COMPETITIVENESS, DIGITAL TRANSFORMATION AND EU POLICIES

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Executive Summary

Why this matters, now

Europe's competitiveness challenge is fundamentally an innovation and productivity one. Price-based competitiveness strategies are neither durable nor sufficient in an era of geo-economic fragmentation: only innovation-led competitiveness can sustain growth and resilience, driven by frontier R&D, effective commercialisation, and wide technology diffusion. Today's general-purpose technologies (GPTs) — notably advanced connectivity, cloud, and AI — are key levers. This report aims to assess how the European Union (EU) performs on these levers, how the EU's current policies are shaping outcomes, and where recalibration may be necessary.

Key cross-cutting findings

1. **What are the principal causes of the EU's innovation gap?**

   EU's competitiveness problem is principally based on innovation and productivity lags. The shortfall is driven by private R&D. Sectoral composition also plays a negative role for Europe, with R&D concentrated in mid-tech industries (automotive, chemicals, transport) rather than high-tech. Finally, EU has weaker productivity returns from R&D spending and underperforms on ICT and AI patenting relative to its research output.

   A remedy is to rebalance public R&D toward high-impact, high-tech innovation and promote cross-sector private financing partnerships. Because productivity gains increase with scale, fragmented public/private R&D funding and industrial policies should be consolidated. Simply spending more on R&D - though likely necessary - will not suffice: the EU also needs to improve the returns on that spending.

2. **To what degree are the creation and scaling of EU-based technology firms essential to competitiveness?**

   The EU has produced few digital firms with global scale. Capital markets are shallow for equity and later-stage growth; corporate venture capital from EU mid-tech champions often flows to US startups, reinforcing the "mid-tech trap. As a result, the EU depends on foreign countries for the great majority of its digital products, services, and infrastructure.

   On the other side, not all the US productivity advantage is directly derived from its major tech platforms: these may instead also be one of its results. Therefore, trying to emulate a "US model" without addressing the underlying problems could be ineffective and very inefficient. A polycentric digital architecture, where EU ICT manufacturers and telecom providers play a more active role, may represent a more appropriate and balanced path for the EU.

3. **How effectively is the EU performing in the diffusion and productive utilisation of digital technologies?**

The EU performs well on rollout of digital infrastructures and is broadly in line with other major jurisdictions for take-up of digital services. It nonetheless lags in the development and productive uptake of more advanced infrastructures and services (e.g., 5G stand-alone and cloud and AI that are deeply integrated in companies' productive processes). Indeed, Europe's labour productivity gap concentrates where ICT is produced and where it is intensively used.

Moreover, European firms convert ICT investment into productivity gains less effectively, largely due to smaller average firm size and under-investment in complementary intangibles - skills, software, and organisational capital - needed for enabling digital transformation. Strengthening mechanisms that boost intangible investment would help close this gap. More broadly, Europe should aim to consistently outperform the United States in the diffusion and productive use of ICT and digital technologies across its industrial ecosystem.

Trade-offs

- **Maintaining a balance between IP-holders and downstream innovators.** It is important to promote downstream incremental innovation and diversification; on the other hand, it is crucial to maintain stable upstream licensing revenues to sustain EU R&D intensity and innovation-led competitiveness. The latter is especially true in strategically relevant industrial segments where EU innovators are globally competitive (e.g., cellular/IoT equipment).
- **Strategic autonomy vs diffusion.** Curtailing market access for non-EU digital services risks slowing ICT adoption and reducing quality and choice. In those cases, where substantiated economic security risks arise, carefully designed measures may be warranted. Overall, the approach should be case-by-case, proportionate, and risk-based—privileging enabling policies that build credible EU alternatives while preserving access to frontier technologies.

- **Demand-led connectivity investment vs anticipatory (public) investment.** Anticipatory public (or publicly incentivised) investments are risky yet can be justified in some circumstances. However, such anticipatory investment should be contingent on a rigorous ex-ante impact assessment of demand-side dynamics, the infrastructure's transformative nature (and thus limited responsiveness to demand-pull), and the net economy-wide effects.

