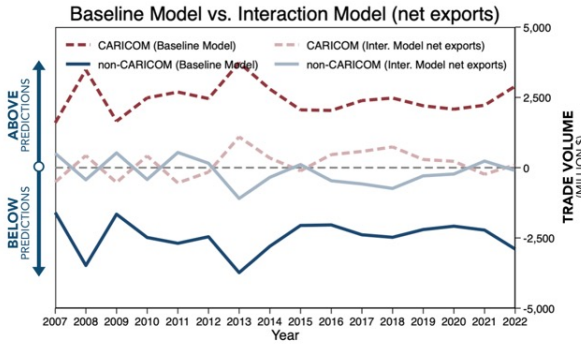
The model predicts that CARICOM countries engage in less trade with regions outside the Caribbean than fundamental factors would suggest. As explained earlier, aggregating the predicted exports of all CARICOM countries across intra-regional partners and extra-regional partners offers insights into their relative under- or over-trading patterns.[19] Panel A in **Figure 35** presents the results derived from the baseline Model, which are shown in dark lines indicating that CARICOM countries trade relatively less with partners outside of the region, and thus relatively more with partners within the region, than the gravity model predicts. The estimated degree of over- and under-trading is on the order of US$2.5 billion annually. This is equivalent to around 10 percent of total goods traded with those partners outside the region. The estimation results from excluding re-exports offer a similar pattern but could reduce the extent of over- and under-trading in recent periods, shown in light lines. In both cases, the trade gap in nominal terms has been relatively stable over time.

Figure 35 Deviations Between Actual and Predicted Trade Patterns in CARICOM

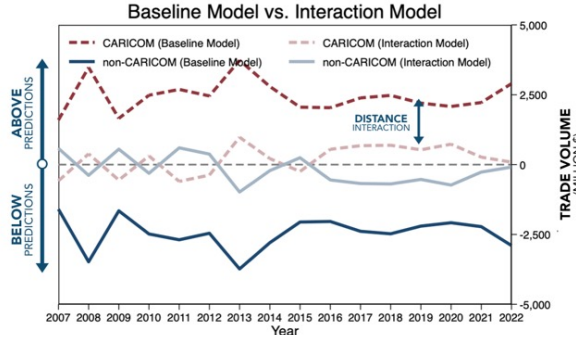
Panel A Baseline Model vs. Model w/o Re-exports



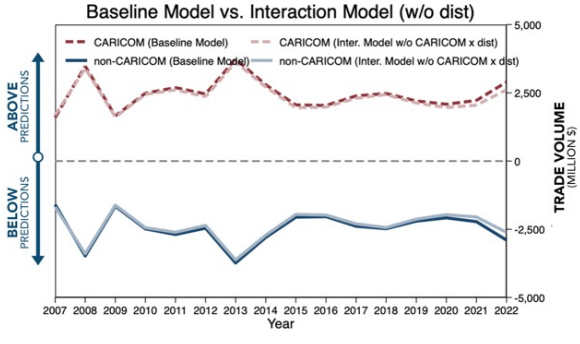
Panel B Baseline model vs Interaction Model (in percent of respective exports)



Panel C Baseline model vs Interaction Model (in percent of respective exports)



Panel D Baseline model vs Interaction Model (in percent of total exports)



The distance variable explains most of the gap between actual and model-predicted trade for CARICOM countries. To identify the key drivers of this gap, we introduce interaction terms between the CARICOM dummy and the baseline explanatory variables and assess which interaction term best accounts for the discrepancy. We find that the distance interaction term is the primary contributor to the gap, while the inclusion of other interaction terms has little effect on the results. This is illustrated in Panels B-D of **Figure**

[19] Given the adding-up constraint and the nature of intra-regional trade where total intra-regional exports equal total intra-regional imports, whether exports or imports are used, we can interpret them as excess/missing *trade*.

35: once a set of interaction terms is included, the gap shown by the light lines shrinks substantially toward zero, implying a significant improvement in model fit (Panel B). The effect is even more pronounced when re-exports are excluded from the dependent variable (Panel C). Notably, including all other interaction terms while excluding the distance interaction term leaves the results largely unchanged relative to the baseline model (Panel D).

Overall, this exercise highlights the central role of geographic distance in shaping Caribbean trade patterns. Imposing a common distance coefficient leads to systematic overprediction of Caribbean trade with distant partners outside the region and an underprediction of trade with nearby countries within the region, resulting in substantial excess and missing trade outside and within the region, respectively. Allowing for a disproportionately large adverse effect of distance on CARICOM trade substantially improves model fit and largely eliminates these discrepancies. This pattern is consistent with the presence of elevated trade costs associated with connectivity constraints affecting Caribbean economies.

TOURISM AND CONNECTIVITY

Background

For many Caribbean economies, tourism is the primary source of income, employment, and foreign exchange. The sector accounts for over 20 percent of GDP and about 70 percent of service exports across CARICOM countries **(Figure 36)**, with significant spillovers to agriculture, transportation, and construction. Although cruise passengers comprised nearly two-thirds of total arrivals in 2024, stayover tourists generate substantially higher revenue and economic multipliers due to longer stays and broader spending across the economy. For instance, tourism receipts per cruise passenger in Dominica were estimated at under $US 200 in 2023, compared with roughly $US 2,000 per stayover visitor (BREA, 2024; authors' calculation). From a global perspective, the Caribbean accounts for a small but relatively stable share of international tourism, reflecting both the region's economic scale and relatively limited access and higher costs compared to other destinations.

Concentration and Vulnerability

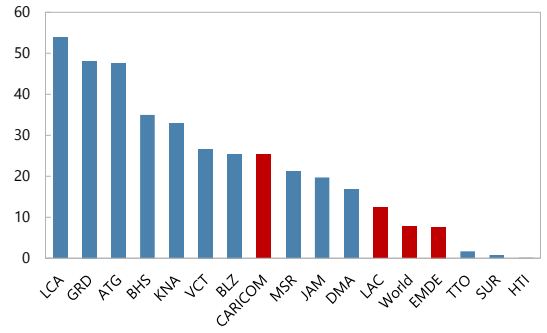
Tourism inflows to the Caribbean are highly concentrated across a narrow set of source markets. Since the mid-1990s, stayover arrivals from the United States have accounted for roughly 60 percent of total arrivals to CARICOM countries, with a further 30 percent originating from Europe and Canada, and the rest from all other countries combined **(Figure 37)**. A similar pattern holds for ECCU countries, although concentration is somewhat lower, reflecting a modestly larger share from Europe relative to the United States.[20] Concentration has intensified since the COVID-19 pandemic, as the U.S. share of arrivals increased further, partly reflecting pandemic-related travel restrictions and

[20] The ECCU is a sub-grouping of eight (8) CARICOM countries that share the Eastern Caribbean dollar as a common currency. These eight countries also share one Central Bank, the Eastern Caribbean Central Bank (ECCB), which manages the ECCU's monetary policy and currency. The ECCU comprises Anguilla, Antigua and Barbuda, Commonwealth of Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint Lucia and Saint Vincent and the Grenadines.

higher travel costs elsewhere. In global comparison, tourism source market concentration in the Caribbean is elevated, with most CARICOM countries ranking above the 50th percentile of the Herfindahl-Hirschman Index (HHI) distribution.

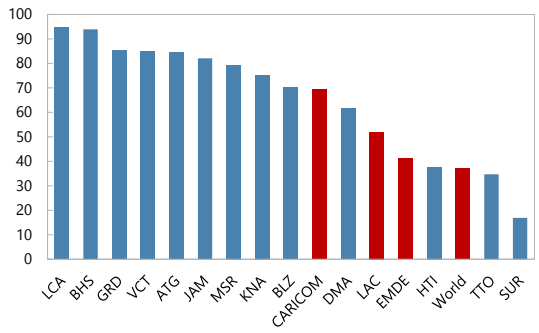
Figure 36 Overview of Caribbean Tourism Sector

Panel A Tourism Services Credits, 2024 (% of GDP)



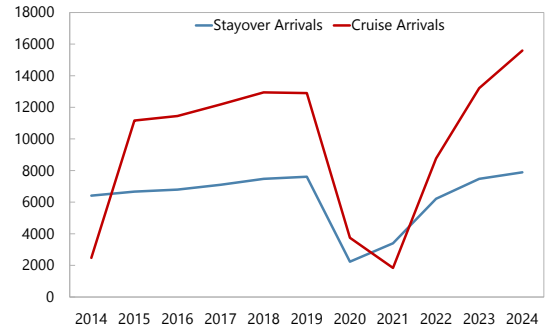
Note: Group aggregate values are simple averages. "EMDE" = Emerging and Developing Economies; "LAC" = Latin America and the Caribbean.

Panel B Tourism Services Credits, 2024 (% of Total Services Credits)



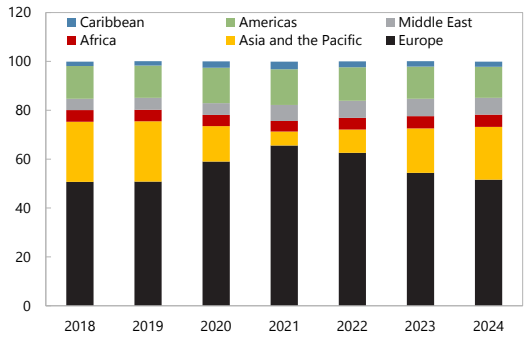
Note: Group aggregate values are simple averages. "EMDE" = Emerging and Developing Economies; "LAC" = Latin America and the Caribbean.

Panel C Stayover vs. Cruise Arrivals (1,000 of arrivals)



Source: CTO and authors' calculations.
Note: Lines sum arrivals for 15 CARICOM members.

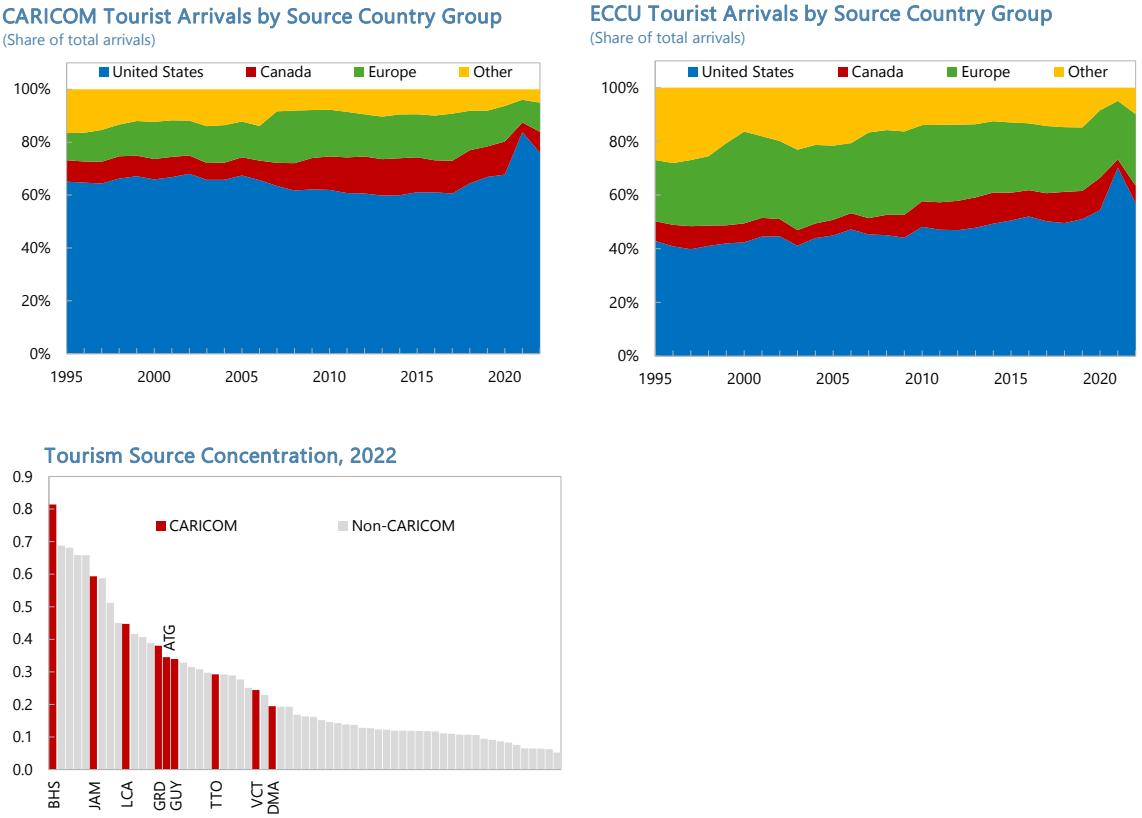
Panel D Share of Caribbean among International Tourists (% of Total)



Source: UN Tourism and authors' calculations.

Tourism source markets in the Caribbean are more highly concentrated than in other regions, even after accounting for income levels and geographic remoteness. **Table 11** reports OLS regressions of the HHI on GDP per capita, remoteness, and regional dummies. Greater remoteness is associated with higher concentration, while higher income is associated with lower concentration, consistent with more remote destinations drawing from fewer markets and richer destinations attracting a more diversified visitor base. Across specifications, the CARICOM dummy is positive and highly significant, indicating that CARICOM countries exhibit substantially higher source-market concentration than the global average, even after controlling for income and remoteness. By contrast, most other regional dummies—Latin America, Sub-Saharan Africa, the Middle East and North Africa, and Emerging and Developing Asia—are associated with lower concentration. Overall, these results point to unusually high tourism source market concentration in small Caribbean economies that cannot be explained by income or geography alone.

Figure 37 Concentration of Caribbean Tourism Source Countries



Source: UN Tourism, UN WTO, and authors' calculations.
Note: Tourism source concentration is the concentration of origin of tourists, measured by Herfindahl-Hirschman Index (HHI) with scale 0-1 with zero reflects the highest concentration.

This high degree of concentration implies that fluctuations in economic conditions in key source markets can have sizable effects on tourism flows. **Table 12** reports estimates of the elasticity of tourist arrivals with respect to source market GDP. The average elasticity is around 0.8, implying a 1 percent increase in source country GDP leads to a 0.8 percent increase in arrivals. For tourism flows from the U.S. to CARICOM, however, the estimated elasticity sharply increases to around 2, indicating substantially higher sensitivity to U.S. economic conditions.[21] Given the dominant role of the U.S. market, this heightened responsiveness contributes to increased volatility in aggregate tourist arrivals and amplifies downside risks during U.S. slowdowns. This finding highlights the potential benefit of diversifying source markets.

[21] The high income elasticity of U.S. outbound tourism likely reflects the strongly discretionary and pro-cyclical nature of international travel for U.S. households.

Table 11 OLS Estimation of Tourism Source Market Concentration

Dependent variable: country-level HHI	(1)	(2)	(3)
GDP per capita	0.012	-0.014 ***	-0.034 ***
	(0.020)	(0.002)	(0.002)
Remoteness index	-0.176 **	0.111 ***	0.216 ***
	(0.060)	0.005	(0.027)
CARICOM dummy		0.195 ***	0.118 ***
		(0.011)	(0.017)
Latin America dummy			-0.086 ***
			(0.020)
Sub-Saharan Africa dummy			-0.130 ***
			(0.015)
Middle East and North Africa dummy			-0.104 ***
			(0.003)
Emerging and Developing Asia dummy			-0.100 ***
			(0.018)
Emerging and Developing Europe dummy			0.012 ***
			(0.014)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	No	No
Observations	1,401	1,401	1,401
Adj. R-squared	0.897	0.171	0.194

Source: UNWTO database, IMF staff calculations.
Note: This table reports the OLS estimation results from the destination country-level panel regression of Herfindahl-Hirschman Index of tourist sources. Robust standard errors clustered at exporter-importer country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

Table 12 OLS Estimation of Tourism Elasticity

Dependent variable: bilateral tourist arrivals	(1)	(2)	(3)	(4)
Distance	-1.433 ***	-1.437 ***	-1.438 ***	-1.429 ***
	(0.050)	(0.050)	(0.053)	(0.050)
Border	0.647 ***	0.629 ***	0.628 ***	0.619 ***
	(0.104)	(0.106)	(0.106)	(0.110)
Language	0.670 ***	0.670 ***	0.667 ***	0.739 ***
	(0.120)	(0.120)	(0.120)	(0.105)
Colonial Ties	0.447 ***	0.462 ***	0.468 ***	0.457 ***
	(0.163)	(0.171)	(0.171)	(0.173)
Real Exchange Rate		-0.273 ***	-0.272 ***	-0.280 ***
		(0.085)	(0.084)	(0.090)
Source Country Real GDP (log)		0.807 ***	0.808 ***	0.821 ***
		(0.116)	(0.116)	(0.117)
Source Country Real GDP (log)			-0.180 **	-0.059
X ECCU destination dummy			(0.059)	(0.037)
Source Country Real GDP (log)				1.139 **
X US source dummy				(0.563)
Destination-year fixed effects	Yes	Yes	Yes	Yes
Origin-year fixed effects	Yes	No	No	No
Origin country fixed effects	No	Yes	Yes	Yes
Observations	124,083	119,872	119,872	119,872
Pseudo R-squared	0.942	0.939	0.939	0.939

Source: UNWTO database, IMF staff calculations.
Note: This table reports the PPML estimation results from the bilateral country panel regression of tourist arrivals on gravity-type variables. A complete set of interaction terms are included in the regression (columns (3) and (4)) but not reported in the table. Robust standard errors clustered at source-destination country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

Connectivity

The Caribbean's air transport system is characterized by small-scale airports, high route concentration, and pronounced seasonality (IDB, 2015). Given the region's geographic isolation, travelers depend almost entirely on air transportation. Passenger volumes per international airport are generally small, runway capacity is limited in several countries, and most destinations rely on a handful of airlines and external hubs. More than 80 percent of flights and passengers from the U.S. originate from the ten largest cities, with Miami serving as the primary gateway (Acevedo *et al.*, 2016). The seasonality of air transport demand due to the tourism cycle also makes it challenging for airline operations. Recent and ongoing airport expansion and modernization projects across the region[22] reflect capacity pressures, particularly during peak tourism periods.

Air connectivity in the Caribbean appears weaker compared with other regions when measured by total flight capacity. Air connectivity can be characterized along multiple dimensions, for instance, number of airports and flights, airfare levels, schedule convenience, and service stability. For our analysis, we focus on total inbound passenger

[22] This includes the construction of a new international airport in Dominica, runway upgrade in Antigua's V.C. Bird International Airport, the opening of Barbuda International Airport, the opening of Argyle International Airport in St. Vincent and the Grenadines, and new terminal construction at The Bahamas Long Island International Airport, among others. Additionally, airport improvement efforts are ongoing in St. Lucia and Haiti.

seat capacity for each destination country, which implicitly combines information on the number of airports, flight frequency, and aircraft size, although it does not account for occupancy rates which are unavailable to us. Although studies have shown that some Caribbean countries are above the world average in terms of air passenger volume per capita (Reeves and others, 2018; IATA, 2020), our model results indicate that after controlling for destination-country income levels and geographic remoteness, Caribbean destinations have substantially lower air connectivity than other regions (Table 13).

Table 13 OLS Estimation of Flight Capacity

Dependent variable: country-level flight capacity	(1)	(2)	(3)
GDP per capita	0.006	1.143 ***	1.073 ***
	(0.027)	(0.006)	(0.011)
Remoteness index	18.230	-1.091 **	-1.797 ***
	(7.672)	(0.136)	(0.098)
Land area		0.353 ***	0.356 ***
		(0.005)	(0.004)
CARICOM dummy		-0.340 **	-0.248 *
		(0.058)	0.070
Latin America dummy			0.338 **
			(0.048)
Sub-Saharan Africa dummy			-0.220 **
			(0.049)
Middle East and North Africa dummy			-0.005
			(0.012)
Emerging and Developing Asia dummy			0.370 ***
			(0.017)
Emerging and Developing Europe dummy			-0.605 ***
			(0.042)
Year fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	No	No
Observations	554	554	554
Adj. R-squared	0.997	0.720	0.730

Source: UNCTAD database, IMF staff calculations.
Note: This table reports the OLS estimation results from the destination country-level panel regression of flight passenger capacity. Robust standard errors clustered at origin-destination country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

Cross-country variation in total flight-based passenger capacity is driven mainly by the extensive margin. By construction, total capacity can be decomposed into an extensive margin (capturing the number of origin countries with direct flight routes and average flight frequency per origin country) and an intensive margin (reflecting average seats per flight). Using a regression-based decomposition, we find that extensive margins account for around 94 percent of the variation in total capacity, with the number of origin countries and flight frequency contributing roughly 40 and 54 percent, respectively (Table 14). This indicates that differences in air connectivity are driven mainly by route availability and flight frequency, rather than by systematic variation in aircraft size once routes are established.

$$TotalCapacity_{it} = \overbrace{(\#\ countries)_{it} \times \frac{(\#\ flights)_{it}}{(\#\ countries)_{it}}}^{extensive\ margin} \times \overbrace{\frac{(\#passenger\ seats)_{it}}{(\#\ flights)_{it}}}^{intensive\ margin}$$

We conduct a quantitative assessment of the relationship between tourism flows and air connectivity. Specifically, we estimate the elasticity of tourist arrivals with respect to passenger flight capacity within a gravity framework. The analysis combines bilateral origin-destination tourism data from the United Nations World Tourism Organization (UNWTO) with flight capacity data constructed from *FlightRadar24*, defined as the total number of seats available on all inbound passenger flights.[23] The resulting panel covers more than 200 countries over the period of 2019-2024.

Table 14 OLS Regression on Flight Capacity Decomposition

	(1)	(2)	(3)
Dependent variable:	# countries	avg # flights	avg # passenger seats
Total # passengers	0.396 ***	0.538 ***	0.066 ***
	(0.015)	(0.018)	(0.005)
Year fixed effects	Yes	Yes	Yes
Observations	554	554	554
Adj. R-squared	0.815	0.888	0.201

Source: UNCTAD database, IMF staff calculations.
Note: This table reports the OLS estimation results from the regression decomposition of total annual passenger capacity. Robust standard errors clustered at origin-destination country pair level are reported in parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent.