Policy recommendations

- **Rebalance public R&D toward high-impact, high-tech missions.** The European Commission (DG Research & Innovation) and EU Member States should align their R&D strategies through the Horizon Europe Strategic Research and Innovation Agenda and the proposed European Competitiveness Fund, concentrating resources at EU level to achieve critical mass and ensure R&D translates into productivity gains.
- **Strengthen the research-to-deployment pipeline**. DG Research & Innovation should redesign Horizon Europe calls to fund cohesive innovation ecosystems—linking large firms, start-ups/SMEs, universities, and venture finance within regional clusters. Condition grants on demonstrated commercialisation pathways and downstream technology adoption.

- **Maintain a balanced regime for intellectual property rights.** The European Commission (DG Grow and DG Connect) should aim to preserve incentives for EU upstream innovators by rejecting overly prescriptive ex-ante licensing controls, while promoting industry-led initiatives to foster SME participation and incremental downstream innovation.

- **Ensure strategic-autonomy measures are risk-based and proportional**. The European Commission should operationalise the Digital Decade targets and CAIDA framework by restricting "resilience" measures to genuinely critical public-sector workloads and high-risk dependencies, while avoiding blanket restrictions on foreign investment or technology diffusion that would slow EU innovation ecosystems and delay AI/cloud deployment.

- **Conduct in-depth ex-ante impact assessments for public (or publicly incentivised) infrastructure investments.** DG Connect and the European Investment Bank should require demand-responsiveness audits before committing to large-scale digital infrastructures, prioritising areas with high knowledge spillovers, strong absorptive capacity, and regional adoption readiness.

- **DG Connect should redesign Digital Decade Index and targets**. Shift metrics from technology availability and service adoption to adoption with productivity-enhancing outcomes — disaggregated by sector and region. Also introduce dynamic benchmarking against US digital trajectories to maintain competitive parity.

- **Create EU-level instruments for intangible capital**. The European Commission (DG Connect, DG Grow and DG Research) should establish dedicated funding streams for skills development, software-development toolkits, organisational-change support, and data-asset governance, enabling firms—especially SMEs—to maximise productivity gains from cloud and AI adoption and reduce the "productive-adoption gap" between EU and US firms.

Why this matters, beyond

Recent seminal reflections from former Italian prime ministers Mario Draghi and Enrico Letta converged on a single diagnosis: innovation is the engine of competitiveness and dictates the ability for the EU to compete geopolitically, and Europe lags in this area. Policy to enhance the EU innovation system and increase competitiveness is not easy, but it is necessary - and innovation matters for reasons that go beyond competitiveness metrics.

Innovation-driven economic growth can expand the “size of the pie”, increasing the potential for shared prosperity and welfare improvements: this is what prevents international trade from necessarily becoming a “zero-sum game”. Historically, innovation and technological progress have reshaped trade patterns, enabled globally integrated value chains, and made the world profoundly more cooperatively interdependent - and they can likely do so again.

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About CERRE

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About the Author

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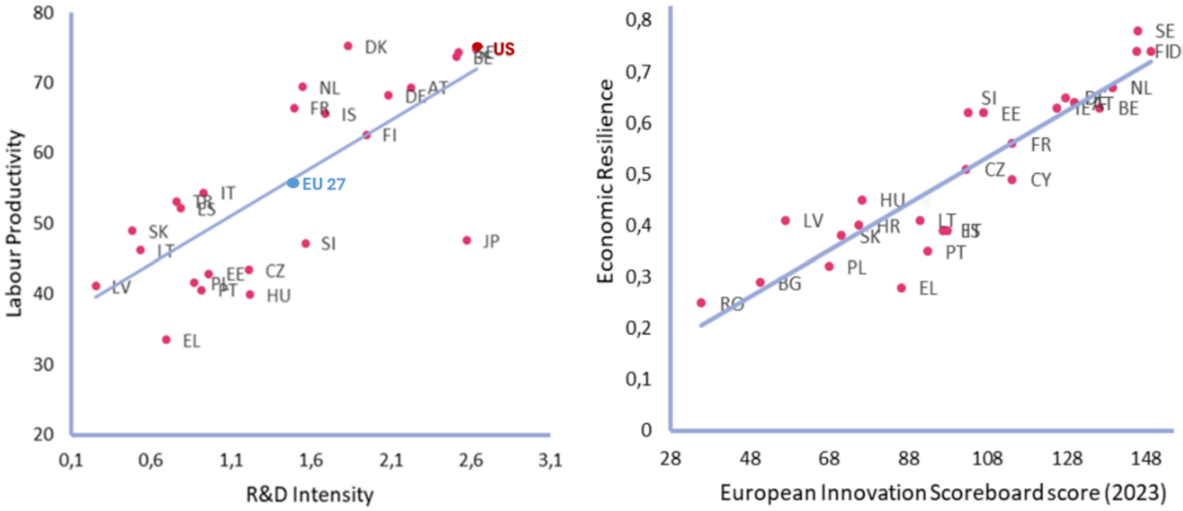
1. Introduction: Competitiveness, Innovation and Productivity

In his report “The future of European Competitiveness”, Mario Draghi calls for decisive action to close Europe’s widening innovation gap, accelerate digital transformation, and strengthen its capacities in key technologies domains—from semiconductors to cloud, AI and quantum technologies. At the same time, Draghi highlights the need to address persistent deficiencies in connectivity infrastructures and digital skills, both of which are essential to resolving the bloc’s competitiveness problem.

The competitiveness concept embraced by Draghi clearly and strongly centres on innovation, as opposed to reducing prices by either depreciation of the real exchange rate or a reduction in unit production costs. While short-term price-based competitiveness is often unsustainable in the long-run,[1] innovation-based competitiveness leads to increased productivity and economic growth over time.[2] Research and innovation are crucial to boost Europe’s (long-term) competitiveness: they are the main drivers of productivity and are directly correlated with economic resilience.[3] (**Figure 1**)

Figure 1 – Research & Innovation impact on productivity and economic resilience



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[1] Relying on exchange rate depreciation as a means of enhancing trade competitiveness is inherently unsustainable, as its short-term benefits are offset by adverse long-term effects. Depreciation increases the domestic currency cost of imported goods, which in turn raises import prices and fuels inflation. Higher inflation erodes purchasing power and discourages domestic investment, ultimately constraining productivity growth. A more durable approach is to improve competitiveness by reducing unit production costs, thereby enabling exports to gain market share without currency manipulation. Yet, this strategy also faces limits: sustained export expansion can place upward pressure on the exchange rate, gradually eroding the initial cost advantage. Moreover, aggressive cost-cutting risks undermining product quality and curtailing long-term investment, which may compromise the very foundations of competitiveness over time.

[2] Aghion P., Howitt P. (1992) A Model of Growth Through Creative Destruction, in Econometrica, 60(2), 323–351; Aghion P., Howitt P. (1998). Endogenous Growth Theory. This kind of economic growth is supposed to expand the “size of the pie,” increasing the potential for shared prosperity and welfare improvements, making it compatible with the idea that relations between countries may be characterised as a “positive-sum game” rather than a “zero-sum game”.

[3] Steeman J-T, Hobza A, Canton E, Di Girolamo V, Mitra A, Peiffer-Smadja O, Ravet J (2024) Why investing in research and innovation matters for a competitive, green, and fair Europe - A rationale for public and private action – EU Commission R&I Paper series.

Note: Graph on the left: business expenditure in R&D (BERD) measured in percentage of gross domestic product (GDP) 2020 and labour productivity 2021 (based on Eurostat). Graph on the right: Economic Resilience Index 2023[4] and EU Innovation scoreboard[5].

A greater focus on innovation is particularly vital in today's geopolitical and economic landscape, which is increasingly defined by trade frictions, tariff escalations, and strategic decoupling among major economies.[6] In such a setting, price-based advantages are easily eroded by sudden tariff shocks or retaliatory measures, and access to foreign markets can no longer be taken for granted.[7] This elevates the strategic value of non-price competitiveness, particularly that one rooted in frontier innovations coupled with consequent widespread and effective diffusions.

Indeed, as international trade relations become increasingly adversarial, countries with strong innovation ecosystems are better positioned to shape global standards, attract investment, and sustain market relevance despite new barriers—often even influencing global demand itself. In this sense, innovation not only enables firms to move up global value chains but also builds economic resilience and reinforces competitiveness, empowering nations to exercise greater bargaining power in geopolitical negotiations. In a world where trade rules are increasingly driven by strategic and power dynamics, long-term, innovation-driven competitiveness emerges as both an economic asset and a geopolitical lever.[8]

These issues become even more critical in the case of General Purpose Technologies (GPTs) - innovations capable of generating broad-based productivity gains and sustained economic growth across virtually all sectors. GPTs share three defining features: (i) they are pervasive in their application, (ii) capable of improvement over time, and (iii) able to catalyse complementary innovations that extend their transformative reach.[9] Classic examples include electricity and computers, followed by the internet and advanced connectivity. Today, the most transformative GPT is artificial intelligence (AI), which sits at the centre of this analysis as a key driver of Europe's future competitiveness.