We adopt a gravity-type model, similar to the specification for goods, where tourist arrivals are explained by flight capacity, as well as several control variables including distance. The baseline gravity model specification is:

$$Visitor_{ijt} = \exp(\beta X_{ijt})\,\eta_{ijt},$$

where $Visitor_{ijt}$ stands for the number of visitors from country *i* to *j* at time *t*. The set of control variables including the main variable of interest, flight capacity, can be expressed as:

$$X_{ijt} = FE_i, FE_{jt}, \ln Dist_{ij}, Geo_{ij}, flight_{ijt}\},$$

These include origin fixed effects, destination-time fixed effects, geographical distance (in logs), and standard geographical dummy variables (e.g., common language, continent, colonial ties). The Pseudo Poisson Maximum Likelihood (PPML) estimation, used here, addresses adding up constraints and heteroskedasticity (Silva and Tenreyro, 2006; Fally 2015).

The empirical analysis focuses on assessing how supply shocks to passenger flight capacity affect tourist arrivals.[24] A key econometric challenge is the endogeneity between

[23] As *FlightRadar24* measures seat capacity rather than realized passenger volumes, variation in load factors could affect the estimated elasticities, especially in markets with pronounced seasonality or structurally low occupancy. However, the use of annual data or the inclusion of time fixed effects in monthly data would reduce this potential bias by averaging out or controlling seasonal fluctuations in load factors.

[24] Like the analysis on goods trade in the previous section, the gravity model approach also allows to predict bilateral tourism flow as $\widehat{Visitor}_{ijt} = \exp(\hat{\beta} X_{ijt})$, while the excess/missing bilateral tourism flow is captured as $Excess_{ijt} = Visitor_{ijt} - \widehat{Visitor}_{ijt}$, where $Excess_{ijt} > 0$ implies excess flows and $Excess_{ijt} < 0$ corresponds to missing flows. However, unlike goods which are relatively more homogeneous in gravity terms, tourism flows are highly differentiated and destination-specific, which may

flight capacity and tourist arrivals, as both may respond to common destination-specific "pull factors," leading to biased OLS estimates. To address this, we employ an instrumental variable (IV) approach designed to isolate exogenous shocks to flight capacity driven by source country "push factors," rather than by demand conditions in destination countries.

We follow the shift-share (Bartik-style) IV approach common in the literature. We use variation in flights driven by supply-side shocks at the origin market level, rather than destination-specific factors, to construct the IV. Specifically, for each origin-destination pair *i-j* at time *t*, we construct the IV:

$$Z_{i,j,t} = w_{i,j,0} \times \ln\left(flight_{i,k!=j,t}\right),$$

where $w_{i,j,0} = \frac{flight_{i,j,0}}{flight_{i,0}}$ is the share of flight capacity from origin *i* to destination *j* out of all the flight capacity from origin *i* in the base year (*t=0*). This design captures origin-wide supply shocks—such as airline fleet reallocations, airport disruptions, or common fuel cost shocks—that affect all outbound flights from an origin and are not related to destination-specific demand. Implicitly, it is embedded in the origin shift-share IV that an origin-wide capacity shock reallocates scarce seats across that origin's routes according to pre-existing route shares. The inclusion of origin fixed effects and destination-time fixed effects helps further isolate origin outbound shocks that affect tourism *via capacity* rather than directly through destination-specific time-varying factors (such as attractiveness, hotel room capacity[25]).

This shift-share design compares origin-destination pairs with similar historical connectivity but varying exposure to origin-level supply shocks. When an origin country's flight capacity drops, the impact is not uniform: destinations that historically rely more on that origin see a sharper decline in inbound flights. This allows us to isolate the effect of reduced accessibility on tourism, independent of changes in bilateral demand.

The use of pre-determined baseline shares strengthens the exclusion restriction required for causal identification. By fixing these shares at a base period, we ensure that instrument variation is driven by origin-level supply shocks rather than evolving bilateral fundamentals. Following Goldsmith-Pinkham *et al.* (2020), our base-period route shares reflect historical connectivity that predates the estimation sample. This ensures that the instrument is moved by origin-wide capacity shocks rather than destination-specific demand. Our identification assumes that these shocks are orthogonal to bilateral tourism demand, conditional on a comprehensive set of fixed effects that absorb origin-specific traits, destination-specific shocks, and global trends. This same Bartik-style framework applies to our financial connectivity analysis, where creditor-country banking shocks serve as the origin-level supply shifts.

make it more difficult to interpret the residuals from the gravity model. In addition, passenger flight capacity can be more inelastic than cargo shipping capacity, and thus missing tourism flow may indicate a *capacity shortfall*, not missing demand.

[25] The fast-growing Airbnb sector appears to have lessened the hotel room constraints in many Caribbean countries.

Table 15 Gravity Regressions of Global Bilateral Tourism Flows

	Model 1 Nationality	Model 2 Residence	Model 3 Adjusted	Model 4 Nationality	Model 5 Residence	Model 6 Adjusted
Dependent Variable	**Tourist Arrival**	**Tourist Arrival**	**Tourist Arrival**	**Tourist Arrival**	**Tourist Arrival**	**Tourist Arrival**
Flight Capacity	0.554*** (0.118)	0.607*** (0.0725)	0.519*** (0.0566)	0.533** (0.182)	0.662*** (0.105)	0.539*** (0.0808)
Distance	-0.405* (0.179)	-0.272* (0.133)	-0.482*** (0.0940)	-0.455 (0.302)	-0.218 (0.204)	-0.470** (0.155)
Border	1.192*** (0.138)	1.195*** (0.148)	1.190*** (0.102)	1.197*** (0.169)	1.190*** (0.195)	1.191*** (0.121)
Language	0.350* (0.150)	0.435*** (0.114)	0.512*** (0.0823)	0.322 (0.187)	0.370* (0.151)	0.473*** (0.100)
Colonial Ties	-0.0113 (0.197)	-0.162 (0.153)	-0.0495 (0.115)	-0.0131 (0.253)	-0.274 (0.230)	-0.0979 (0.174)
Real Exchange Rate	0.116 (0.209)	-0.336 (0.271)	-0.0524 (0.156)	0.127 (0.159)	-0.281 (0.292)	-0.0365 (0.155)
Flight Capacity x CARICOM				-1.905 (3.121)	-0.358** (0.120)	-0.169 (0.124)
Distance x CARICOM				1.877 (2.370)	0.0395 (0.228)	0.171 (0.142)
Border x CARICOM				-2.516 (3.118)	0.112 (0.685)	-0.373 (0.633)
Language x CARICOM				3.427 (4.950)	0.990 (0.577)	0.625 (0.402)
Colonial Ties x CARICOM				-1.219 (3.947)	-0.192 (0.779)	0.198 (0.518)
Real Exchange Rate x CARICOM				-12.13 (19.47)	-1.704 (0.906)	-0.784 (0.782)
Observations	2797	3823	6296	2797	3823	6296
Origin FE	Yes	Yes	Yes	Yes	Yes	Yes
Destination-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Origin-Destination Cluster	Yes	Yes	Yes	Yes	Yes	Yes
R-square	0.553	0.486	0.553	0.522	0.462	0.549

Note: This table reports Two-Stage Least Squares (2SLS) regression results for various measures of tourist arrivals with different regressors. Robust standard errors clustered at origin-destination country pair level are reported in the parenthesis. Significance: *** 1 percent; ** 5 percent; * 10 percent. The first-stage results of the 2SLS regressions are not reported for brevity.

Overall, the estimates indicate air connectivity and geographic frictions as key determinants of bilateral tourist arrivals. Across all six model specifications **(Table 15)**, the coefficient on flight capacity remains large (around 0.52-0.66) and highly statistically significant ($p< 0.01$). This implies an elasticity of around 0.5 to 0.6: a 10 percent increase in flight capacity is associated with roughly a 5-6 percent increase in tourist arrivals. This result is robust to using different definitions of tourists—nationality-based, residence-based, or a harmonized measure based on both ("adjusted")—after controlling for multiple bilateral and macro variables. Geography also matters, as distance and common border are statistically significant in most specifications with signs as expected. Common cultural factors such as language matter to some extent, while colonial ties do not appear significant. Once controlled for flight capacity and bilateral factors, real exchange rates alone do not seem to affect tourism. CARICOM interaction terms are generally insignificant, suggesting determinants of tourism flows work similarly for CARICOM and non-CARICOM pairs.

To complement the global analysis, we repeat a similar exercise on a monthly dataset exclusively focused on the ECCU region. While the global analysis on annual bilateral data provides broad evidence that air connectivity is an important driver of tourism flows, the monthly ECCU data offer two advantages. First, infrastructure constraints (such as runway length, limited carriers and/or airports, high reliance on regional hubs) are likely to be more binding in small states, potentially amplifying the impact of supply shocks. Second, connectivity shocks especially relevant for small state economies (such as hurricanes and airport disruptions) usually operate at short horizons and are better captured at monthly frequency. At the same time, because adjustments in capacity utilization and travel demand unfold gradually, short-run elasticities may differ from long-run responses.

Table 16 Gravity Regressions of Monthly Tourism Flows to the ECCU

	Model 1 Full Sample	**Model 2** ex. Caribbean
Dependent Variable	**Tourist Arrival**	**Tourist Arrival**
Flight Capacity	0.204*** (0.0543)	0.221*** (0.0537)
Oil Price x Distance	-0.121* (0.0529)	-0.172* (0.0675)
Border	*dropped*	*dropped*
Language	-0.144 (0.502)	-0.479 (0.589)
Colonial Ties	1.321 (0.721)	*dropped*
Real Exchange Rate	5.451** (1.593)	7.165** (1.928)
Observations	1784	1423
Destination-Month FE	Yes	Yes
Origin-Destination Cluster	Yes	Yes
R-square	0.511	0.565

Note: This table reports Two-Stage Least Squares (2SLS) regression results for monthly tourist arrivals to the ECCU, with or without intra-Caribbean destinations. Robust standard errors clustered at origin-destination country pair

The empirical specification mirrors the global framework, with log arrivals regressed on log flight capacity using a leave-out shift-share instrument covering the period of *2018M11-2024M12*. Destination-month fixed effects are included to absorb destination-specific demand shocks. The regressions also control for real exchange rates, oil prices, and standard geographic variables (including common borders, common language, and historical colonial ties).

The estimates confirm the role of flight capacity in driving tourist arrivals at the monthly level **(Table 16)**. The regression finds a statistically significant coefficient on flight capacity of around 0.20, smaller than that from the annual model. This reflects the fact that the market (both travelers and tour operators) has time to adjust to higher capacity, leading

to a greater elasticity in arrivals. When excluding intra-Caribbean tourist flows, the elasticity becomes slightly higher at around 0.22, pointing to a larger role played by air connectivity in enabling tourism flows from outside of the region. The coefficients on the real exchange rate and the interaction between oil price and distance are both significant and with expected signs. Both coefficients are larger when excluding intra-Caribbean tourist flows, suggesting bigger price sensitivities for longer-haul routes.

The analysis on monthly ECCU data reinforces the global findings, confirming that air connectivity is a key determinant of tourism flows. The results indicate that the relationships identified in the global regressions also hold in small island states, where infrastructure constraints are more pronounced.

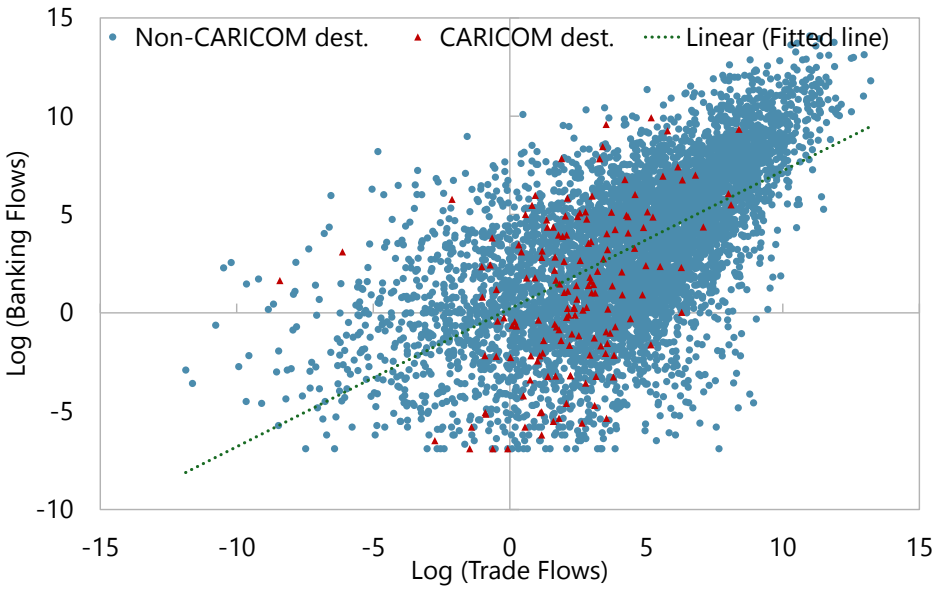
FINANCE AND CONNECTIVITY

Background

Does weak financial connectivity also constrain Caribbean trade? The post-GFC withdrawal of correspondent banking relationships disproportionately affected the Caribbean (Erbenova *et al.*, 2016; Alleyne *et al.*, 2017), raising the question of whether financial frictions may operate alongside the physical connectivity constraints documented above. A simple scatter plot of bilateral banking positions and trade flows shows a positive association between financial linkages and trade. Financial institutions facilitate trade through various channels, motivating an examination whether stronger banking connections, measured by larger bilateral banking flows, are associated with higher trade flows. **Figure 38** suggests that this relationship may be weaker for Caribbean economies (red dots). Building on this observation, our analysis moves beyond global averages to shed light on potential heterogeneity in the banking-trade nexus for the Caribbean.

Figure 38 Banking Flows and Trade Flows, 2022

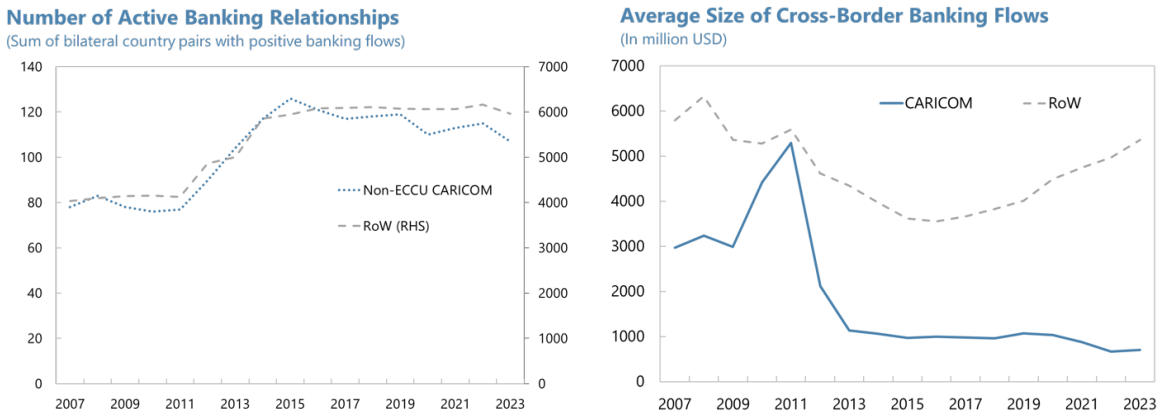
Log scale, bilateral flows



Source: CEPII BACI, BIS LBS, and authors' calculations.

The share of global banking linkages involving CARICOM economies has decreased over time, indicating weakening financial connectivity with international interbank networks. While the number of active bilateral banking relationships increased worldwide following the GFC (Panel A in **Figure 39**), reflecting a recovery in interbank activity, the average size of banking positions vis-à-vis CARICOM economies fell noticeably (Panel B in **Figure 39**). This divergence relative to other regions accounts for much of the decline in CARICOM's share of cross-border banking flows. Moreover, CARICOM countries saw a downward tendency in active banking relationships after 2015, likely reflecting that they were disproportionally affected by the retrenchment of correspondent banking relationships (World Bank, 2015; Erbenova, 2016; Alleyne *et al.*, 2017; Rice *et al.*, 2020).

Figure 39 CARICOM Banking Flows

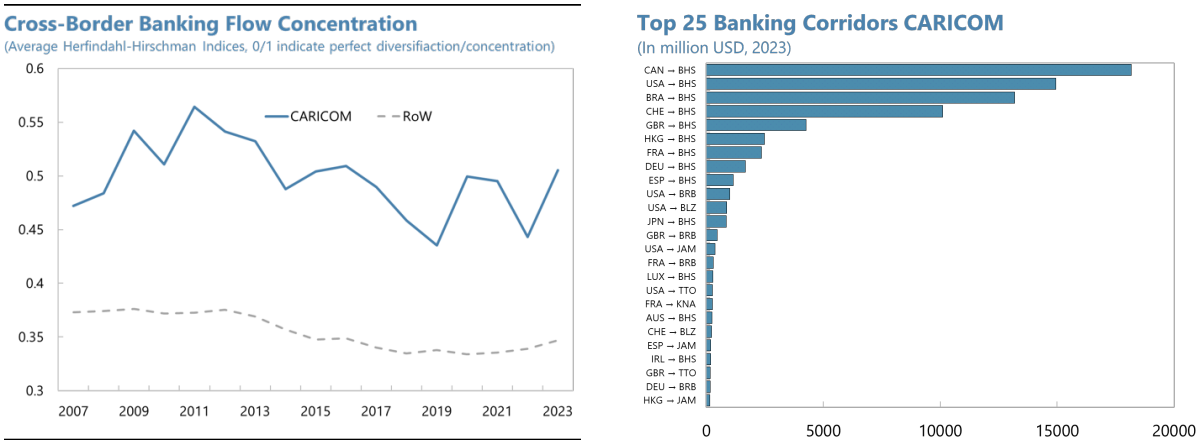


Source: BIS LBS and authors' calculations.

Concentration and Vulnerability

Banking linkages in the Caribbean are highly concentrated among a few creditor countries, with most CARICOM economies relying on a limited number of external partners—at levels well above those observed elsewhere (Panel A of **Figure 40**). Although sources for banking flows to CARICOM economies diversified in the aftermath of the GFC, in line with global trends, this pattern largely reversed during the pandemic, with concentration increasing more sharply than in other regions. Within CARICOM, The Bahamas and Jamaica stand out as relatively more diversified (Panel B of **Figure 40**). At the same time, cross-border banking activity is dominated by a handful of bilateral corridors, linking CARICOM members to major global financial centers for correspondent banking, wealth management, and investment services.

Figure 40 Concentration Patterns of Caribbean Banking Positions



Source: BIS LBS and authors' calculations.

Connectivity: Financial Linkages and Goods Trade

We investigate whether stronger interbank relationships causally increase bilateral goods trade flows, with particular attention to CARICOM-specific patterns. As highlighted above, the literature establishes that banking relationships support bilateral goods trade. While the literature largely considers average effects, a key contribution of our study lies in exploring heterogeneous banking-trade relationships across regions, with a focus on Caribbean economies, where structural characteristics may limit the trade-facilitating benefits of banking relationships. To address simultaneity between banking and trade flows—which could bias OLS estimates—we employ a Bartik-type shift-share instrumental variable approach, analogous to that used in the tourism analysis above.[26]

We construct an instrument that exploits exogenous variation in the banking capacity of creditor countries. Specifically, for each country pair ij at time t:

$$Z_{ijt} = \sum_{c} s_{ij,c}^{2008} \cdot \Delta Shock_{ct},$$

where $s_{ij,c}^{2008}$ represents the frozen shares of creditor country c in country-pair ij's banking relationship in 2008 and $\Delta Shock_ct$, computed as $\ln(OutwardClaims_{c,t}) - \ln(OutwardClaims_{c,t-1})$ where $OutwardClaims_{c,t}$ is the total outward claim of credit country c in year t, excluding bilateral relationships ij, and $\Delta Shock_{ct}$ reflects creditor-country banking shocks. The origin-level supply shocks in this context take the form of banking distress in creditor countries—such as domestic bank recapitalization, sovereign downgrades, or deposit flight—which reduce the creditor's ability to supply international banking services. Country pairs with historically higher exposure to a distressed creditor thus experience larger contractions in banking capacity, affecting trade through reduced access to trade finance and increased transaction costs.

[26] While Baier and Bergstrand (2007) show that country-pair fixed effects effectively address endogeneity concerns for time-invariant bilateral determinants, the simultaneity between time-varying financial and trade flows remains a potential concern. We employ our Bartik-type shift-share IV to address this.

In the first stage, we estimate how our instrument predicts bilateral banking positions with the following regression:

$$\ln\left(BankingFlows_{ijt}\right) = \eta Z_{ijt} + X_{ijt}'\Pi + \alpha_{ij} + \lambda_{it} + \delta_{jt} + \nu_{ijt},$$

where $X_{ijt}'\,\Pi$ represent the effects of the controls—distance, common border, common language, and historical colonial ties—on bilateral interbank flows. α_{ij} are country-pair fixed effects, λ_{it} origin-year effects, δ_{jt} destination-year effects, and ν_{ijt} captures unexplained variation in bilateral banking positions.

In the second stage, we estimate the causal effect of instrumented banking linkages on goods trade:

$$\ln\left(TradeFlows_{ijt}\right) = \boldsymbol{\beta}\ \ln\left(BankingFlows_{ijt}\right) + X_{ijt}'\Upsilon + \alpha_{ij} + \lambda_{it} + \delta_{jt} + \varepsilon_{ijt},$$

where $\boldsymbol{\beta}$ quantifies the causal effect of bilateral interbank flows on bilateral trade flows, controlling for structural effects through $X_{ijt}'\Upsilon$, with $\alpha_{ij}, \lambda_{it}, \delta_{jt}$ representing fixed effects as before and ε_{ijt} capturing the unexplained variation in bilateral trade flows.

To identify whether CARICOM economies experience different banking-trade relationships, we estimate the following interaction specification:

$$\begin{aligned}\ln\left(TradeFlows_{ijt}\right) &= \boldsymbol{\beta_1}\ln\left(BankingFlows_{ijt}\right) + \boldsymbol{\beta_2}\ln\left(BankingFlows_{ijt}\right)\cdot CARICOM_j \\ &+ \boldsymbol{\beta_3} CARICOM_j + X_{ijt}'\Upsilon + \alpha_{ij} + \lambda_{it} + \delta_{jt} + \varepsilon_{ijt},\end{aligned}$$

where $CARICOM_j$ indicates whether the destination country is part of CARICOM. $\boldsymbol{\beta_1}$ quantifies the baseline effect for non-CARICOM countries, the main global effect. $\boldsymbol{\beta_2}$ measures the difference for CARICOM destinations, so that $(\boldsymbol{\beta_1} + \boldsymbol{\beta_2})$ captures the total effect for CARICOM destinations and $\boldsymbol{\beta_3}$ reflects systematic differences in trade levels independent of banking relationships.

Globally, bilateral banking relationships have a positive effect on trade flows. We estimate an elasticity of 0.580, indicating that a one percent increase in bilateral bank flows increases bilateral trade by 0.58 percent **(Table 17)**.[27] This finding aligns with the literature establishing the importance of banking relationships for facilitating global trade. Our IV estimate is statistically significant at the one percent level and 31 percent larger than the corresponding OLS estimate of 0.443, confirming the importance of addressing simultaneity concerns.[28]

[27] Similar to Caballero *et al.* (2018), we find economically meaningful trade-facilitating effects of banking relationships. They find that a one standard deviation increase in bank linkages, i.e. from forming new banking connections, raises exports by 3.5 percent, and we find that a one percent increase in bilateral banking flows raises trade by 0.58 percent. Converting to comparable units would require accounting for the different distributions of the independent variables.

[28] By employing a Bartik-style instrument based on creditor banking shocks, we aim to address reverse causality and endogeneity concerns. The first-stage F-statistic in the baseline specification is close to conventional thresholds for instrument strength. Instrument strength decreases for the CARICOM interactions and especially when financial centres are entirely excluded. While this warrants some caution in interpreting precise magnitudes, the qualitative finding–that the banking-trade relationship is weaker for the Caribbean–is consistent across specifications. Future work could apply the methodology of Coppola *et al.* (2021) to address bilateral capital flow distortions created by financial centres more rigorously.

Table 17 Estimation Results for Effects of Banking Relationships on Goods Trade

	Specification 1 (Baseline)	**Specification 2** (CARICOM)	**Specification 3** (Excluding Crises)	**Specification 4** (Financial Centers)	**Specification 5** (Lagged Banking Shocks)
Dependent Variable/			**Bilateral Goods Trade Flows**		
Explanatory Variable:					
Bilateral Bank Flows	0.580***	0.580***	0.604***	0.583***	0.554***
	(0.076)	(0.076)	(0.091)	(0.078)	(0.099)
Distance	-0.086	-0.066	-0.047	0.118	-0.114
	(0.115)	(0.112)	(0.136)	(0.094)	(0.146)
Border	1.042***	1.020***	1.016***	1.128***	1.069***
	(0.153)	(0.154)	(0.159)	(0.152)	(0.158)
Language	0.274***	0.328***	0.288***	0.273***	0.283***
	(0.084)	(0.086)	(0.090)	(0.085)	(0.096)
Colonial Ties	-0.751***	-0.676***	-0.728***	-0.775***	-0.722***
	(0.216)	(0.212)	(0.213)	(0.220)	(0.217)
Bilateral Bank Flows x CARICOM		-0.437***			
		(0.093)			
Bilateral Bank Flows x Financial Centers				-0.111	
				(0.085)	
Unconditional difference in bilateral trade levels		-0.559			
		(-0.349)			
Observations	76,441	76,441	56,817	76,441	69,818
Origin FE	Yes	Yes	Yes	Yes	Yes
Destination-Year FE	Yes	Yes	Yes	Yes	Yes
Origin-Destination					
Clustered SEs	Yes	Yes	Yes	Yes	Yes
R-squared	0.368	0.380	0.356	0.373	0.379

Note: Standard errors in parentheses Bartik IV: Creditor banking shocks—2008 frozen shares; standard errors clustered by country-pair; fixed effects: Origin + Destination-year * p<0.05, ** p<0.01, *** p<0.001.

But compared to the rest of the world, CARICOM economies exhibit weaker trade responses to banking relationships, suggesting unrealized benefits from such. The negative and highly significant CARICOM interaction coefficient yields the effect of bank flows on trade flows for CARICOM countries to equal 0.580-0.437=0.143, about 75 percent weaker than for non-CARICOM economies. This result is robust to excluding The Bahamas from the CARICOM group, whose large banking sector positions rather reflect its role as an offshore center rather and pure trade-related banking activity[29], as well as to excluding the oil exporting CARICOM members.[30] This suggests that CARICOM economies do not realize the trade-facilitating benefits of banking relationships to the same extent as other regions. Notably, the CARICOM trade level coefficient remains

[29] Excluding The Bahamas from the CARICOM group yields a more negative interaction coefficient than for the baseline CARICOM specification, so that the total banking-trade elasticity for the remaining CARICOM members amounts to 0.05. Rather than driving the muted CARICOM result, The Bahamas increase the CARICOM interaction coefficient, which is consistent with The Bahamas aligning more closely with global patterns given their offshore banking sector.

[30] In this specification, Guyana, Suriname, and Trinidad and Tobago are excluded. As a result, the CARICOM elasticity increases slightly, to about 65 percent of the global elasticity, indicating that trade-banking relationships are weaker for the oil exporting members. This is consistent with commodity exports requiring less traditional trade finance amid being homogenous goods that are associated with lower payment risks and transparent pricing and, therefore, less need for bank intermediation to authenticate transactions (Hoefele *et al.* 2016; Im 2021).

statistically insignificant, indicating that while CARICOM trade responds differently to banking relationships, overall trade levels do not systematically differ from other regions.

Several structural features of CARICOM economies likely explain their muted banking-trade relationship. First, the withdrawal of correspondent banking relationships by large international banks post-GFC, driven by de-risking and anti-money laundering strategies, particularly affected the Caribbean (World Bank, 2015; Erbenova, 2016; Alleyne *et al.*, 2017; Rice *et al.*, 2020). Second, most CARICOM countries either export commodities or rely heavily on services trade (particularly tourism), both of which may depend less on traditional bank-related trade finance compared to merchandise goods trade. Third, connectivity constraints and limited integration into global banking networks, stemming from remote locations and accessibility as well as small-scale economies, create binding constraints that likely worsened post-GFC. Fourth, the relatively small trade volumes characteristic for CARICOM economies may exhibit different sensitivity to banking constraints due to scale effects and alternative financing mechanisms and may rely on alternative financing mechanisms such as cash-in-advance terms.

Credit crunches and interbank market frictions during the GFC disproportionately affected Caribbean economies, with a persistent structural gap in the banking-trade nexus emerging. Estimating our model separately for the GFC years reveals that the banking-trade elasticity for CARICOM economies collapsed to just 0.01, essentially zero, which indicates that bilateral banking relationships ceased to facilitate trade in the Caribbean during the crisis. The worldwide elasticity also declined but remained substantial at 0.50 (compared to 0.58 for the full sample), which indicates some resilience even during the crisis. In recent years and post-GFC, CARICOM's elasticity recovered to 0.23, substantially higher than during the crisis but still far below the worldwide elasticity, which suggests a rather persistent impact on the region's financial connectivity.[31] Not least, the post-GFC withdrawal of correspondent banking relationships, which provides a structural explanation of the results, reveals that CARICOM economies depend on fragile financial channels that are vulnerable to global banking shocks. Despite post-crisis recovery, a structural gap persists in how effectively banking relationships facilitate trade in the region compared to elsewhere.

Geographic and linguistic proximity remain important determinants of goods trade even after controlling for banking relationships, while distance effects are muted. Compared to the goods and service results discussed above, distance loses significance in our banking-trade specifications, which likely reflects the global banking system's ability to overcome physical barriers more easily. Sharing a common border or language, on the other hand, is still associated with higher bilateral trade, indicating that information transmission and communication costs remain relevant channels.

Our main findings remain robust across alternative specifications and sample restrictions. When we exclude crisis-related observations (GFC and COVID-19 periods), the banking-trade elasticity increases slightly, though differences remain small. While this suggests that

[31] In this exercise, we include observations for the years between 2015 and 2023 and anchor our shift-share instrumental variable in 2015. The worldwide banking-trade elasticity increases sharply to 0.92 percent, indicating that a one percent increase in cross-border banking linkages increases bilateral trade almost one to one.

trade flows decrease during times of (financial) crises partly due to tightening financial constraints, it also suggests banking-trade relationships to be generally resilient. The financial center specification[32] reveals no material differences in how banking relationships affect trade for financial centers compared to other countries.

Using lagged banking shocks as an alternative instrument strengthens causal interpretation and reveals persistent effects. Considering the impact of creditor shocks of the previous year as an alternative instrument on current banking and trade flows further reduces reverse causality and simultaneity concerns since banking shocks of the previous year are even less likely to cause current bilateral trade patterns. It also sheds light on how persistent the effects of banking disruptions are. Our results indicate that banking shocks have lasting rather than temporary effects on trade flows. Maintaining banking connectivity is, thus, likely associated with lasting benefits.

Connectivity: Gravity-based Evidence—Financial Linkages and Tourism Flows

Given the central role of tourism in the Caribbean, we extend our analytical framework to investigate a potential nexus between banking relationships and tourism flows. We replicate the analysis using bilateral tourism flows instead of goods trade flows to explore channels beyond the well-established banking-trade nexus. To our knowledge, this is the first study to assess whether systematic linkages exist between cross-border banking relationships and tourism flows. Unlike in the goods trade context, the theoretical foundation for such a relationship is less straightforward.

We employ the same econometric approach to identify causal effects using Bartik-type shift-share instruments and find a positive worldwide effect alongside a muted channel for CARICOM economies, suggesting that banking relationships do not necessarily translate into increased tourist arrivals in the region. While the worldwide elasticity is positive and economically meaningful—a one percent increase in cross-border banking flows increases tourism linkages by 0.486 percent—the combined effect for CARICOM economies is slightly negative at -0.076 percent and essentially zero **(Table 18)**.[33]

The positive worldwide effect of cross-border bank flows on tourism likely reflects a base effect of banking relationships supporting tourism by providing financial infrastructure and facilitating business-oriented travel. The BIS LBS data employed in this study reflects formal interbank relationships supporting activities such as trade finance for merchandise exports, corporate lending, government borrowing, and FDI flows. Our baseline estimates, thus, indicate that cross-border bank flows primarily facilitate business-related travel (e.g., corporate conferences or trade shows), which are more likely financed through bilateral banking channels than leisure tourism. Additionally, bilateral banking relationships may indirectly support tourism by providing financial infrastructure, reducing

[32] We consider the United States, the United Kingdom, Switzerland, Germany, France, Japan, Singapore, the People's Republic of China–Hong Kong Special Administrative Region, Luxembourg, and the Netherlands as financial centers.

[33] Excluding commodity exporters (Guyana, Suriname, and Trinidad and Tobago) does not materially change the results. If only the subset of ECCU economies is considered, we do not find the interaction coefficient to be significantly negative, but to remain indistinguishable from zero. In this exercise, the ECCU interaction coefficient on bank flows is estimated imprecisely with a large standard error.

transaction costs, and signalling economic integration, though Caribbean leisure tourism does not seem to be driven by these mechanisms. The elasticity magnitude we observe remains smaller in absolute terms than typically found for income, population, or distance elasticities, confirming that while cross-border financial flows matter, they are not primary determinants of tourism flows (Rosselló-Nadal and Santana-Gallego, 2022).

Our results indicate that banking linkages do not play a significant role in driving Caribbean tourism flows, consistent with the structure of international tourism transactions. Several factors help explain this finding. A large share of tourism expenditures is pre-paid through intermediaries in origin countries and retained by foreign airlines, tour operators, and hotel chains before reaching destination economies (UNCTAD, 2010). All-inclusive packages and cruise transactions are typically processed through international operators, while in-destination spending often occurs in cash or via international credit cards settled through major financial centers. Cash transactions, for example for local transport or tours, continue to play a more prominent role in the Caribbean compared to other regions (see recent data from the Survey of International Air Travelers and IDB, 2022). Furthermore, diaspora-related travel and remittance flows in the Caribbean are also less reliant on formal interbank channels. Taken together, these features help explain why cross-border banking relationships appear less closely linked to tourism flows in the Caribbean than to goods trade.

Table 18 Estimation Results for Effects of Banking Relationships on Goods Trade

	Specification 1 (Baseline)	**Specification 2** (CARICOM)	**Specification 3** (CARICOM excl. commodity exporters)
Dependent Variable/		**Bilateral Tourism Flows**	
Explanatory Variable:			
Bilateral Bank Flows	0.486***	0.487***	0.488***
	(0.042)	(0.044)	(0.044)
Distance	-0.701***	-0.645***	-0.655***
	(0.077)	(0.076)	(0.078)
Border	1.478***	1.499***	1.495***
	(0.180)	(0.179)	(0.179)
Language	0.248*	0.309**	0.308**
	(0.097)	(0.100)	(0.098)
Colonial Ties	-1.976***	-1.969***	-1.946***
	(0.394)	(0.421)	(0.413)
Bilateral Bank Flows x CARICOM		-0.563***	-0.558***
		(0.104)	(0.109)
Observations	24,327	22,507	22,507
Origin FE	Yes	Yes	Yes
Destination-Year FE	Yes	Yes	Yes
Origin-Destination Clustered SEs	Yes	Yes	Yes
R-squared	0.522	0.537	0.536

Note: Standard errors in parentheses Bartik IV: Creditor banking shocks—2008 frozen shares; standard errors clustered by country-pair; fixed effects: Origin + Destination-year * p<0.05, ** p<0.01, *** p<0.001.

CONCLUSION

Econometric evidence points to connectivity constraints as a central feature shaping trade and tourism outcomes in Caribbean economies. This paper examines goods trade, tourism flows, and cross-border banking linkages to assess how physical and financial connectivity shape outcomes across the region.

Gravity model results suggest that Caribbean goods trade is disproportionally sensitive to geographic distance. Caribbean countries trade less with partners outside the region and more within the region than predicted by economic fundamentals alone. Our estimation results indicate that this pattern is driven largely by the disproportionate effect of geographic distance—which suggests connectivity is a constraint for Caribbean countries. This is consistent with limited direct shipping routes and high freight costs. High import dependence from concentrated source markets further amplifies exposure to external shocks and shifts in global trade policies.

Tourism flows in the Caribbean also appear sensitive to physical connectivity. Controlling for standard demand factors, the analysis finds that inbound flight capacity plays a quantitatively significant role in determining arrivals. These results suggest that supply-side constraints—stemming from small airports, limited carrier networks, and dependence on a few connection hubs—materially affect tourism outcomes, reinforcing the important role of air connectivity in services trade.

By contrast, financial connectivity appears to play a more limited role. While banking relationships can play an important role in facilitating trade globally, this link is weaker for Caribbean economies, consistent with the region's export structure. Similarly, although banking relationships tend to support tourism flows, this channel is muted for CARICOM economies. The region's tourism model—characterized by pre-paid packages, international credit card transactions, and local cash transactions—largely bypasses bilateral banking channels. Taken together, these findings suggest that, relative to financial linkages, physical connectivity plays a more prominent role in shaping Caribbean trade patterns and external vulnerabilities.

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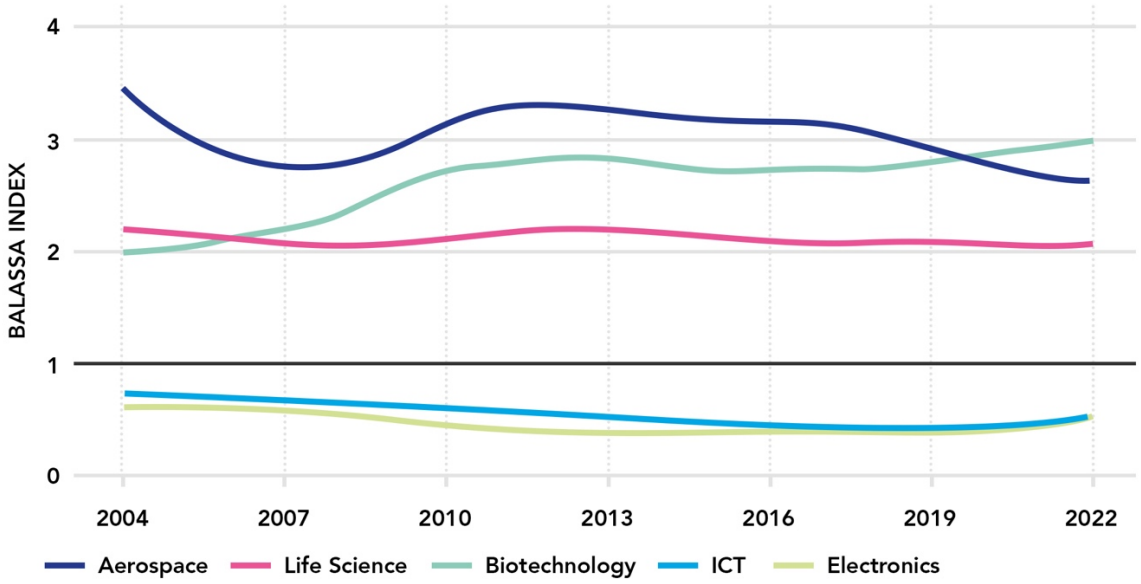
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APPENDIX A

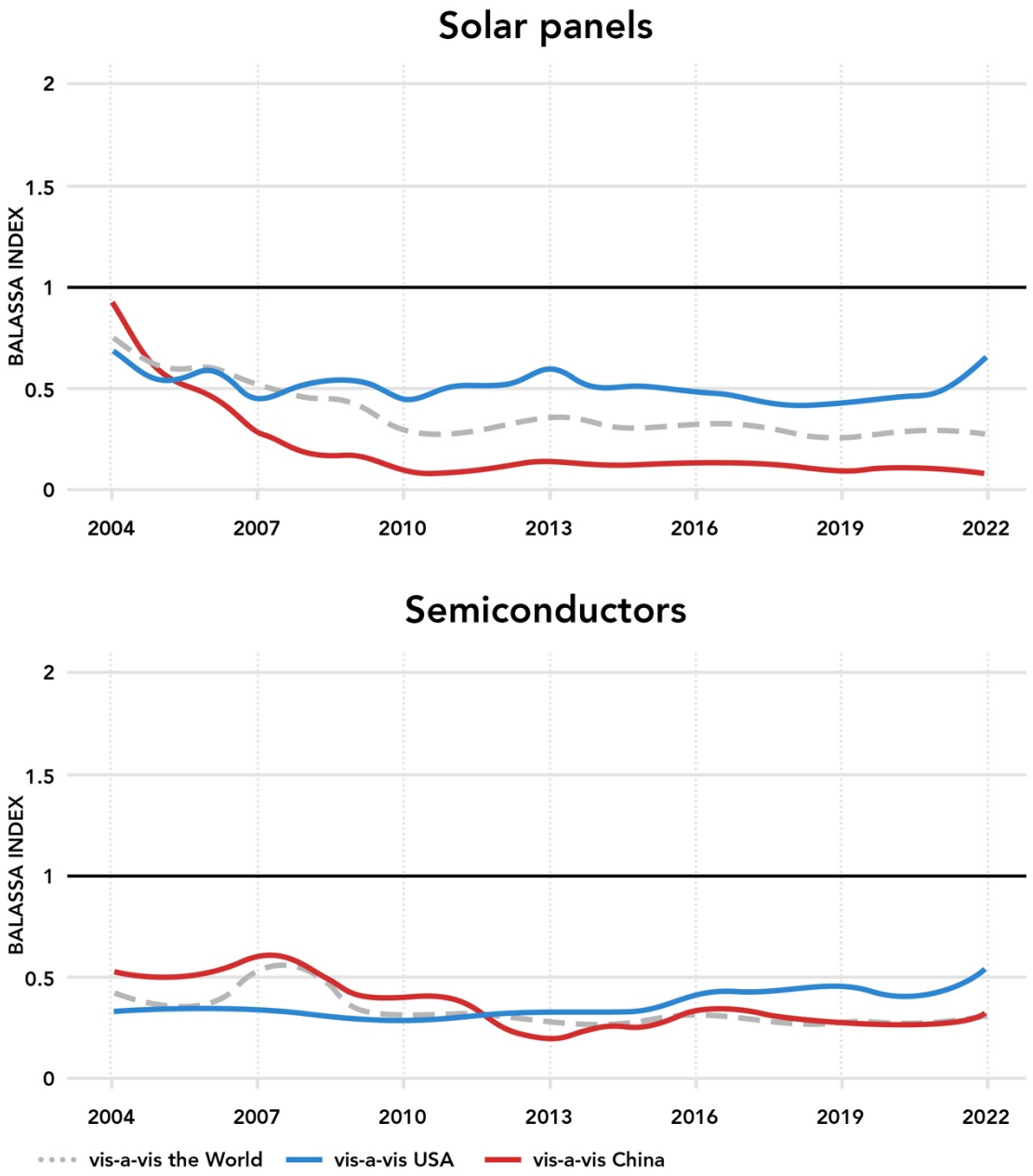
EU INNOVATION POLICY

Appendix Figure 1 European RCA with the rest of the world (ATP)