Innovation-driven competitiveness can be achieved primarily through three key drivers: (i) pushing the boundaries of frontier innovation; (ii) commercialising research into scalable, market-ready products; and (iii) fostering widespread technology adoption to embed digital tools and advanced

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[4] Zoe Institute for Future-fit Economies (2024) The Economic Resilience Index: Assessing the ability of EU economies to thrive in times of change. This composite index comprises 27 indicators grouped into six resilience dimensions: Economic Independence, Education & Skills, Financial Resilience, Governance, Production Capacity, and Social Progress & Cohesion. These dimensions are derived from 96 resilience characteristics mapped across four provisioning actors (households, businesses, state, and communities) and three resilience capacities (absorption, recovery, and adaptation).

[5] EU Commission (2024) European Innovation Scoreboard 2023. The European Innovation Scoreboard (EIS) 2025 provides a comparative assessment of research and innovation performance across 39 European countries using a measurement framework organised around four main pillars—Framework conditions, Investments, Innovation activities, and Impacts—comprising 32 indicators distributed across 12 innovation dimensions.

[6] Baba C., Lan T., Mineshima A., Misch F., Pinat M., Shahmoradi A., Yao J., van Elkan, R. (2023) Geoeconomic Fragmentation: What's at Stake for the EU, IMF Working Paper No. 2023/245.

[7] As exemplified by the import tariff policy adopted by the United States under the Trump administration — a policy that was, in fact, preceded and later accompanied by a broader global resurgence of protectionist measures since 2020, perhaps less visible but not necessarily less intense.

[8] Conversely, while raising trade barriers may yield short-term gains in price competitiveness, such protectionist measures tend to generate negative, self-reinforcing spillovers over the longer term — including reduced innovation, slower productivity growth, and heightened risks of global retaliation.

[9] Bresnahan T., Trajtenberg M. (1995), General Purpose Technologies: 'Engines of Growth'?, Journal of Econometrics 65, 83-108.

digital services across economic sectors and society.[10] These innovation drivers are interdependent and mutually reinforcing - for instance, European firms that invest in the adoption of advanced digital technologies consistently exhibit a higher propensity to engage in innovation and R&D.[11] This shows that digitalisation is not merely a support function, but a catalyst for firms to innovate more rapidly, integrate into global value chains, and sustain competitiveness in increasingly knowledge-intensive markets.

This interdependence strongly echoes Enrico Letta's 2024 report "Much More Than a Market", which strongly reaffirms the critical importance of a fully functioning Single Market for Europe.[12] At the same time, it calls for a transformative conceptualisation by placing the free movement of research, knowledge, and innovation at the heart of the European project. Building on the existing four freedoms, this proposed "fifth freedom" is not simply a valuable addition but a transformative force - crucial to enhancing the effectiveness of the others in an increasingly knowledge-based global economy.

Indeed, Europe's "competitiveness crisis" is fundamentally rooted in insufficient innovation capacity and lagging productivity growth. The European Commission itself has recently articulated this diagnosis, stating that "*Europe has not kept pace with other major economies, due to a persistent gap in productivity growth. … The root cause is a lack of innovation. Europe is failing to translate its ideas into new, marketable technologies, and failing to integrate those technologies into its industrial base*."[13]

The European Union's efforts to enhance competitiveness and drive productivity through digital transformation are currently embodied in two comprehensive policy frameworks: the EU Competitiveness Compass and the Digital Decade Policy Programme 2030.[14]

The Digital Decade Policy Programme (DDPP)[15] sets out concrete targets to enhance the EU's digital performance across four key dimensions: (i) a digitally skilled population and workforce; (ii) secure and sustainable digital infrastructures; (iii) the digital transformation of businesses; and (iv) the digitalisation of public services. To translate these priorities into measurable commitments, the European Commission has established quantified benchmarks aligned with the Digital Economy and Society Index (DESI).[16]

Complementing this framework, the EU Competitiveness Compass (CC)[17] identifies three strategic pillars, of which the first—closing the innovation gap—and the third—reducing strategic

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[10] Mazzucato M., Perez, C. (2023) Redirecting growth: inclusive, sustainable and innovation-led. In A Modern Guide to Uneven Economic Development.