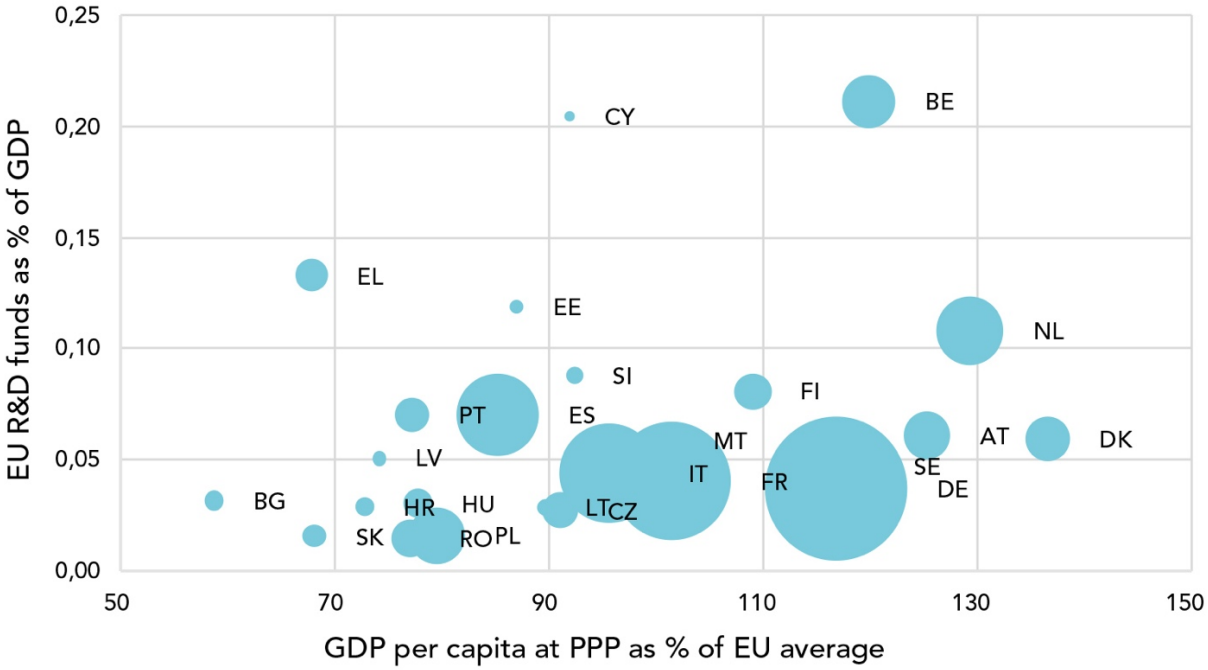
Note: 5 biggest ATP-categories by trade volume. Least-squares smoothing applied

Appendix Figure 2 Sector spotlight: European RCA in strategic industries



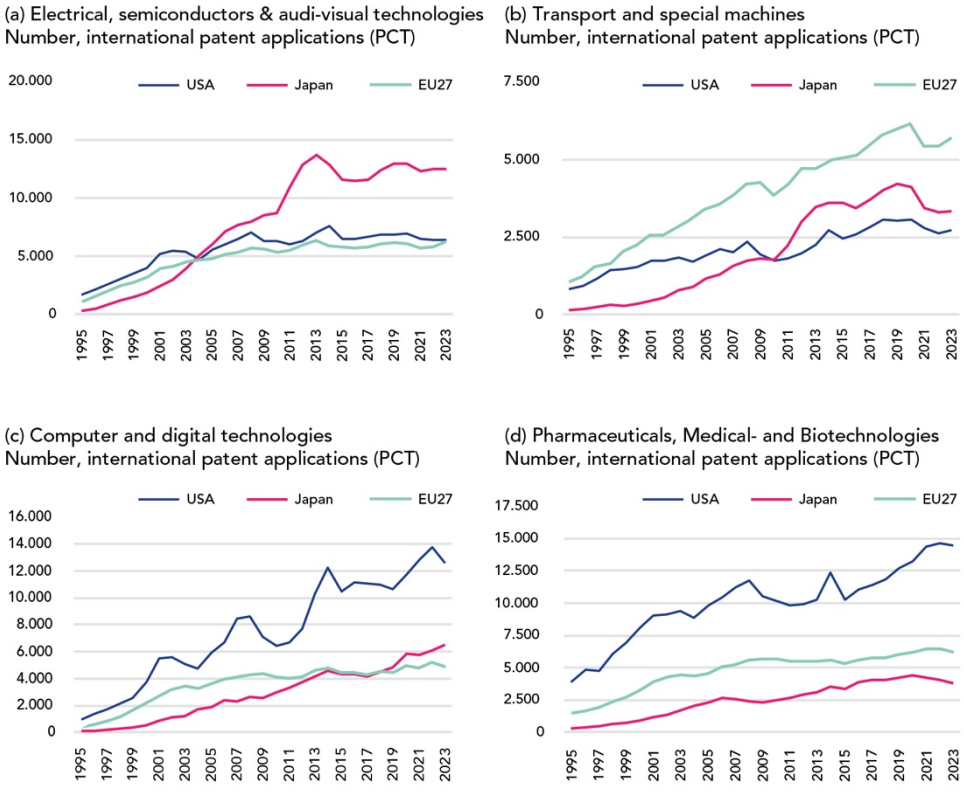
Note: Least-squares smoothing applied

Appendix Figure 3 EU R&D funding and per-capita GDP



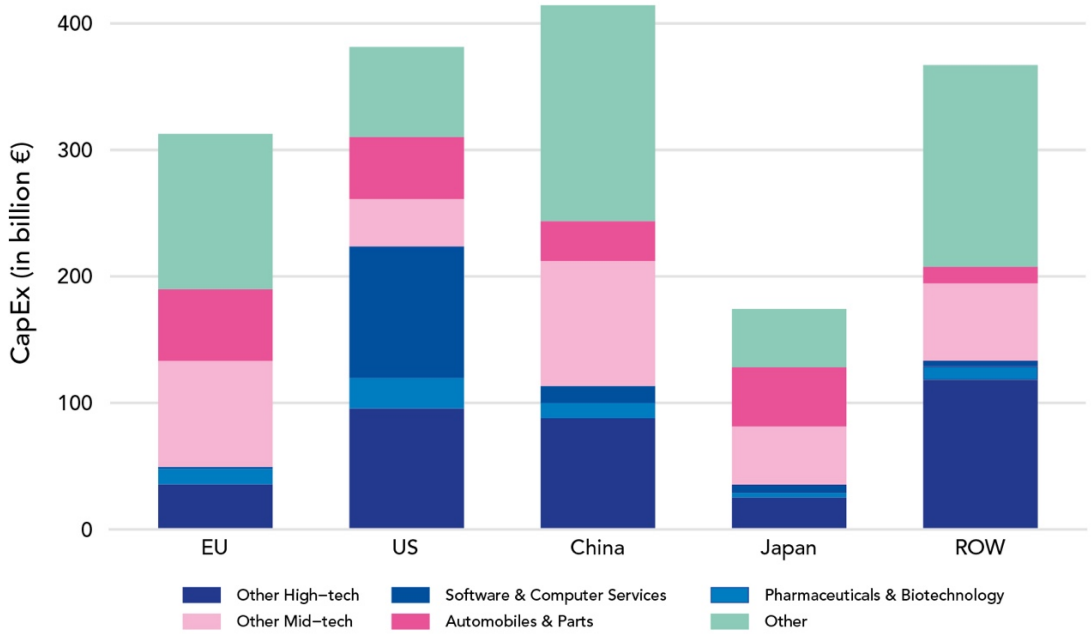
Source: authors' calculations based on Eurostat https://ec.europa.eu/eurostat/statistics-explained/index.php?title=R%26D_expenditure&oldid=627002.

Appendix Figure 4 Number of international patent applcications (PCT) by industry



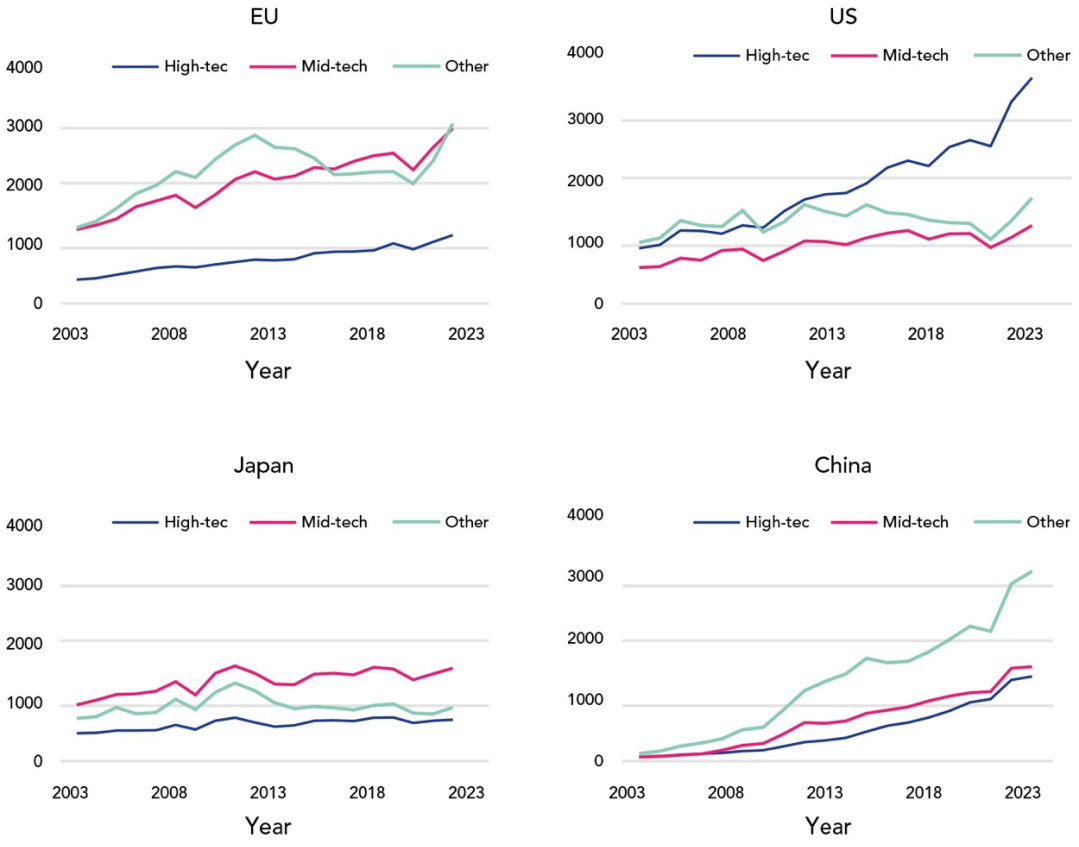
Source: WIPO.

Appendix Figure 5 Capital expenditure by technology level 2022 (Top 2,500 companies)



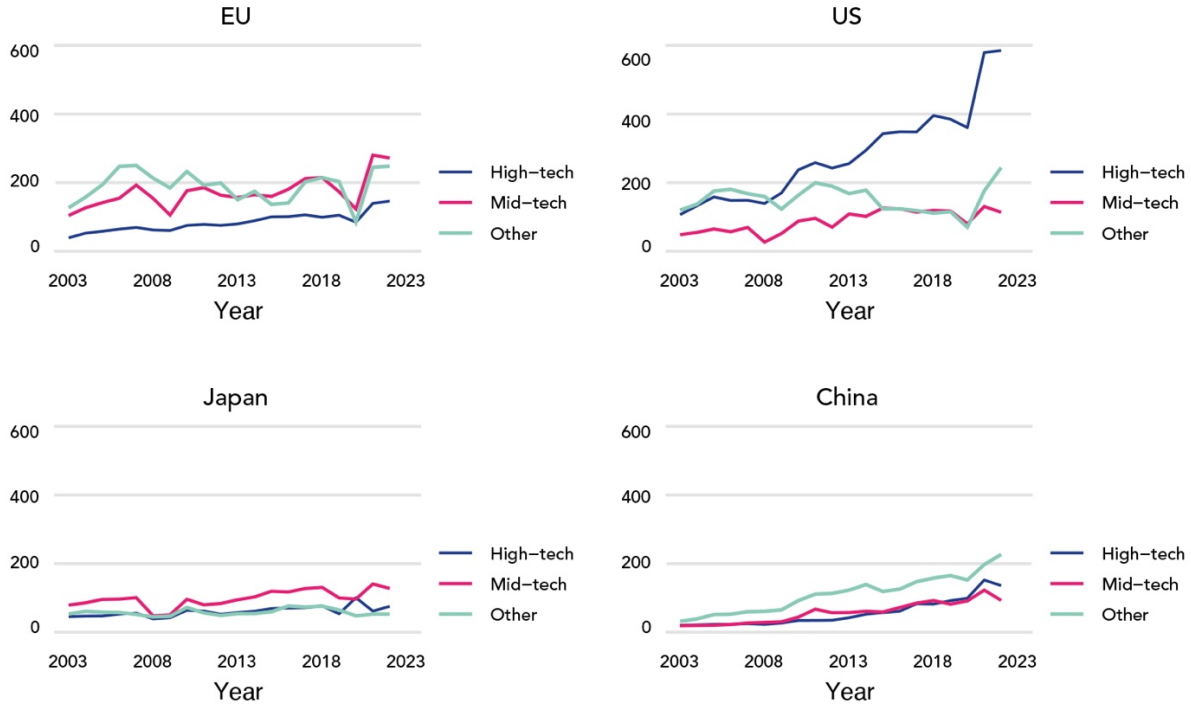
Source: Industrial R&D Investment Scoreboard.

Appendix Figure 6 Net sales by technology level (billion €)



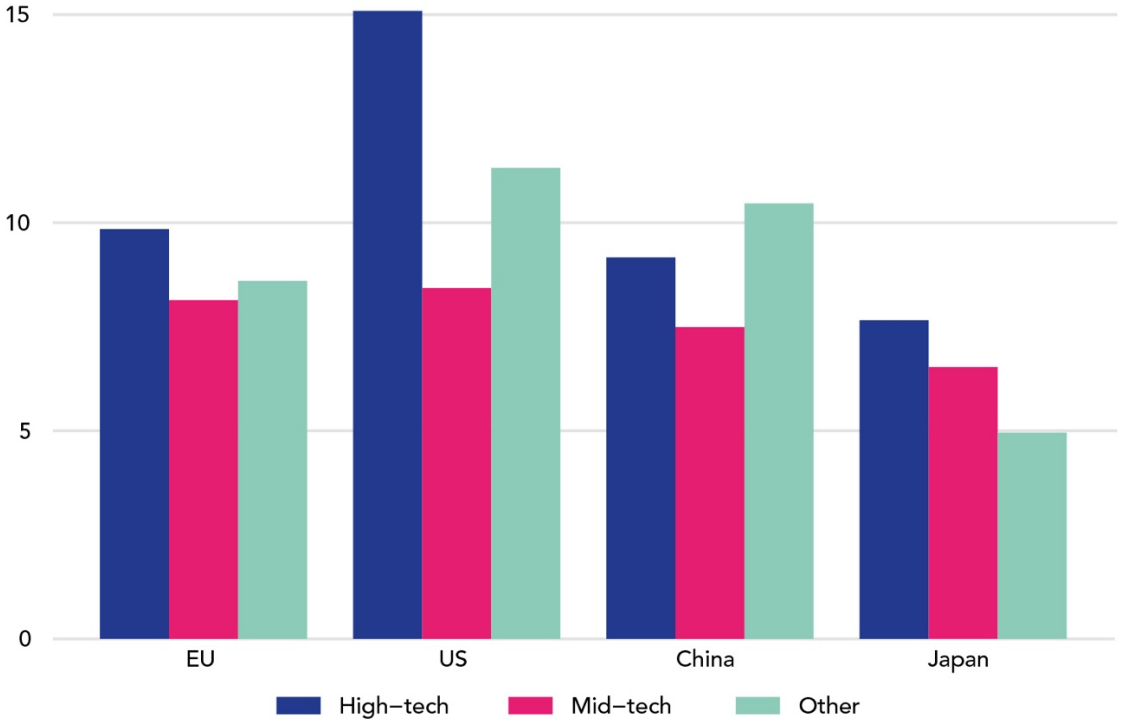
Source: Industrial R&D Investment Scoreboard.

Appendix Figure 7 Profit margins by technology level (billion €)



Source: Industrial R&D Investment Scoreboard.

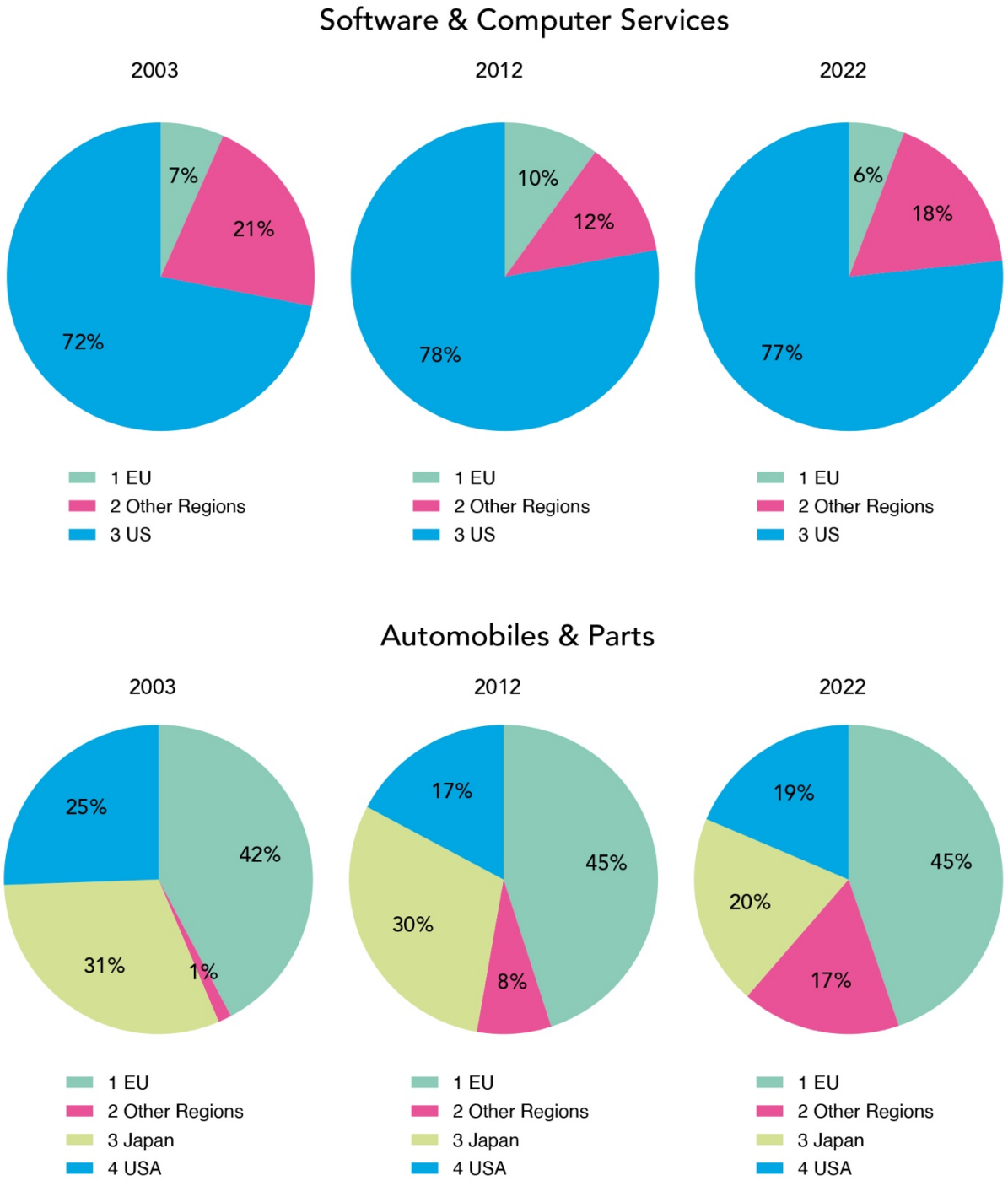
Appendix Figure 8 Profits margins by technology level (% of sales, 2003–2022)



Note: sector profit margin is the ratio of profits to sales. Average for the years 2003-2022.

Source: Industrial R&D Investment Scoreboard.

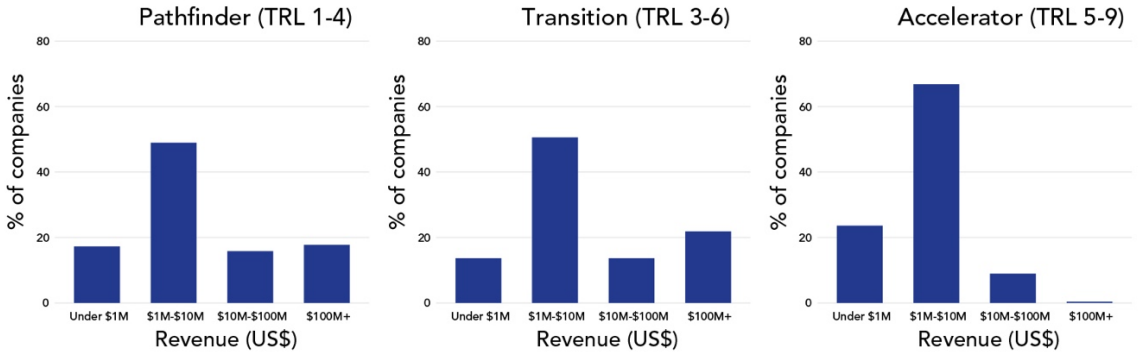
Appendix Figure 9 Country share of total international BERD



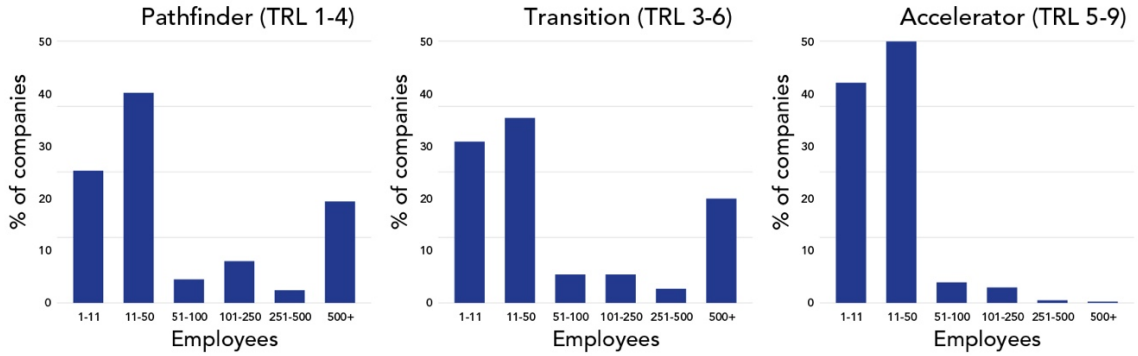
Note: BERD based on sample of global 500 largest companies.

Source: Industrial R&D Investment Scoreboard (2004, 2013, 2022).

Appendix Figure 10 Revenue of Horizon Europe companies by programme

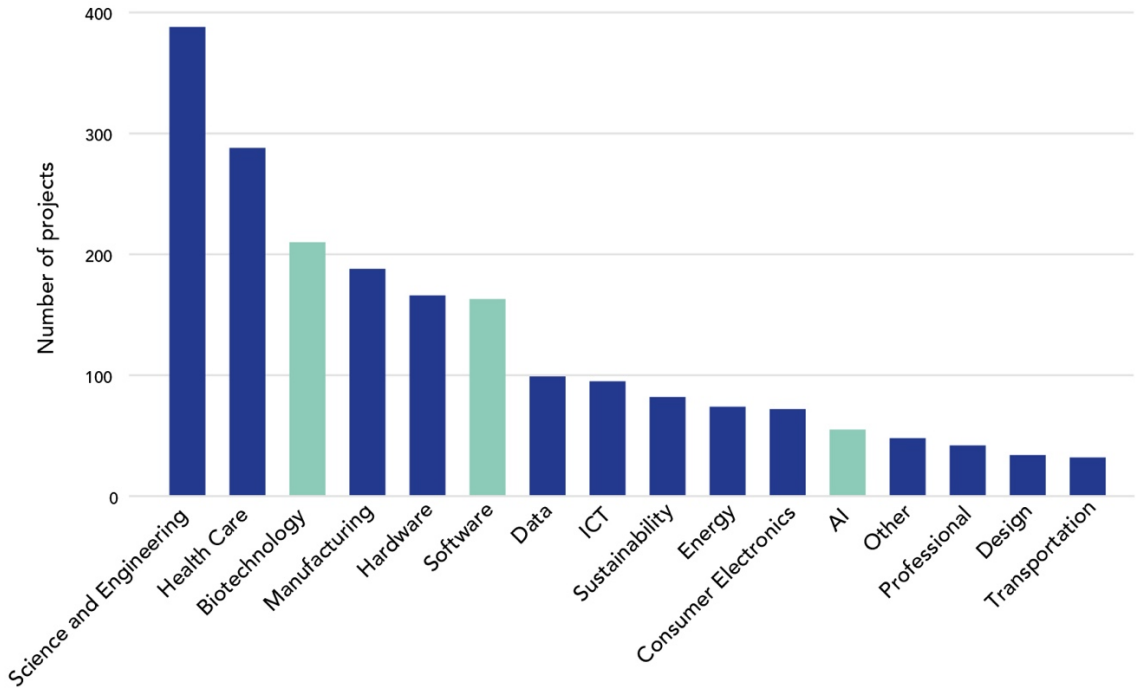


Employees of Horizon Europe companies by programme



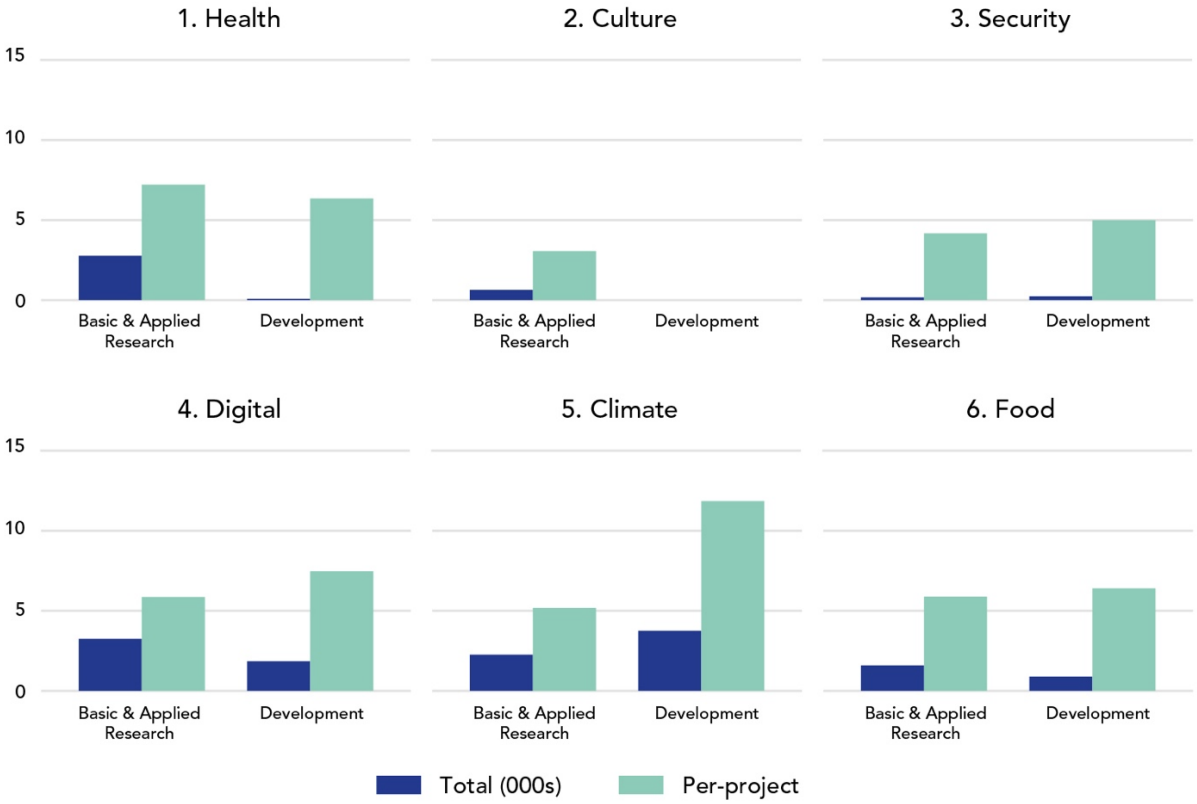
Source: Crunchbase.

Appendix Figure 11 Number of financed projects by Crunchbase industry



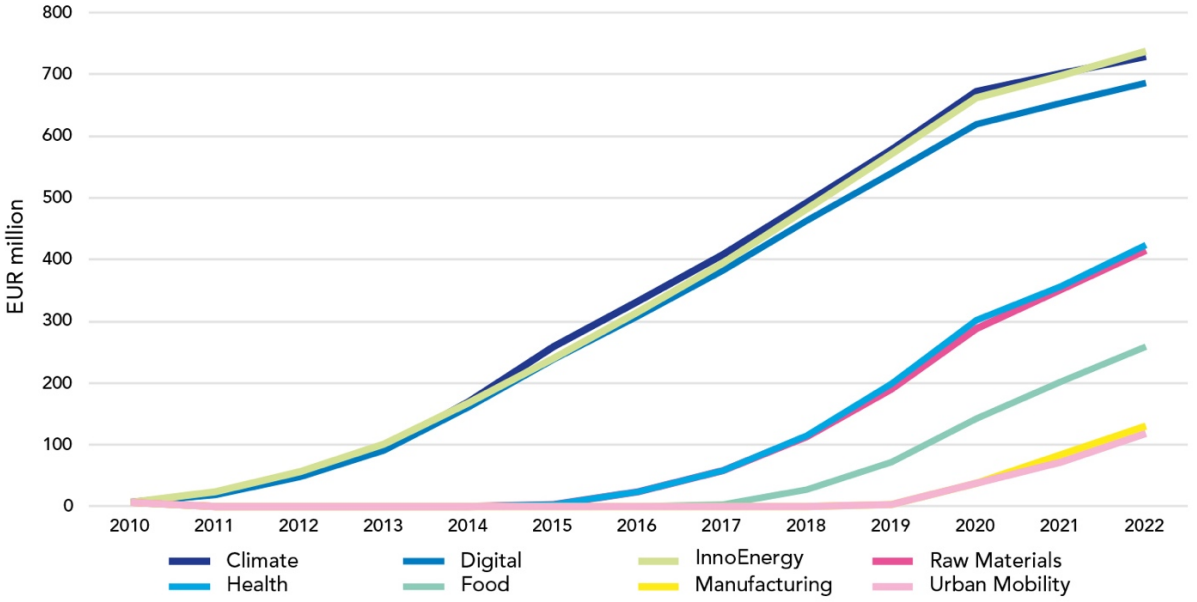
Source: Crunchbase.

Appendix Figure 12 EU funding by activity type (million €)



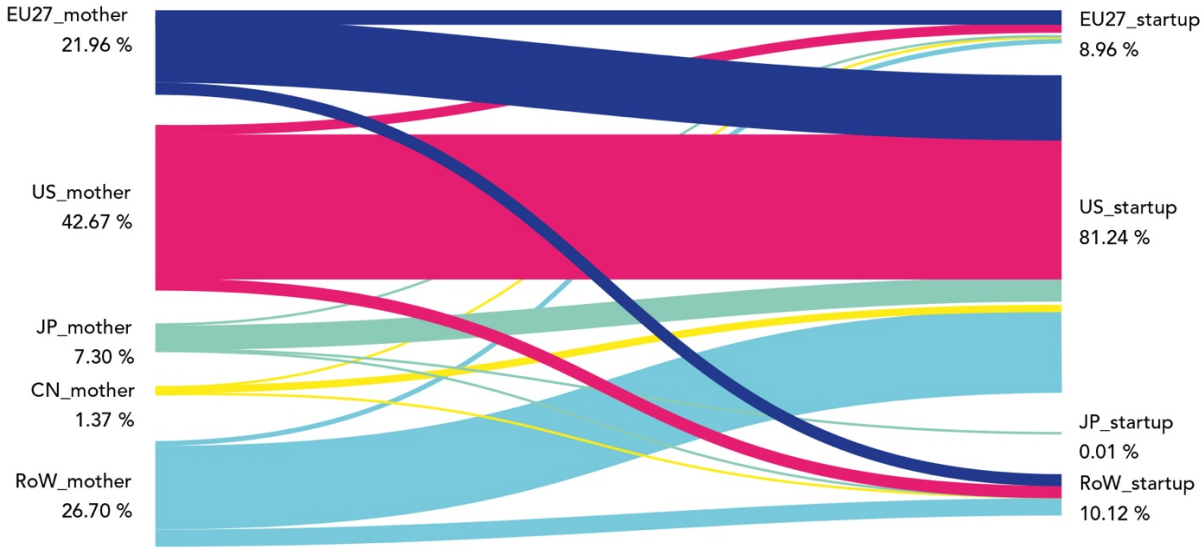
Source: authors' calculations based on CORDIS.

Appendix Figure 13 Cumulative Funding of EIT KCIs



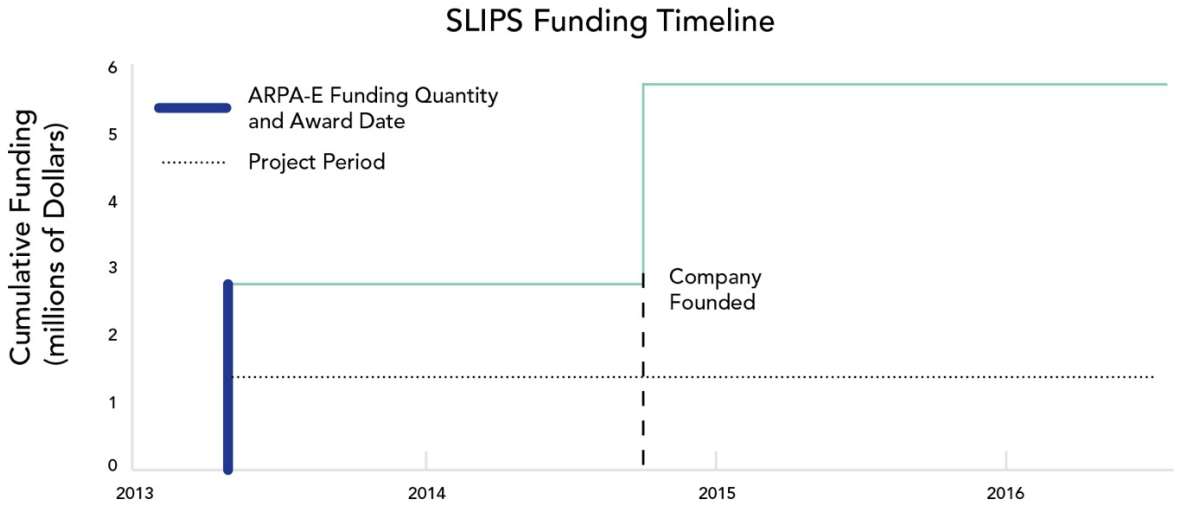
Source: own calculations based on https://eit.europa.eu/global-challenges/about-our-communities.

Appendix Figure 14 Corporate venture capital investment by headquarter region of the Scoreboard parent company



Source: Grassano et al. (2022), page 30.

Appendix Figure 15 Case study diagram



Source: National Academies of Science (2017).

Appendix Table 1 Overview of main governance elements of EU research/innovation bodies

	European Research Council	European Innovation Council	European Institute of Innovation and Technology
President's qualifications	Senior and internationally respected scientist	A high-profile public figure linked to the world of innovation	Governing Board shall elect its Chairperson from among its members
Appointment of the president	Appointed by the Commission, which selects one among three names proposed by the Scientific Council[66]	Appointed by the Commission	Appointed by the Commission
Board members' appointment	The Scientific Council is appointed by the Commission under the recommendation of an Independent Identification Committee	Appointed by the Commission	Appointed by the Commission
Qualifications required	Independent scientists, engineers and scholars of the highest repute	Entrepreneurs, corporate leaders, investors, public administration experts and researchers, including academic experts on innovation	Proven experience in the fields of higher education, research, innovation or business
Scientific/technical qualifications of the Board/ Scientific Council	All 22 members are professors and in the Web of Science, with an average h-index of 58 and average citations of over 18,000.	5 out of 21 members are professors, 11 have a PhD, of whom 7 are in the Web of Science with an average h-index of 18 and average citations of 2,000.	2 out of 14 members are professors, 8 have a PhD, of whom 5 are in the Web of Science with an average h-index of 25 and average citations of 8,000.
Term	4 years, renewable once	2 years, renewable twice	4 years, extendable by the Commission once by 2 years on a proposal of the Governing Board
Independence	Independent of extraneous interests	Not required	Not required
Tasks/competences	(a) overall strategy for the ERC (b) the work programme for the implementation of the ERC's activities (c) the methods and procedures for peer review and proposal evaluation	Advise the Commission Upon request address recommendations to the Commission	Provide strategic guidance and select, evaluate, and support the Knowledge and Innovation Communities
Work programme	Established by the ERC Scientific Council	Commission decision, following the advice of the EIC Board	Strategic Innovation Agenda set by EU regulation for the 7-year period

66 The Chair is appointed by the European Commission to a position as Special Advisor to the Commission, after submission of the dossiers of the three finalists in the selection made by an independent committee to the Scientific Council, which can only issue a veto.

Note: The legal framework of EIT has been modified since its creation in 2008, in particular in 2021.
See https://eur-lex.europa.eu/EN/legal-content/summary/european-institute-of-innovation-and-technology-eit.html

Sources. Own evaluation on the basis of Publications Office (europa.eu) for the EIC and ERC;
for the EIT, see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2021:189:FULL

APPENDIX B

A SIMPLE SCHUMPETERIAN MODEL

BACKGROUND AND RELATED LITERATURE

This section develops a simple conceptual framework linking industrial policy, firm dynamics, and technological upgrading. The aim is not to build a full endogenous-growth model, but rather a compact, reduced-form Schumpeterian structure that organises the empirical findings on the "mid-technology trap," clarifies the mechanisms behind it, and provides a framework for evaluating how innovation policy can redirect technological trajectories. Consequently, the model does not explain the historical origins of Europe's industrial structure. Its purpose is to clarify how, conditional on inherited specialisation and incumbent concentration, innovation may become persistently directed toward mid-tech trajectories.

The framework draws upon four ingredients from the existing literature. First, from Aghion *et al.* (2016), it borrows the idea that innovation can be directed toward two competing trajectories of technological sophistication, and that the direction of innovation is path dependent. This means that, similar to Aghion *et al.* (2016), on a given trajectory, current research productivity depends on the economy's existing stock of knowledge in that same trajectory. In other words, firms that have innovated in mid-technologies in the past are much more likely to continue to innovate in mid-technologies in the future.

Second, the conceptual framework borrows the transition logic from Acemoglu *et al.* (2016), meaning that if one trajectory starts sufficiently ahead, the lagging trajectory may fail to take off because its low knowledge stock discourages further research. Like in their model, temporary and well-targeted innovation policy can then matter by helping the economy cross a threshold.

Third, from Akcigit and Kerr (2018), it borrows the distinction between internal and external innovation. Internal innovation improves product lines already owned by the firm and is more closely associated with the incremental innovation taking place in mature mid-technologies, while external innovation creates new lines and captures business from others.

Finally, the framework borrows the Schumpeterian entrant–incumbent asymmetry logic from Acemoglu and Cao (2015). It suggests that incumbents mainly improve existing lines, whereas entrants are a key source of more radical innovations that replace incumbents. Overall, the model remains deliberately simple. There are no households, no labour-market block, and no general-equilibrium price system. The focus is the direction of innovation and the transition between a mid-tech and a high-tech equilibrium.

SETUP

Consider an economy with a unit mass of product lines. Each line belongs to one of two trajectories:

$$j \in \{M, H\}$$

where M denotes the *mid-tech* trajectory and H denotes the *high-tech* trajectory. This two-trajectory structure mirrors the dirty/clean distinction in Aghion *et al.* (2016) and

Acemoglu *et al.* (2016), which is a natural parallel given that Aghion *et al.* (2016) explicitly associate dirty technologies with car manufacturers producing internal combustion engines—the sector most representative of the mid-tech trap documented in this thesis. For simplicity, attention is restricted to two trajectories, although the framework could be extended in a straightforward way to allow for a third trajectory, in the spirit of Aghion *et al.* (2016).

Let $A_{M,t}$ and $A_{H,t}$ denote the economy's stock of usable knowledge on the two trajectories at time t. These stocks summarise the accumulated expertise specific to a given trajectory, such as engineering capabilities, patents, supplier networks, scientific know-how, and complementary institutions that make subsequent innovation more productive.

The model distinguishes between two types of agents: incumbent firms and potential entrants. The set of incumbent firms is indexed by i, where firm i owns n_i product lines, with

$$\sum_i n_i = 1$$

Firm concentration is directly tied to the distribution of product lines: larger values of n_i correspond to a more concentrated incumbent structure, measured by the Herfindahl index

$$H \equiv \sum_i n_i^2$$

Following Akcigit and Kerr (2018), incumbent firms can undertake two types of innovative effort: *internal innovation* $\mathrm{x_{i,t}}$, which improves product lines already owned by the firm and scales more strongly with firm size, and *external innovation* $\mathrm{z_{i,t}}$, which creates a new line and captures business from rivals. In the present context, internal innovation maps onto incremental upgrading along the mid-tech trajectory, while external innovation maps onto exploratory switching toward high-tech. This interpretation is motivated by the empirical patterns in the thesis: incumbents in mature mid-tech sectors invest primarily in improving existing production processes, whereas transitioning toward high-tech trajectories—software, AI, biotechnology—typically requires establishing new product lines that compete with rather than complement existing capabilities.

In addition, the economy contains a mass of potential entrants which, unlike incumbents, can engage only in external innovation, since they must establish new product lines from scratch. Each potential entrant draws an entry cost K from a cumulative distribution $G_c(K)$, where c indexes the economy. Countries with more experimental ecosystems—more venture capital for high-risk, high-reward projects, greater societal tolerance of failure, stronger university technology transfer offices (TTOs), or lower barriers to startup formation—are represented by a distribution G_c that places greater mass on low entry costs.

Overall, this leaves three innovation margins to consider: (1) incumbents engaging in mid-tech innovation, (2) incumbents engaging in high-tech innovation, and (3) entrants engaging in high-tech innovation.

INNOVATION TECHNOLOGIES

Internal mid-tech innovation by incumbents

The arrival rate of successful internal innovation for incumbent firm i is

$$\lambda_{i,t}^{I} = \chi_M x_{i,t} n_i A_{M,t}^{\phi} \tag{1}$$

where $\chi_M > 0$ is a productivity parameter for mid-tech and $\phi > 0$ captures path dependence.

Equation (1) highlights two features. First, internal innovation scales linearly with firm size, reflecting the idea that larger firms with more product lines can also improve more of them. Second, consistent with path dependence, a larger inherited mid-tech knowledge stock $A_{M,t}$ raises the productivity of further mid-tech innovation.

A successful internal innovation raises the quality of an existing line by a relatively small amount:

$$q' = (1 + \eta_M)q$$

where $\eta_M > 0$ is the incremental step size.

External high-tech innovation by incumbents

The arrival rate of successful external innovation for incumbent firm i is

$$\lambda_{i,t}^{X} = \chi_H z_{i,t} n_i^{\beta} A_{H,t}^{\phi} \qquad 0 \leq \beta < 1 \tag{2}$$

where $\chi_H > 0$ is a productivity parameter for high-tech.

Equation (2) adapts the Akcigit–Kerr external-innovation margin. Relative to internal innovation, external innovation scales less strongly with firm size because $\beta < 1$. This gives rise to the model's core firm-dynamics mechanism: large firms are relatively tilted toward internal innovation, while smaller firms are relatively better vehicles for exploratory switching.

A successful external innovation creates a new high-tech line and yields a larger quality step:

$$q' = (1 + \Gamma_H)q \qquad \Gamma_H > \eta_M$$

Thus external innovation is both the technological-upgrading margin and the Schumpeterian creative-destruction margin for incumbents.

High-tech entry by startups

A potential entrant that pays entry cost K can invest effort e_t to create a new high-tech line. Its innovation arrival rate is

$$\mu_t = \chi_E e_t A_{H,t}^{\phi} \tag{3}$$

where $\chi_E > 0$ is an entrant-specific productivity parameter.

A successful entrant creates a high-tech cluster and replaces an incumbent producer. This captures the Schumpeterian creative-destruction channel in the model. The entrant innovation technology is deliberately specified to mirror the directed-innovation structure in Aghion *et al.* (2016) and Acemoglu *et al.* (2016), i.e. entry into high-tech is easier when the high-tech knowledge stock is already larger. This is the sense in which path dependence extends to startup formation.