[11] European Investment Bank (2022) Investment Report 2021/2022. Recovery as a springboard for change.

[12] Letta's vision fundamentally emphasises the completion and deepening of the Single Market as an indispensable precondition for innovation-driven competitiveness. Indeed, 60% of exporting from European firms – and 74% from firms with cutting-edge innovation – signal clearly that the intra-EU market fragmentation (due to different national consumer protection standards, value-added tax, labelling, and licensing requirements) is still a big obstacle to business opportunities.

[13] European Commission (2025) A Competitiveness Compass for the EU - COM (2025) 30 finals.

[14] A detailed description of Digital Decade Policy Programme 2030 and 2025 Competitive Compass can be found in the **Annex**.

[15] Decision (EU) 2022/2481 establishing the Digital Decade Policy Programme 2030.

[16] The DESI (Digital Economy and Society Index) is the set of indicators through which the European Commission has monitored the "digital performance" of EU companies and Member States since 2015. It was updated in 2021 to align with the Digital Decade Compass.

[17] European Commission (2025) A Competitiveness Compass for the EU, cit.

dependencies—are closely linked to the deployment of ICT and the development of robust digital ecosystems. Moreover, the Compass integrates several flagship initiatives designed to advance the objectives of the Digital Decade, including the forthcoming Digital Networks Act (proposal expected in Q4 2025) and the Cloud and AI Development Act (proposal expected in Q1 2026).

This report examines Europe’s approach to digital transformation, with particular attention to the mutually reinforcing roles of innovation and productivity in sustaining long-term competitiveness. It evaluates how current EU policy frameworks contribute to these objectives, assessing whether ongoing initiatives are delivering results or require strategic recalibration.

Section 2 analyses the EU’s performance across the core drivers of innovation-led competitiveness, benchmarking outcomes against those of the United States. Section 3 delves more deeply into the adoption and diffusion of ICT across Member States, focusing on three foundational pillars of digitalisation: advanced connectivity, cloud infrastructures, and artificial intelligence. Section 4 concludes by synthesising the main findings and presenting policy recommendations to enhance the effectiveness of Europe’s innovation and digital transformation agendas.

As complements to the report’s main sections, three thematic appendices are included: A) The Mid-Tech Trap and Access to Finance, B) Strategic Autonomy and the Cloud and AI Development Act, and C) Digital and ICT Ecosystems Orchestration. These appendices offer deeper analyses of key cross-cutting issues and are structured as appendices to facilitate readability and coherence. They are, however, consistently referenced throughout the report, forming an integral part of its overall analytical narrative and argumentation.

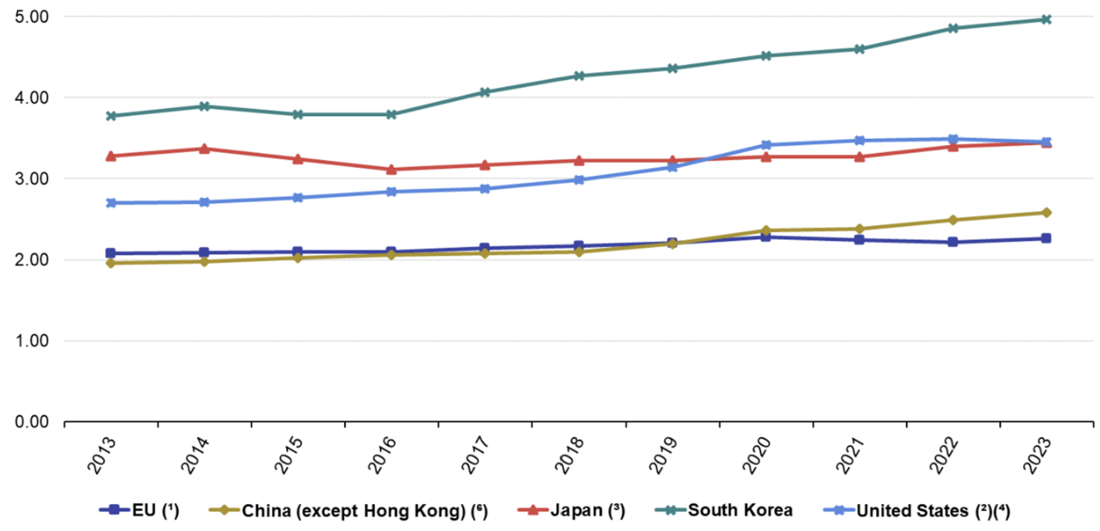
2. Competitiveness Drivers in EU and US

2.1 R&D, Sector Specialisation and Productivity

It is widely recognised that the European Union faces persistent gaps compared with other major economies in both research and development (R&D) and productivity performance.