FIRM PROBLEMS

Incumbent firms

Each incumbent chooses internal R&D ($x_{i,t}$) and can choose to invest in external R&D ($z_{i,t}$) to maximise expected private payoffs. For simplicity, assume quadratic variable costs and a fixed cost of maintaining an exploratory high-tech program. The incumbent objective is

$$\Pi_{i,t} = \pi_M \lambda_{i,t}^{I} - \frac{c_x}{2} x_{i,t}^2 + \mathbf{1}\{z_{i,t} > 0\}\left[(\pi_H + \tau_H)\lambda_{i,t}^{X} - \frac{c_z}{2} z_{i,t}^2 - F_H\right] \tag{4}$$

where:

- π_M is the private value of a successful mid-tech incremental innovation,
- π_H is the private value of a successful high-tech innovation,
- $\tau_H \geq 0$ is a policy instrument targeted at low-TRL high-tech research,
- $F_H > 0$ is the fixed cost of maintaining an exploratory high-tech program.

Optimal internal R&D

Using (1) and (4), incumbent i solves

$$\max_{x_{i,t} \geq 0} \pi_M \chi_M x_{i,t} n_i A_{M,t}^{\phi} - \frac{c_x}{2} x_{i,t}^2$$

The first-order condition yields

$$x_{i,t}^{*} = \frac{\pi_M \chi_M}{c_x} n_i A_{M,t}^{\phi} \tag{5}$$

Optimal external R&D (conditional on exploring)

Conditional on activating exploration, the incumbent solves

$$\max_{z_{i,t} \geq 0} (\pi_H + \tau_H)\chi_H z_{i,t} n_i^{\beta} A_{H,t}^{\phi} - \frac{c_z}{2} z_{i,t}^2 - F_H$$

The first-order condition yields

$$z_{i,t}^{*} = \frac{(\pi_H + \tau_H)\chi_H}{c_z} n_i^{\beta} A_{H,t}^{\phi} \tag{6}$$

Substituting (6) back into profits shows that exploration is active if and only if

$$\frac{[(\pi_H + \tau_H)\chi_H n_i^{\beta} A_{H,t}^{\phi}]^2}{2c_z} \geq F_H \tag{7}$$

Equivalently, exploration is active only for firms above the size cutoff

$$n_i \geq \bar{n}_t \equiv \left(\frac{\sqrt{2c_z F_H}}{(\pi_H + \tau_H)\chi_H A_{H,t}^{\phi}} \right)^{1/\beta} \tag{8}$$

Relative allocation

Combining (5) and (6) gives

$$\frac{z_{i,t}^{*}}{x_{i,t}^{*}} = \frac{(\pi_H + \tau_H)c_x}{\pi_M \chi_M c_z} \frac{\chi_H A_{H,t}^{\phi}}{A_{M,t}^{\phi}} n_i^{\beta-1} \tag{9}$$

Because $\beta < 1$, this ratio is decreasing in firm size.

Remark 1 (Absolute versus relative exploration)

There is no contradiction between (7) and (9). Larger firms are more likely to satisfy the exploration threshold in absolute terms because the left-hand side of (7) increases with n_i^{β}. But among firms that do explore, larger firms devote a smaller share of their R&D to exploration because (9) decreases with n_i when $\beta < 1$. The economically relevant implication for the mid-tech trap is the relative allocation result: incumbent concentration tilts the composition of innovative effort toward internal mid-tech upgrading.

Potential entrants

A potential entrant with cost draw K solves

$$V_t(K) = \max_{e_t \geq 0} \left\{ (\pi_H + \tau_H)\chi_E e_t A_{H,t}^{\phi} - \frac{c_e}{2} e_t^2 - K \right\} \tag{10}$$

Following a similar logic as above, the optimal entrant effort is

$$e_t^{*} = \frac{(\pi_H + \tau_H)\chi_E}{c_e} A_{H,t}^{\phi} \tag{11}$$

and the maximised value is

$$V_t^{*}(K) = \frac{[(\pi_H + \tau_H)\chi_E A_{H,t}^{\phi}]^2}{2c_e} - K \tag{12}$$

Hence a potential entrant enters if and only if

$$K \leq \bar{K}_t \equiv \frac{[(\pi_H + \tau_H)\chi_E A_{H,t}^{\phi}]^2}{2c_e} \tag{13}$$

The mass of new high-tech startups is therefore

$$E_t = G_c(\bar{K}_t) \tag{14}$$

As discussed above, the entry cost distribution (G_c) is country-specific. For the "more experimental" economy c, with startup-friendly institutions that lower effective entry costs, G_c lies everywhere above the corresponding distribution in a less experimental economy. This is a reduced-form way to capture differences in startup culture, venture financing, tolerance of failure, or non-technological entry barriers without adding a separate cultural parameter to the production side of the model.

Remark 2 (Relation to the shift-share evidence)

The firm-size mechanism in the model concerns the direction of R&D allocation, not its aggregate level. The shift-share decomposition in Chapter 1 shows that differences in firm-size distributions explain only a negligible share of the EU-US R&D intensity gap within the high-tech sector, whereas sectoral composition explains a substantial share of the aggregate gap. This is consistent with the present framework, which does not predict that Europe's lower R&D intensity is driven by the scarcity of large firms per se. Rather, the model predicts that, conditional on innovating, larger incumbent firms (i.e. a more concentrated incumbent structure) tilt the composition of R&D toward internal, incremental upgrading and away from exploratory switching.

AGGREGATE INNOVATION AND KNOWLEDGE DYNAMICS

Substituting optimal choices into the innovation technologies yields explicit aggregates.

Aggregate mid-tech innovation

Using (1) and (5),

$$\Lambda_{M,t} = \sum_i \lambda_{i,t}^I = \frac{\pi_M \chi_M^2}{c_x} A_{M,t}^{2\phi} \sum_i n_i^2 = a_M H A_{M,t}^{2\phi} \tag{15}$$

where $a_M \equiv \pi_M \chi_M^2 / c_x$ and $H \equiv \sum_i n_i^2$ is incumbent concentration.

Aggregate high-tech innovation by incumbents

Using (2), (6), and the size cutoff (8),

$$\Lambda_{H,t}^{\text{inc}} = \sum_{i:n_i \geq \bar{n}_t} \lambda_{i,t}^{X} = \frac{(\pi_H + \tau_H)\chi_H^2}{c_z} A_{H,t}^{2\phi} \sum_{i:n_i \geq \bar{n}_t} n_i^{2\beta} \tag{16}$$

Aggregate high-tech innovation by entrants

Using (3), (11), and (14),

$$\Lambda_{H,t}^{\text{ent}} = E_t \chi_E e_t^* A_{H,t}^{\phi} = G_c(\bar{K}_t) \frac{(\pi_H + \tau_H)\chi_E^2}{c_e} A_{H,t}^{2\phi} \tag{17}$$

Total high-tech innovation is

$$\Lambda_{H,t} = \Lambda_{H,t}^{\text{inc}} + \Lambda_{H,t}^{\text{ent}} \tag{18}$$

Knowledge stocks evolve according to

$$A_{M,t+1} = (1 - \delta)A_{M,t} + \nu_M \Lambda_{M,t} \tag{19}$$

$$A_{H,t+1} = (1 - \delta)A_{H,t} + \nu_H \Lambda_{H,t} \tag{20}$$

where $\delta \in (0,1)$ is depreciation and $\nu_M, \nu_H > 0$ translate successful innovation into usable knowledge.

THE MID-TECH TRAP AS A LOW-INNOVATION EQUILIBRIUM

Because of the model's path dependence, mid-tech trajectories tend to be self-perpetuating. To formalise this idea, define the relative technological position of the high-tech trajectory as

$$r_t \equiv \frac{A_{H,t}}{A_{M,t}}$$

A *mid-tech trap* is a low-r_t equilibrium path in which

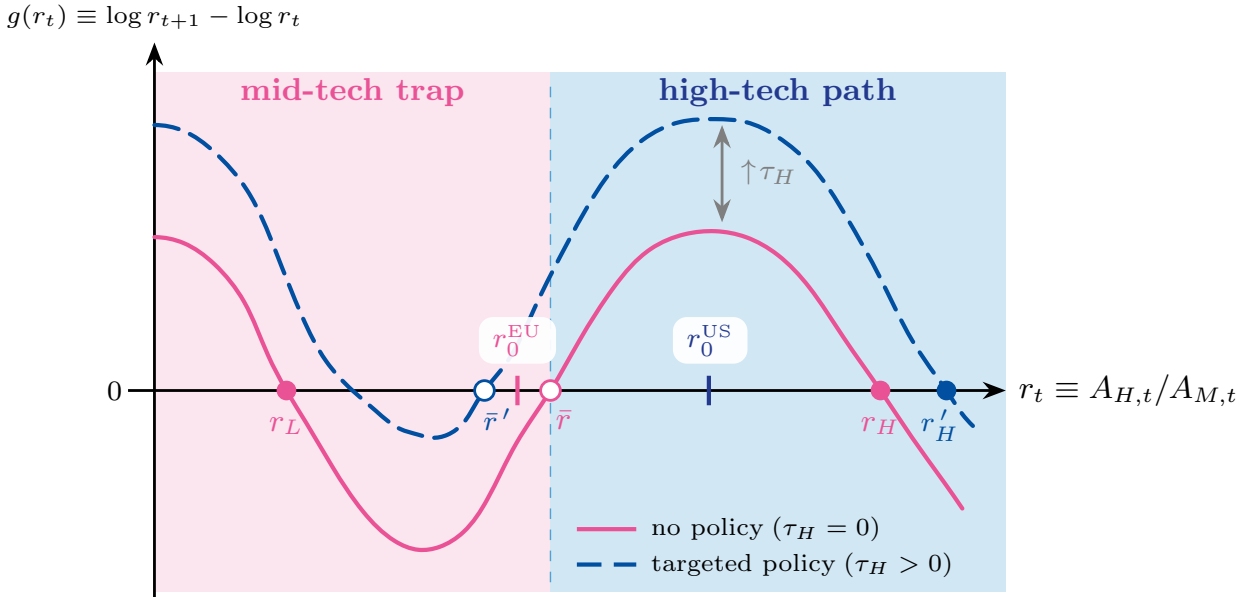
1. internal mid-tech innovation remains strong because $A_{M,t}$ is large and incumbent concentration H is high;
2. the incumbent exploration threshold (7) fails for most firms;
3. startup entry into high-tech remains weak because $\bar{K}_t$ is small and $E_t = G_c(\bar{K}_t)$ remains low;
4. as a consequence, $A_{H,t}$ stays too low for path dependence to turn in favour of high-tech.

The key structural point is that the aggregate high-tech innovation function $\Lambda_{H,t}$ is highly non-linear in $A_{H,t}$. At low levels of $A_{H,t}$, few incumbent firms satisfy the exploration threshold (7) and few entrants find it profitable to enter (13). As $A_{H,t}$ rises, more incumbents cross the threshold and more entrants enter, so the high-tech innovation schedule becomes much steeper.

Appendix Figure 16 illustrates this logic in terms of the relative high-tech position r_t. It plots an S-shaped trajectory with a low stable equilibrium at r_L, an unstable threshold $\bar{r}$,

and a high stable equilibrium at r_H. The pink line shows the baseline scenario without policy intervention. An economy such as the EU, which starts slightly below the threshold $\bar{r}$, remains in the pink-shaded low-A_H basin, gradually converging to the low-innovation mid-tech trap because path-dependence effects dominate exploration and market-entry effects. In contrast, an economy such as the US, which starts above $\bar{r}$, converges to the self-sustaining high-tech path.

Appendix Figure 16 Size Distribution by Entity Type



Note: The figure plots $g(r_t) \equiv log\, r_{t+1} - log\, r_t$ against $r_t = A_{H,t} / A_{M,t}$. Filled circles denote stable equilibria, while open circles denote unstable thresholds. Under the baseline (solid pink, $\tau_H = 0$), the economy features a low stable trap r_L, an unstable threshold $\bar{r}$, and a high stable path r_H. Under targeted low-TRL policy (dashed blue, $\tau_H > 0$), the relative high-tech growth schedule shifts upward, moving the threshold leftward to $\bar{r}'$ and the upper equilibrium rightward to r'_H. An economy at r_0^{EU}— between $\bar{r}'$ and $\bar{r}$ — remains trapped under the baseline but converges to r'_H with the policy; an economy at r_0^{US} escapes the trap regardless. Pink shading indicates the baseline mid-tech basin, and light blue shading indicates the high-tech basin.

Proposition 1 (Threshold dynamics)

Suppose path dependence is strong enough and the entry-cost distribution G_c is sufficiently responsive. Then the mapping

$$A_{H,t+1} = (1-\delta)A_{H,t} + \nu_H \Lambda_{H,t}\left(A_{H,t}; \tau_H, G_c\right)$$

can generate three fixed points in relative technological position: a low stable equilibrium, an intermediate unstable threshold, and a high stable equilibrium. The low equilibrium corresponds to the mid-tech trap, the high equilibrium to a self-sustaining high-tech path, and the unstable fixed point to the transition threshold.

ORIGINS OF THE MID-TECH TRAP

The model explains not only persistence inside the trap, but also how an economy can enter it in the first place. The mechanism is straightforward. Suppose an economy begins with a historically inherited strong mid-tech base, so that $A_{M,0}$ is large, a concentrated incumbent structure, so that H is high and average incumbent size is large, and a weak startup ecosystem, so that G_c places relatively little mass on low-cost entrants.

As the technological frontier gradually shifts toward high-tech activities, these initial conditions imply three things. First, a large $A_{M,0}$ makes further mid-tech innovation highly productive. Second, a more concentrated incumbent structure strengthens internal innovation and shifts incumbent R&D toward internal rather than external activity. Consistent with Remark 1, higher incumbent concentration can increase the number of firms engaging in R&D, while still reducing the aggregate share of R&D devoted to exploration. Third, a weak startup ecosystem prevents new high-tech firms from entering while $A_{H,t}$ is still low.

The model also provides a natural interpretation of the transatlantic contrast. European economies can be represented as combining a larger inherited mid-tech base, a more incumbent-dominated industrial structure, and a thinner startup pipeline. The United States, by contrast, can be represented as an economy with more low-cost experimentation and earlier startup entry. Churning and firm dynamics are stronger, high-tech entry occurs sooner, and $A_{H,t}$ rises more quickly, so that path dependence eventually works in favour of the high-tech trajectory rather than against it.

Proposition 2 (Entry into the mid-tech trap)

An economy is more likely to enter and remain in the mid-tech trap when it combines (i) a large inherited mid-tech knowledge stock $A_{M,0}$, (ii) a concentrated incumbent structure, captured by large average incumbent size and a high Herfindahl index H, and (iii) a weak startup ecosystem, represented by an entry-cost distribution G_c with relatively little mass on low-cost entrants. By contrast, stronger firm dynamics and high-tech entry at low levels of $A_{H,t}$ make it more likely that the economy crosses the unstable threshold and converges to the high-tech path.

INDUSTRIAL POLICY

The model distinguishes sharply between three types of innovation policy.

Supply-side pro-innovation reforms

As discussed above, supply-side reforms that improve firm dynamics and the startup ecosystem enter the model through the entry-cost distribution G_c.

Demand-side low-TRL high-tech support

Demand-side innovation policy — for example targeted R&D grants or public procurement — enters the model through τ_H by directly augmenting the private return to successful high-tech innovation. The model also suggests that support targeted at entrants or small high-tech firms can be particularly effective, since it may help such firms cross the entry and exploration thresholds (13) and (7), respectively. Crucially, this can lower the transition threshold from $\bar{r}$ to $\bar{r}'$, putting an economy that starts at r_0^{EU} below the threshold on a stable high-tech path. In this way, the economy moves from the basin of attraction of the mid-tech trap into the basin of attraction of the high-tech path.

Demand-side generic or late-stage support

Finally, policies that mainly support incumbent firms or later-stage commercialisation may increase total R&D but need not change its direction. In the model, they mostly reinforce the already profitable mid-tech trajectory.

ORIGINS OF THE MID-TECH TRAP

Overall, the theoretical framework maps directly into the results of the first dissertation chapter, and its parameters have direct empirical counterparts in Fuest *et al.* (2024). The inherited mid-tech knowledge stock $A_{M,0}$ directly corresponds to the sectoral specialisation illustrated by **Table 2**, where historically mid-tech car manufacturers and suppliers such as VW, Mercedes, and Bosch have been the main innovators. The relative high-tech position $r_t = A_{H,t}/A_{M,t}$ can be seen as the counterpart to the transatlantic gap in high-tech vs. mid-tech innovation spending. For example, **Figure 2** documents that the ratio of business R&D expenditure from all high-tech sectors to that of mid-tech sectors is 0.85 / 0.09 = 9.4 in the US compared to 0.46 / 0.43 = 1.0 in the EU.

The Herfindahl index H and the dominance of large incumbents in the model is reflected in the observation by Fuest *et al.* (2024) that most of Europe's largest firms by market capitalisation were incorporated 50 to 100 years ago, suggesting limited contestability and weak creative destruction.

The quality of the startup and venture capital ecosystem is captured by the distribution parameter G_c. Given that only one in five EIC Accelerator beneficiaries meets the age definition of a startup and only 20% of total funding reaches independent companies (Fuest et al., 2024, 2025), this can be proxied in the model by a distribution G_c with relatively little mass on low-cost high-tech entrants.

Finally, the policy instrument τ_H maps directly onto the report's central proposal: a shift of resources toward low-TRL, ARPA-style programmes such as Pathfinder and Transition, which target exploratory innovation far from commercial application. This connection also resonates with the central finding of the second dissertation chapter: the subsidy τ_H lowers the exploration threshold and enables entry into productive high-tech innovation, but only for firms that are not credit-constrained and structurally prevented from redirecting their R&D effort. As shown in Chapter 2, a corporate subsidiary whose R&D

agenda is set by its parent's strategy may not respond to τ_H at all, since the constraint is organisational rather than financial.

Overall, the model's conclusion that generic late-stage funding reinforces rather than redirects the mid-tech trajectory provides a formal rationale for the critique in both dissertation chapters of large parts of the European Innovation Council (EIC), which Fuest *et al.* (2024, 2025) find to be primarily supporting mature entities rather than breakthrough innovation.

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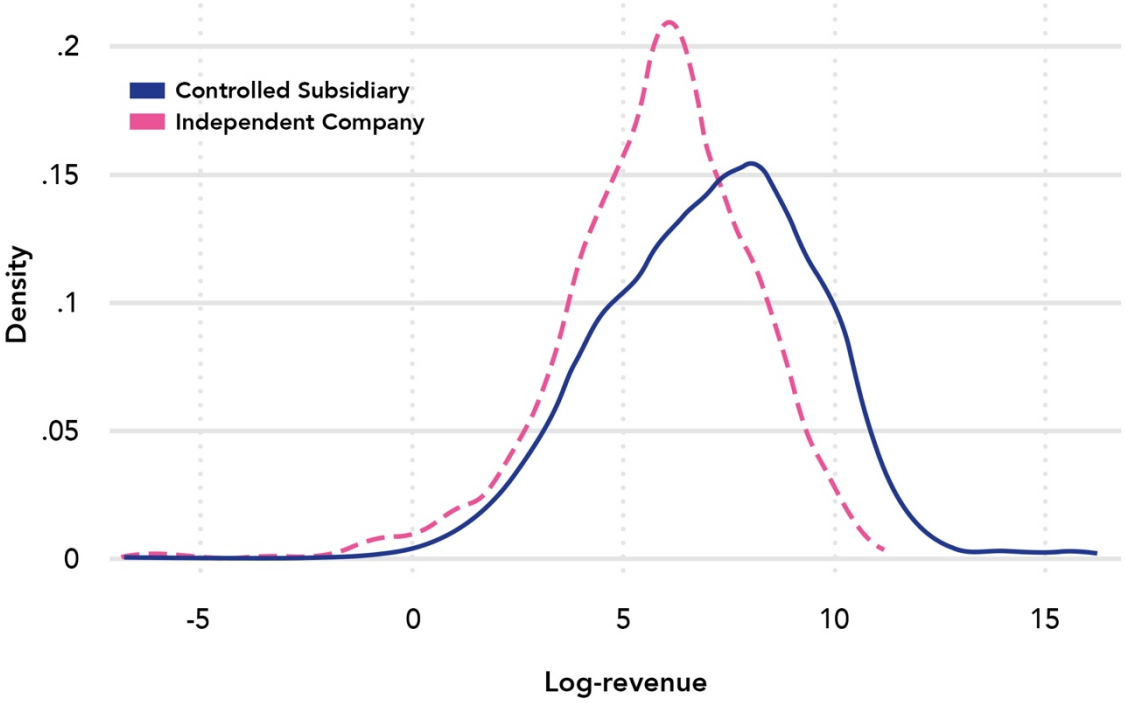
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APPENDIX C

THE EFFECTIVENESS OF EU GRANTS

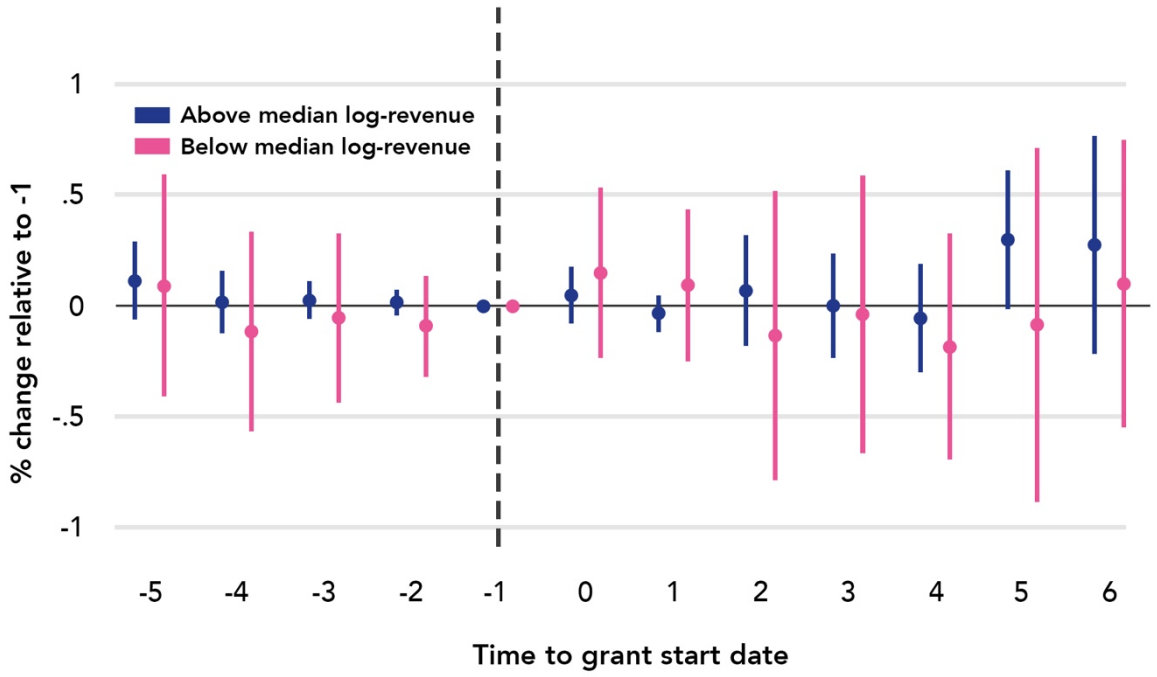
Appendix Figure 17 Size Distribution by Entity Type



Appendix Figure 18 The causal impact of R&D grants on various outcomes



Appendix Figure 19 Causal Impact of R&D Grants on TFP by Size Class



Appendix Table 2 Summary Statistics by Industry

NACE sector	Obs	Firms	% sample	Avg. Revenue ('000)
A — Agriculture, forestry and fishing	123	15	0.8	1,913
C — Manufacturing	5,170	594	30.6	7,500
D-H — Utilities, construction, transport	570	68	3.5	5,051
G — Wholesale & retail trade	1,010	116	6.0	3,813
J — Information & communication	3,454	434	22.4	2,834
K — Financial & insurance activities	121	16	0.8	4,203
L — Real estate activities	66	7	0.4	2,246
M-N — Professional, tech. & support services	5,288	649	33.5	1,209
P — Education	47	5	0.3	948
Q — Human health & social work services	175	21	1.1	1,607
R — Arts, entertainment & recreation	20	2	0.1	.
S — Other service activities	82	11	0.6	1,782
NA — Not available	9	2	0.1	2
Total	16,135	1,940	100.0	

Source: IEP-COMPET (Gros *et al.*, 2025).
Note: All variables are winsorized at the 1st and 99th percentiles. Monetary values are in euros unless stated otherwise.

Appendix Table 3 Summary Statistics by Country

Country	Obs	Firms	% sample	Avg. Revenue ('000)
Austria	399	46	2.4	15,237
Belgium	224	28	1.4	7,265
Bulgaria	102	12	0.6	841
Switzerland	400	47	2.4	2,720
Cyprus	10	1	0.1	19,550
Czechia	163	20	1.0	559
Germany	863	124	6.4	7,003
Denmark	378	59	3.0	356
Estonia	270	31	1.6	1,844
Greece	20	2	0.1	2,390
Spain	2,124	248	12.8	2,412
Finland	672	77	4.0	3,013
France	672	105	5.4	5,616
Croatia	29	3	0.2	434
Hungary	547	58	3.0	1,414
Ireland	487	63	3.2	6,657
Israel	84	28	1.4	20,984
Iceland	199	24	1.2	749
Italy	3,208	344	17.7	5,718
Lithuania	66	7	0.4	965
Luxembourg	42	5	0.3	7,926
Latvia	97	10	0.5	503
Malta	6	1	0.1	10
Netherlands	523	68	3.5	6,711
Norway	471	58	3.0	1,438
Poland	388	50	2.6	2,591
Portugal	477	56	2.9	2,621
Romania	118	13	0.7	1,003
Serbia	37	4	0.2	5,460
Sweden	772	86	4.4	2,984
Slovenia	374	39	2.0	3,667
Slovakia	152	16	0.8	1,143
Turkey	3	1	0.1	34
Ukraine	10	1	0.1	15
United Kingdom	1,699	195	10.1	13,038
Total	16,135	1,940	100.0	

Source: IEP-COMPET (Gros *et al.*, 2025).
Note: All variables are winsorized at the 1st and 99th percentiles. Monetary values are in euros unless stated otherwise.

Appendix Table 4 Summary Statistics by Entity Type

Entity type	Obs	Firms	% sample	Avg. Revenue ('000)
Controlled subsidiaries (ContrSubs)	9,695	1,110	38.5	5,476
Independent companies (IndepCo)	6,440	830	28.8	1,736
Single-location firms (SingleLoc)	4,689	652	22.6	1,378
Global ultimate owner (GUO)	2,509	290	10.1	7,994
Branch	2	2	0.1	.
Total	23,335	2,882	100.0	

Source: IEP-COMPET (Gros *et al.*, 2025).
Note: All variables are winsorized at the 1st and 99th percentiles. Monetary values are in euros unless stated otherwise.

Appendix Table 5 Ownership Statistics by Shareholder Type

Variable†	Obs	Firms	Mean	Median	Std. Dev.	Min	Max
Panel A: All firms							
Corporate share (%)	7,357	891	51.30	50.00	39.20	0.00	100.00
Finance share (%)	3,710	452	25.50	16.10	28.00	0.00	100.00
Individual share (%)	10,884	1,258	67.10	92.00	39.50	0.00	100.00
Public research share (%)	413	49	19.00	10.00	26.50	0.00	100.00
HHI (all)	15,591	2,277	0.50	0.50	0.30	0.00	1.00
Panel B: Controlled subsidiaries							
Corporate share (%)	3,537	403	68.00	89.20	37.30	0.00	100.00
Finance share (%)	1,265	144	30.70	19.40	33.10	0.00	100.00
Individual share (%)	5,098	560	75.70	100.00	35.90	0.00	100.00
Public research share (%)	116	14	30.60	12.30	36.90	0.00	100.00
HHI (all)	8,008	1,062	0.70	0.70	0.30	0.00	1.00
Panel C: Independent companies							
Corporate share (%)	2,018	260	30.20	22.00	30.00	0.00	100.00
Finance share (%)	1,384	182	19.60	13.00	22.10	0.00	95.90
Individual share (%)	3,455	414	58.00	69.70	41.20	0.00	100.00
Public research share (%)	201	24	9.30	6.80	11.70	0.00	49.90
HHI (all)	4,195	659	0.30	0.20	0.20	0.00	1.00

Source: IEP-COMPET (Gros *et al.*, 2025).
Note: All variables are winsorized at the 1st and 99th percentiles. Monetary values are in euros unless stated otherwise.

DATA

Matching CORDIS to ORBIS

In order to combine the company-grant information from CORDIS with firms' financial data from OBRIS we rely on name matching. For details, consult Gros *et al.* (2025). In short, we identify unique matches in three steps. First, we use the VAT codes which Corids provides to find entities in ORBIS. This identifies candidate matches in ORBIS, often multiple ORBIS entities per Cordis entry. To narrow down potential matches, we use additional information like country, postcode or street adress. After this procedure, we find 28,606 ORBIS entities for 22,930 entries. We add a variable with the number of matches for each Cordis entry. For the remaining Cordis entries, we use ORBIS 'batchsearch' tool to identify unique entities. We accept high-confidence matches (A-score), and review the remaining matches manually. We end up with 8,828 one-to-one matches. For 1,071 Cordis entries we could not find any match in ORBIS. Of the total 37,434 companies we then select the relevant subset for our case of study. We merge the funding information with the firms' financial data requires using the project start date provided by CORDIS.

Shareholders Data

To get shareholder data for our ORBIS matches, we download shareholdership from 2002 to 2024 data from ORBIS and clean it in line with Rosati *et al.* (2020). This includes the shareholder id, the shareholder share, and the update date of this information. We then impute the link existence like Rosati *et al.* (2020), where we assume that a link persists if it is only missing for one year. We also transform non-numerical shares, e.g. 'MO', or 'Majority owned' into numbers like Rosati *et al.* (2020). Details can be found in the code.

One issue of note is that shares can sum up to more than 100% in ORBIS. This is because of how ORBIS updates their data. In essence, they add new data when they find it, together with an update-date. So, if a new share is added (e.g. because of a press announcement) which brings the sum above 1, no action is taken and ORBIS simily shows all shares, even if they sum to more than one. To remedy this, we assume that, within a year, the newest shares are the most reliable ones. To then compute the yearly shareholdership, we check if the share sums to more than one. If it does, we remove the oldest share in that year until we get below a sum of 1. The remaining shares are then taken as shareholdership for that year (Note, we download the data always for the end of the year, so the shareholdership for a given year should be ready as end-of-year shareholdership). In our final dataset there are then no observations where the sum of all shareholder-shares for a given year is above 1.

In the end, we have a dataset with, for every company, the year, shareholder name, shareholder bvdid, and the share. We do have entries with 'empty' shares, i.e. no information. However, we keep these to be able to count the number of shareholders. Note, we have this dataset for the whole COMPET dataset, which we later subset to only include company that fit our purpose of study. From this dataset we can then construct indicators for ownership. For example, we group shareholder types and form three categories: i) Corporations; ii) Financial institutions (Bank; Financial company; Hedge

fund; Insurance company; Mutual and pension fund, nominee, trust, trustee; Private equity firm; Venture capital); iii) Individuals (One or more named individuals or families; Self ownership), and iv) Public and research entities.[1]

PRODUCTION FUNCTION ESTIMATION

Proxy Variable Estimator

We assume that in each year t, firm f produces value added v_{ft} with the following production function (in logs):

$$v_{ft} = f(k_{ft}, l_{ft}; \beta) + \omega_{ft} + \epsilon_{ft} \quad \text{(C1)}$$

The term ω_{ft} represents the log of Hicks-neutral productivity, which is known by plants' managers but not by us. The variable ϵ_{ft} is an i.i.d. error term that captures factors such as measurement errors.

We are interested in estimating the vector of the production function parameters β. To recover unbiased and consistent estimates of firms' production function (C9), we need to address the well-known simultaneity problem deriving from the fact that ω_{ft} is correlated to labour and materials but not to capital, which is chosen one period ahead. We build on the methodology of Ackerberg *et al.* (2015) and treat capital as a dynamic input, and labour and materials as static inputs. In particular, we make the following timing assumptions concerning inputs' decisions: i) capital k_{ft} is chosen at $t-1$ and ii) l_{ft} is chosen at $t-b$ after observing ω_{ft}. We further assume that iii) materials m_{ft} are chosen at $t-a$, with $1 < b < a$.

We specify the materials demand function, $m_{ft} = \tilde{h}(\omega_{ft}, k_{ft}, l_{ft})$. Assuming that the materials' demand function of the plant, $\tilde{h}$ is monotonically increasing and invertible in ω, we obtain a control function that proxies for unobserved productivity:

$$\omega_{ft} = h(k_{ft}, l_{ft}, m_{ft}) \quad \text{(C2)}$$

where $h \equiv \tilde{h}^{-1}$. Adding $h(\cdot)$ to Equation (C9), we get

$$v_{ft} = f(k_{ft}, l_{ft}; \beta) + h(k_{ft}, l_{ft}, m_{ft}) + \epsilon_{ft} \quad \text{(C3)}$$

We follow Ackerberg *et al.* (2015) by approximating the right-hand-side of (C3) with a third-order polynomial in all its elements.

From the first stage, we obtain expected output $\hat{q}_{ft}$ and the residuals $\hat{\epsilon}_{ft}$.[2] The next step is specifying a law of motion for productivity ω_{ft}. We assume that ω_{ft} follows a Markov process that can be shifted by plant managers' action:

[1] We drop the categories left as they constitute less than 2% of the sample.

[2] It should be noticed that in the first stage, none of the production function parameters are identified, because they enter both $f(\cdot)$ and $h(\cdot)$.

$$\omega_{ft} = g(\omega_{f,t-1}) + \xi_{ft} \tag{C4}$$

The variable ξ_{ft} denotes the innovation to productivity.[3] Current expected productivity is then expressed as a function of the data and parameters:

$$\omega(\beta)_{ft} = \hat{v}_{ft} - f(k_{ft}, l_{ft}; \beta) \tag{C5}$$

To estimate β, we form moments based on the innovation ξ_{ft} in the law of motion (C4),

$$\xi(\beta)_{ft} = \omega(\beta)_{ft} - E[\omega(\beta)_{ft} \mid \omega(\beta)_{f,t-1}] \tag{C6}$$

The moments that identify the parameters are:

$$E[\xi(\beta)_{ft} M_{ft}] = 0 \tag{C7}$$

where the vector M_{ft} includes current capital and lagged labor, and materials consumption.

For our empirical application, we use a flexible Translog specification to approximate $f(\cdot)$.

The parameters of the production functions $\hat{\beta}$ are estimated separately for six 1-digit industries[4] with the Generalised Method of Moments (GMM), which we implement bootstrapping errors over hundred repetitions.[5]

Dynamic Panel Estimator

We assume that in each year t, producer f produces gross output Q_{ft} with the following production function:

$$Q_{ft} = F(K_{ft}, L_{ft}, M_{ft}) \cdot \Omega_{jt} \tag{C8}$$

where M_{ft} are intermediate inputs, K_{ft} the capital stock and L_{ft} labor. The term Ω_{jt} represents Hicks-neutral productivity. Taking logs, we have:

$$q_{ft} = f(k_{ft}, l_{ft}, m_{ft}; \beta_0) + \omega_{ft} + \epsilon_{ft} \tag{C9}$$

In (C9), ϵ_{ft} is an error term, described further below. We follow Blundell and Bond (2000) and assume that the productivity term ω_{ft} follows an AR(1) process:

$$\omega_{ft} = \bar{\omega}_{ft} + \rho^{\omega} \omega_{f,t-1} + \eta_{ft}$$

[3] In our application we impose a simple AR(1) form for (C4).

[4] TFP is estimated only for firms in the retained 1-digit NACE sectors (C; D–F and H; G; I; J; and M–N). Sectors are included only if they contain at least two distinct years of observations. We exclude sectors A, B, K, L, P, Q, R, S, and NA.

[5] Estimates are robust to using different numbers of bootstrap replications.

where η_{ft} is a MA(0) productivity shock.

Our objective is estimating β_0.[6] The dynamic representation of the model is:

$$\begin{aligned} q_{ft} &= f(k_{ft}, l_{ft}, m_{ft};\ \beta_0) \\ &+ \rho^{\omega}\left(q_{ft-1} - f(k_{ft-1}, l_{ft-1}, m_{ft-1};\ \beta_0)\right) \\ &+ \varepsilon_{ft} - \rho^{\omega}\,\varepsilon_{ft-1} + \bar{\omega_f} + \eta_{ft} \end{aligned} \tag{C10}$$

We assume that the error term ϵ_{ft} includes a component reflecting shocks common to all producers (u_t), a time-invariant firm-specific shifter (u_f), and an i.i.d. error term capturing measurement errors (ε_{ft}):

$$\varepsilon_{ft} = u_t + u_f + \epsilon_{ft}$$

We define the following terms:

$$u_t^* \equiv u_t - \rho^{\omega}\,u_t$$

$$u_f^* \equiv u_f - \rho^{\omega}\,u_f + \bar{\omega_f}$$

$$\epsilon_{ft}^* \equiv \epsilon_{ft} - \rho^{\omega}\,\epsilon_{ft-1}$$

Then, we can rewrite (C10) as

$$\begin{aligned} q_{ft} &= f(k_{ft}, l_{ft}, m_{ft};\ \beta_0) \\ &+ \rho^{\omega}\left(q_{ft-1} - f(k_{ft-1}, l_{ft-1}, m_{ft-1};\ \beta_0)\right) \\ &+ u_t^* + u_f^* + \epsilon_{ft}^* + \eta_{ft} \end{aligned} \tag{C11}$$

where η_{ft} is MA(0) and $\varepsilon^*{}_{ft}$ is MA(1).

As in Blundell and Bond (2000), we further assume that $E[\Delta\,\tilde{x}_{ft}\,u_f^*] = 0$, where $\tilde{x}_{ft} = \{k_{ft}, l_{ft}, m_{ft}\}$, and $E[\Delta\,q_{f2}\,u_f^*] = 0$

Letting $w_{ft} = \epsilon_{ft}^* + \eta_{ft}$, which is thus MA(1), and defining $x_{ft} = (q_{ft}, \tilde{x}_{ft})$, we can write the following moment conditions:[7]

$$E\left[x_{ft-s}\,\Delta\,w_{ft}\right] = 0, s \geq 3$$

$$E[\Delta\,x_{ft-s}(u_f^* + w_{ft})] = 0, s = 2$$

We choose a flexible Translog specification to approximate $f(\cdot)$. The parameters of the production functions $\hat{f}_0$ are estimated separately for 16 2-digit industries with the Generalised Method of Moments (GMM). We calculate standard errors with the sandwich estimator, which are thus robust to heteroskedasticity.[8]

[6] We also estimate ρ^{ω}, but it is not of primary importance in our framework.

[7] These are the same moment conditions used by Yeh *et al.* (2022).

[8] The cost of robust standard errors is that by relaxing the assumption of i.i.d. residuals, one cannot compute the Sargan test for the validity of over-identifying restrictions.

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APPENDIX D

COMPET DATASET

IEP COMPET DATASET

IEP@BU Working Paper Series

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ABSTRACT

This paper presents the construction of the IEP-COMPET dataset, which links approximately two-thirds of all EU Horizon 2020 and Horizon Europe grants awarded to companies with their financial performance and patents, using various data sources. The dataset can be used to examine the allocation and impact of EU funding for innovation. Interested researchers should contact giorgio.presidente@unibocconi.it

JEL Classification: C80, L53

INTRODUCTION

This paper documents the construction of the IEP-COMPET dataset, a panel dataset linking EU-funded R&D and innovation support measures to firms' financials and patents.

OVERVIEW OF EU FUNDING

The European Union funds R&D and innovation through what are known as *framework programs*, multi-annual budget allocations set every seven years by EU officials. The EU has had multiple Framework Programs since the early 1980s. The most recent (and largest) two[1] are:

- Horizon 2020 (2014–2020)
- Horizon Europe (2021–2027)

Within each Framework Program, there are many different *funding instruments*, each with its own characteristics and participation requirements.[2]

Entities can request support by applying to *funding calls* on the online "EU Funding & Tenders Portal", which publishes calls issued under the different funding instruments.

The two main sources of the IEP-COMPET dataset are the European Commission's CORDIS (Community Research and Development Information Service) and Bureau van Dijk's ORBIS.

Further funding and firm-level characteristics are collected by Crunchbase.

CORDIS FILES

We use two files from CORDIS, which are described below.

3.1 organizations.dta

This file is taken from this link:

https://data.europa.eu/data/datasets/cordisref-data?locale=en

The file provides information by "organization id", a unique identifier of the funding beneficiary.

[1] We do not consider the previous, FP7 (2007–2013)–The Seventh Framework Program.

[2] One example is the "SME Instrument", an accelerator for start-ups and SMEs more broadly, active under Horizon 2020. Another example is "Pathfinder", an instrument focusing on projects still far from commercialization. The latter belongs to the institutional umbrella of the "European Innovation Council", which is itself part of Horizon Europe.

Each organization can receive multiple funding from the same instrument and/or participate in multiple funding instruments/calls. Therefore, the same id can appear multiple times in the data.

At the same time, for each organization id, the file lists the projects to which it participates, each uniquely identified by a project identifier (see below).

The file provides the EUR amount received by an organization. Since most funding programs involve collaborations across entities, the amounts reported in each entry of the file are not necessarily equal to the total project amount awarded by a funding call. However, the sum across all consortium members is equal to the total project amount.

Most organizations in the file receive some funding. However, some funding calls involve multipleentity-consortia which include "third parties", i.e. entities that do not receive financial support.

Organizations can be of 5 types: Private Company (PRC), Higher Education (HES), Research Organisation (REC), Public Body (PUB) & Other entities (OTH), which comprise mostly NGOs.

3.2 project.dta

This file is taken from this link: https://data.europa.eu/data/datasets/cordisref-data?locale=en

The file provides information by "project id", which uniquely identifies a project funded by the EU within a specific funding call.

For each project, it further includes the code of the call, the name of the funding instrument through which it is awarded, and the respective framework program.

The file also provides the signing date (co-signing if involving multiple participants), start date, and end date of the projects.

3.3 CORDIS files merged

Each project can be linked to the respective project participants (e.g. companies, universities, organisations) as illsutrated by **Appendix Figure 20**. A one-to-many merge of project.dta to organizations.dta allows to assign time stamps for the funding to organizations corresponding to calendar dates. As noted, three dates are considered: signing, start, and end date.

The information is aggregated at the year level. If an organization receives multiple grants from the same funding instrument within a year—for instance due to participation in different calls—the amounts are simply summed at the year level.

If an organization receives multiple grants from different funding instruments within a year, the amounts are summed by funding instrument and year.

Thus, the merged CORDIS dataset vary at the organization-funding instrument-year level.

Appendix Figure 20 Structure CORDIS dataset



Project_name	Title	EU_program	Member_name	Member_type	VAT_number	EU_funding
promise	BraiN20®: A pa…	Accelerator	TIME IS BRAIN SL	Company	ESB01717156	2.50M
qc-rosa	a Quasi Cohere…	Accelerator	BIFROST COMMUNICATIONS APS	Company	DK38748211	2.50M
qx	Automating qu…	Accelerator	QUANTROLOX FINLAND OY	Company	FI32285485	2.50M
rMSI	Real-time multi-…	Accelerator	THERICON GMBH	Company	DE329135495	2.50M
regenera	A natural breas…	Accelerator	TENSIVE SRL	Company	IT08045870964	2.50M
sa.engine	End to end Rea…	Accelerator	STREAM ANALYSE SWEDEN AB	Company	SE559000648101	2.50M
sbli-ant3310	A novel combin…	Accelerator	ANTABIO	Company	FR94517511291	2.50M
sepoqc	Scalable Entan…	Accelerator	QUANDELA	Company	FR21830721098	2.50M
tilkal	Next Generatio…	Accelerator	TILKAL	Company	FR09828499988	2.49M
xTrap	Real-time auto…	Accelerator	XFARM TECHNOLOGIES ITALIA…	Company	IT02594980068	0.87M
zLOCK	The first true mi…	Accelerator	ZYGOFIX LTD	Company	IL515565208	2.22M
3D-BRICKS	3D Biofabricate…	Pathfinder	CNT INNOVATION	Company	BE0723767874	0.17M
3D-BRICKS	3D Biofabricate…	Pathfinder	KERR S.R.L	Company	IT02575450214	0.27M
3D-BRICKS	3D Biofabricate…	Pathfinder	FUNDACIO INSTITUT CATALA D…	Organisation	ESG63277776	0.30M
3D-BRICKS	3D Biofabricate…	Pathfinder	FONDAZIONE ISTITUTO ITALIA…	Organisation	IT09198791007	0.61M
3D-BRICKS	3D Biofabricate…	Pathfinder	University of Fribourg	University		
3D-BRICKS	3D Biofabricate…	Pathfinder	UNIVERSITAET HAMBURG	University	DE245584140	0.50M
3D-BRICKS	3D Biofabricate…	Pathfinder	KARLSRUHER INSTITUT FUER…	University	DE266749428	0.40M
3D-BRICKS	3D Biofabricate…	Pathfinder	UNIVERSITAET LEIPZIG	University	DE141510383	0.37M
3D-BRICKS	3D Biofabricate…	Pathfinder	UNIVERSITEIT ANTWERPEN	University	BE0257216482	0.35M
3D-BrAIn	Revolutionary h…	Pathfinder	3BRAIN AG	Company	CHE387460635…	
3D-BrAIn	Revolutionary h…	Pathfinder	MAX-PLANCK-GESELLSCHAFT…	Organisation	DE129517720	0.40M
3D-BrAIn	Revolutionary h…	Pathfinder	UNIVERSITA DEGLI STUDI DI G…	University	IT00754150100	0.47M
3D-BrAIn	Revolutionary h…	Pathfinder	ERASMUS UNIVERSITAIR MEDI…	University	NL801427228B01	1.13M
3DSecret	3D spheroids d…	Pathfinder	SPHERE FLUIDICS LIMITED	Company	GB104604653	

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ORBIS FILE

For every "organization id" in CORDIS (n=32,829), we find the corresponding organization in the ORBIS database[3] from Bureau van Dijk (2025) and assign its "BvD Number". ORBIS is a database that provides a range of company information. We use it for retrieving financial data, like turnover and employment.

To match CORDIS to ORBIS we proceed as follows: When available, we use the European VAT number from CORDIS to find a direct match in ORBIS (n=23,340). If unavailable, we use ORBIS' "batch-search" tool to look for suitable matches based on name, city, and country (n=9,899). If we do not find a company manually, we classify it as not found (n=1,071).[4]

For the VAT numbers, ORBIS returned all companies with the given VAT number. This included not only the Global Ultimate Owner (GUO) but also branches, subsidiaries, single locations, and independent cooperations. Overall, we get 163,285 potential matches. We use the country, city, postcode, street, and street number to identify the correct and final matches. This exercise is approached from two angles. First, we focus on finding unique matches using combinations of these data points. Second, we exclude firms that clearly do not match.

[3] https://login.bvdinfo.com/R1/Orbis

[4] Careful readers will spot that 32,829 ≠ 23,340 + 9,899. That is because 410 companies with VAT codes were also matched manually. If available, the manual matches were chosen.

In the first step, we look for unique matches as combinations of the available information. Using different combinations reduces the sensitivity to misspellings. For example, if we were to match all data points, we might not find accurate matches due to inconsistent spelling (e.g., Munchen, Muenchen, or München). By focusing on subsets of the information (e.g., the same country, postcode, and street), we can confidently identify the correct match, even if not all data points align. Importantly, we only consider a match valid if it is unique. For example, if two firms match the description due to different street numbers, we would not make a decision and would leave the match unresolved. Using this approach, we identify 20,703 of the 23,340 firms. For the remaining firms, there are still 41,418 potential matches to consider.

In the second step, we remove implausible matches within the remaining subset of 41,418 observations. For example, if we have 10 matches for one VAT number, but only half of them are in the right country, we remove those matches accordingly.

After these two steps, we are left with 29,772 matches. To account for the ambiguity, we include a weight-variable to the dataset that indicates the number of remaining matches (i.e. it would be equal to five in the previous country example), and potential matches (i.e. ten).

In the manual search, we upload the name, city, and country to ORBIS' batch-search tool. ORBIS then returns candidate matches with a confidence score from A to E. We take matches with score A as correct. For all others, we check the candidates and choose the most plausible one. If none of the candidates is plausible, we classify as no match. This is the case for 1,071 out of 32,829 companies. Because of some anomalies, we also match a small subset of the VAT companies manually but remove the VAT duplicates from the final ORBIS dataset.

Finally, we combine the data from the two matching procedures to obtain a dataset with 38,505 observations, 8,828 from the manual process, 28,606 from the VAT matching (22,930 firms with multiple matches), and 1,071 which could not be found.

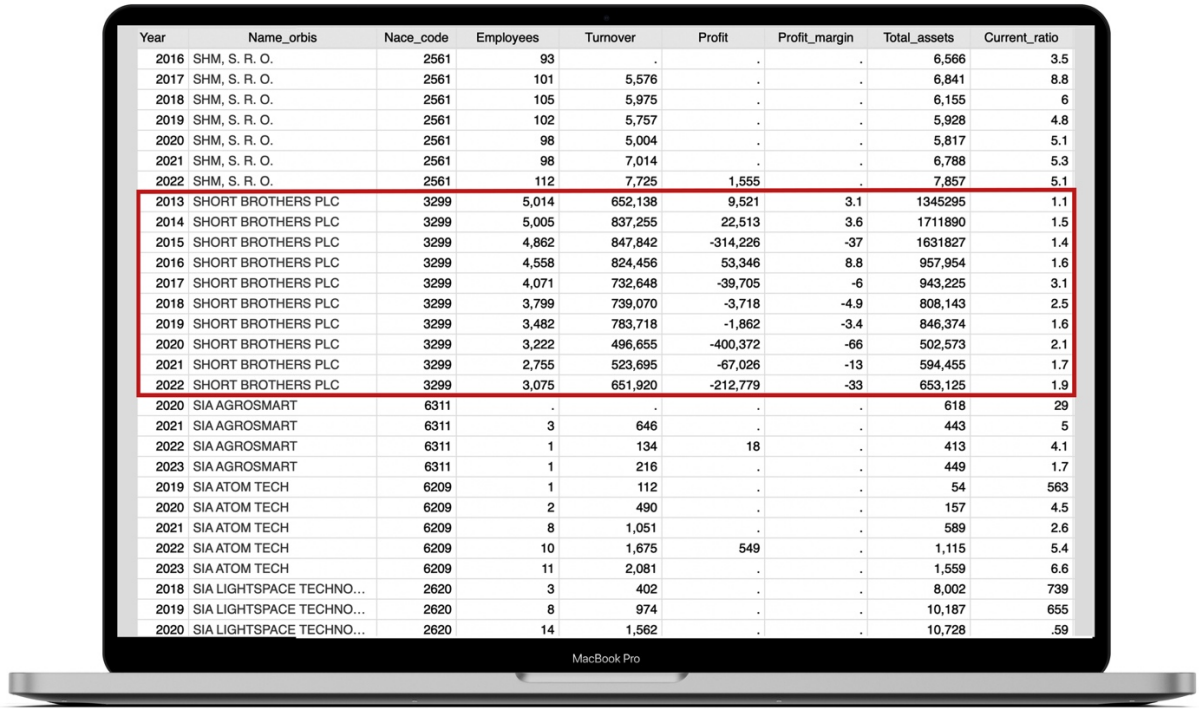
After linking ORBIS to CORDIS, we proceed to downloading the data . We download ORBIS information for all available firm, i.e. 38,505 - 1,071 = 37,434. Of these, 37,357 firms were unique, as some firms were matched to multiple CORDIS firms.[5] Of those, only one company could not be found for the download, even when using the BvD ID.

To keep all CORDIS firms in the data frame, we left-join the ORBIS data to CORDIS observations. So, the data comprises 38,505 observations again—including all CORDIS IDs, with some otherwise empty rows.

The final ORBIS dataset contains 38,505 observations. **Appendix Figure 21** illustrates the structure of this dataset.

[5] Looking at CORDIS, we suspect some companies in CORDIS to be duplicates.

Appendix Figure 21 Structure ORBIS dataset



Year	Name_orbis	Nace_code	Employees	Turnover	Profit	Profit_margin	Total_assets	Current_ratio
2016	SHM, S. R. O.	2561	93	.	.	.	6,566	3.5
2017	SHM, S. R. O.	2561	101	5,576	.	.	6,841	8.8
2018	SHM, S. R. O.	2561	105	5,975	.	.	6,155	6
2019	SHM, S. R. O.	2561	102	5,757	.	.	5,928	4.8
2020	SHM, S. R. O.	2561	98	5,004	.	.	5,817	5.1
2021	SHM, S. R. O.	2561	98	7,014	.	.	6,788	5.3
2022	SHM, S. R. O.	2561	112	7,725	1,555	.	7,857	5.1
2013	SHORT BROTHERS PLC	3299	5,014	652,138	9,521	3.1	1345295	1.1
2014	SHORT BROTHERS PLC	3299	5,005	837,255	22,513	3.6	1711890	1.5
2015	SHORT BROTHERS PLC	3299	4,862	847,842	-314,226	-37	1631827	1.4
2016	SHORT BROTHERS PLC	3299	4,558	824,456	53,346	8.8	957,954	1.6
2017	SHORT BROTHERS PLC	3299	4,071	732,648	-39,705	-6	943,225	3.1
2018	SHORT BROTHERS PLC	3299	3,799	739,070	-3,718	-4.9	808,143	2.5
2019	SHORT BROTHERS PLC	3299	3,482	783,718	-1,862	-3.4	846,374	1.6
2020	SHORT BROTHERS PLC	3299	3,222	496,655	-400,372	-66	502,573	2.1
2021	SHORT BROTHERS PLC	3299	2,755	523,695	-67,026	-13	594,455	1.7
2022	SHORT BROTHERS PLC	3299	3,075	651,920	-212,779	-33	653,125	1.9
2020	SIA AGROSMART	6311	.	.	.	.	618	29
2021	SIA AGROSMART	6311	3	646	.	.	443	5
2022	SIA AGROSMART	6311	1	134	18	.	413	4.1
2023	SIA AGROSMART	6311	1	216	.	.	449	1.7
2019	SIA ATOM TECH	6209	1	112	.	.	54	563
2020	SIA ATOM TECH	6209	2	490	.	.	157	4.5
2021	SIA ATOM TECH	6209	8	1,051	.	.	589	2.6
2022	SIA ATOM TECH	6209	10	1,675	549	.	1,115	5.4
2023	SIA ATOM TECH	6209	11	2,081	.	.	1,559	6.6
2018	SIA LIGHTSPACE TECHNO...	2620	3	402	.	.	8,002	739
2019	SIA LIGHTSPACE TECHNO...	2620	8	974	.	.	10,187	655
2020	SIA LIGHTSPACE TECHNO...	2620	14	1,562	.	.	10,728	.59

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SEAL OF EXCELLENCE

We follow the same steps outlined above to obtain ORBIS information for companies awarded the Seal of Excellence (SoE). The SoE is a quality label given to high-ranking Horizon Europe project proposals that are not funded due to budget constraints—hence these companies are not necessarily included in CORDIS.[6]

We retrieved the data for the SoE firms from Dealroom (Demolin *et al.*, 2025). They compiled a non-exhaustive list of 814 firms that have received the Seal.

We match them to CORDIS firms using first the Levenshtein distance to get potential matches, and confirm them manually. Through this process we identify a subset of the SoE companies are also listed in CORDIS (213 firms, indicated via a dummy). This is because these firms previously applied for an EU grant unsuccessfully but later received EU funding in a subsequent funding call. For the other Seal of Excellence companies we perform another manual batch search in ORBIS and download the batch (518 firms). We add both batches to the rest of the ORBIS data and tag it with a corresponding dummy variable. The remaining firms could not be found and are not added to any dataset.

[6] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/seal-excellence_en

ORBIS IP FILE

We rely on data from the Orbis IP database[7] to build patent-based innovation outcomes. That is, we retrieve all patent publications owned by the firms of interest, given the BvD Numbers identified, as suggested above. Out of the 37,357 linked firms, 12,637 (34%) own at least one patent. Overall, roughly 10 mil. distinct patent publications are associated with these firms.

To avoid counting the same invention multiple times, we rely on *patent families* instead of individual patent filings, or corresponding publications. The ORBIS IP database provides indicators for patent families, including simple patent families, which are equivalent to DOCDB patent families used in PATSTAT, the patent database of the European Patent Office. Such a patent family comprises a set of patent filings across jurisdictions, protecting the same underlying invention or technology. For brevity, we refer to a patent family simply as a patent in the report. We date each patent by its priority date, i.e., the date of the earliest filing within the family which is the closest in time to the origin of the invention.

We assign each patent family a main technology class, by identifying its main International Patent Classification (IPC) subclass (4-digit code), i.e. the subclass that is most common across all filings in the patent family. Whenever a mode cannot be identified, we randomly choose one subclass from those that are most common. In a second step, based on the subclass identified, we assign each patent family a main technological area based on the classification introduced by Schmoch (2008).

We follow the methodology provided by Eurostat (2024) to classify high-tech patents. Given the different granularity level of technology subclasses considered in this classification, we rely on the complete set of IPC codes assigned to each patent in the family. A patent family is classified as high-tech if at least one of these IPC codes matches a code listed in Eurostat's high-tech classification.

When aggregating patents at the firm-year level, we assign a co-owned patent to each of the awardees that acts as an owner.

[7] Data extraction: June 2024.

CRUNCHBASE FILE

Crunchbase is a widely used database that provides comprehensive information on both private and public companies, including details about founders, key executives, investors, and funding rounds (Crunchbase, 2025). Established in 2007, the database has significantly expanded in scope and coverage over the years.

The Crunchbase dataset is structured into three primary categories: organizations, people, and investments. "Organizations" includes data on companies; "people" captures information on individuals affiliated with these organizations, particularly those in leadership or key decisionmaking positions; "investments" encompasses data on funding rounds. It also provides granular details such as funding event dates, amounts raised, and investment types (e.g., Seed Funding, Angel Funding, Series A, B, C, etc.). A detailed glossary of funding types is available online at:

https://support.crunchbase.com/hc/en-us/articles/115010458467-Glossary-of-Funding-Types

To ensure data accuracy and completeness, Crunchbase employs artificial intelligence and machine learning algorithms for validation and anomaly detection, supplemented by manual curation from a team of data analysts.

For our purposes, we focus on the funding dataset, which includes details as the number of funding rounds, the date of the announced funding, amounts raised, and investment types.

The dataset used in this study was collected between January and February 2025. For each "organization id" in the CORDIS database, we identified the corresponding entity in Crunchbase and retrieved the relevant funding information. The data extraction process followed these steps:

1. Entity Matching via API-Search: Given an entity name in CORDIS, we queried Crunchbase's Autocomplete API,[8] which returns a list of suggested entities based on the input string. The output includes a list of permalinks corresponding to potential matches.

2. Retrieving Organization Details: For each permalink obtained in the previous step, we retrieved the corresponding Crunchbase location information using the "Lookup an Organization" API.[9]

3. Entity Disambiguation Using Text Similarity: To refine entity matching, we employed a similarity score between CORDIS Entity Name and the suggested

[8] https://data.crunchbase.com/docs/using-autocomplete-api
[9] https://data.crunchbase.com/reference/getorganization

Crunchbase Entity Names. Using the Python library "linktransformer",[10] we generated text embeddings and computed a similarity score based on vector space distance. The transformer model "allMiniLM-L6-v2" from Hugging Face[11] was used due to its efficiency and domain suitability.

4. Final Entity Selection and Manual Review: Using the similarity score and location information, we identified the best-matching Crunchbase entity for each CORDIS organization. A manual review was conducted to ensure accuracy.

5. Retrieving Funding Information: Once a single permalink was assigned to each CORDIS entity, we extracted Crunchbase's funding information, finalizing a dataset that included: "Crunchbase permalink", "Announced Date", "Transaction Name", "Number of Investors", "Money Raised", "Lead Investors". The "Money Raised" column was parsed to extract the currency and funding amounts, which were then converted to EUR for consistency.

7.1 Crunchbase File Summary Statistics

The dataset comprises 11,139 Crunchbase permalinks, from which we retrieved funding information. Among these, 4,790 permalinks contain details on Money Raised and Announced Date, covering a total of 10,494 funding events. The funding amounts are reported in multiple currencies, with 57.80% in EUR and 22.83% in USD. The earliest recorded funding event dates back to 1996, while the most recent one is from February 2025. Notably, 80% of funding events were announced between 2015 and 2023.

On average, companies in the dataset received 2.5 funding rounds, with a median of 2 rounds per company. The number of fundings per company ranges from a minimum of one to a maximum of 21 rounds. Regarding funding types, 80% of all funding events fall into four main categories:

Grants (36.7%), Seed Funding (18.5%), Venture Rounds (16.9%), and Series A & B (13.1%).

ASSEMBLING IEP-COMPET

To assemble IEP-COMPET, we perform a 1:m merge of the ORBIS file with the CORDIS merged file. Merging the funding information with the firms' financial data requires setting the 'treatment' year. Crucially, the CORDIS dataset includes the start dates of funded projects but does not specify the exact date when a firm received the subsidy. However, as noted by Mulier and Samarin (2021), most firms typically received the subsidy within eight months of submitting their application. Accordingly we use the project start date as a good approximation to the 'treatment' year.

[10] https://github.com/dell-research-harvard/linktransformer
[11] https://huggingface.co/sentence-transformers/all-MiniLM-L6-v2

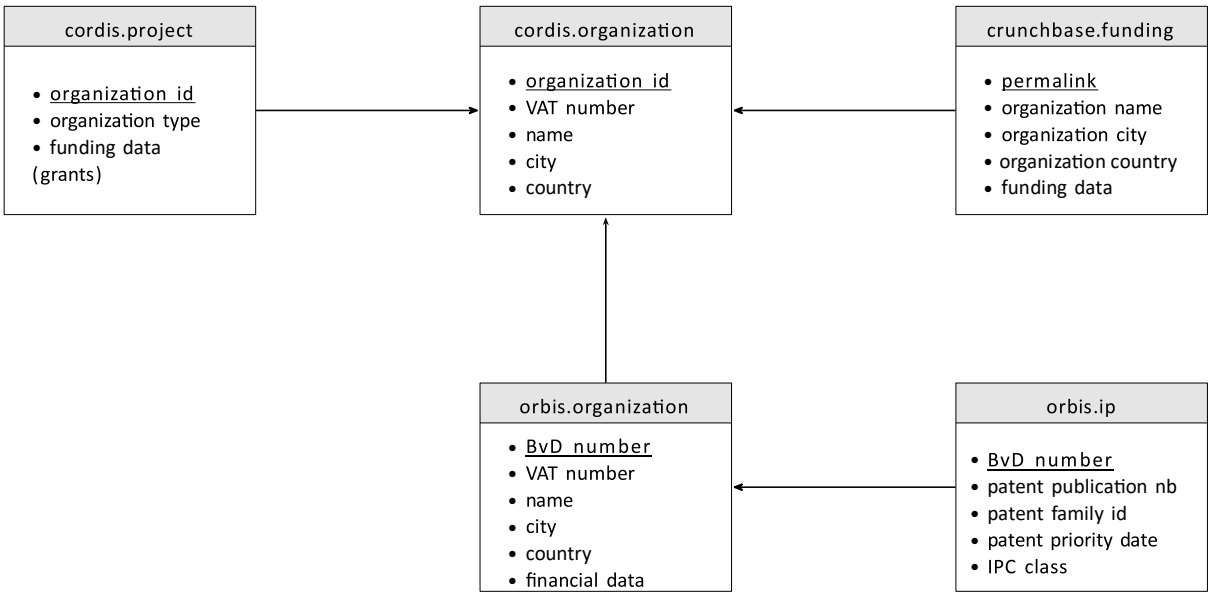
We are able to match two-thirds of the universe of grants disbursed by the Commission. **Appendix Figure 22** presents graphically the various components of the dataset.

8.1 Data Cleaning

We clean the financial data from ORBIS following a procedure similar to Kalemli-Özcan *et al.* (2024). Specifically:

- Keep company-years with non-missing information on sales, employment and total assets.
- Drop the entire company if sales, employment or total assets are negative in any year.
- Drop companies with employment larger than Walmart (2 million) in any year.Winsorize all balance-sheet and CORDIS variables below 1st & above 99th percentile.

Appendix Figure 22 Relationship between Data Sources



SUMMARY STATISTICS

IEP-COMPET includes information on 23,574 firms operating in 20 one-digit NACE industries between 1995 and 2024. The dataset includes 17,675 funded projects and 40,081 individual grants to companies disbursed along two framework programs and 619 funding instruments.

Appendix Table 6 presents key summary statistics of IEP-COMPET.

Appendix Table 6 Summary Statistics

	(1) N	(2) Mean	(3) Median	(4) SD	(5) Min	(6) Max
Operating Revenue/Turnover (billion €)	150,230	0.593	0.001	2.621	0	20.63
Number Employees	162,448	1,374	30	6,284	0	51,114
# Patents	59,985	30.11	3.00	217.18	1	12,258
# High-tech Patents	59,985	6.24	0.00	84.84	0	6,205
Company EU grant (million €)	38,261	0.367	0.254	0.358	<0.001	1.409
Company funding per year (million €)	38,261	0.119	0.084	0.125	<0.001	1.619
Grant per Employee (million €)	30,739	0.0337	0.001	0.0892	<0.001	1.409
Duration of the project (years)	46,323	3.454	3.500	1.221	0.331	6.245
Size of the consortium	46,323	19.95	15.5	21.38	1	207
Share of research institutions	46,323	0.348	0.340	0.215	0	1

Notes: This table contains summary statistics for the grant recipients included in CORDIS. The annual patent counts are computed for the period 2005-2022 and include only firm-year observations with at least one patent.

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