The EU R&D expenditure (GERD), as a percentage of GDP, remains stagnant and significantly lower than that of the United States and other major economies - a pattern that has persisted for a considerable period (**Figure 2**). In 2023, the EU devoted 2.26% of its GDP to R&D, well below the figure recorded in the United States (3.45%), Japan (3.44%), and the global frontrunner South Korea (4.96%). China reached 2.58%, continuing to increase its spending and further widening its positive divergence from the EU.

Figure 2 – Gross domestic expenditure on R&D (GERD) as % of GDP, 2013-2023



Source: Eurostat and OECD database

It is important to underline that this EU-US gap in R&D is not due to differences in public investment, but rather to starkly different levels of private sector involvement (Business Expenditure on Research and Development, BERD). In fact, public R&D percentage of GDP was relatively similar in both regions - approximately 0.7% in 2023. However, it is also crucial to note that public R&D funding in the EU is often fragmented across national programmes and lacks the strategic coordination characteristic of federal R&D in the US. As a result, the effectiveness and impact of public R&D investment may differ significantly between the two economies. [18]

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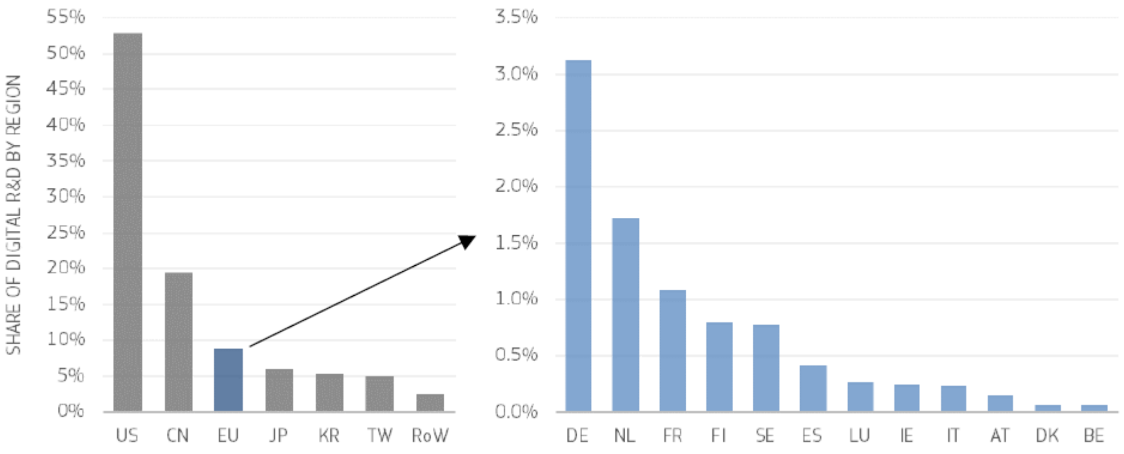
[18] In the United States, almost all public R&D spending is financed directly from the federal budget. In the European Union, by contrast, around 95% in 2021 comes from the budgets of the 27 Member States, with only a small share provided at EU level. Crucially, these national public R&D investments are not systematically coordinated to align with EU-wide strategic priorities, resulting in fragmentation and missed opportunities for scale. In 2023 more than half of the EU member states public R&D budget - 52.47% - is allocated through "undirected funding" aimed at the general advancement of scientific knowledge, enabling researchers to pursue innovative ideas, that may not necessarily align with immediate policy goals or EU-wide

When examining the world's leading private R&D investors, US-based companies dominate the rankings: six of the top-ten and twelve of the top-twenty firms are headquartered in the United States. In contrast, the European Union counts only one company among the top ten and two among the top twenty. As a result, the aggregate share of global Business Expenditure on R&D (BERD) attributable to US firms is more than twice that of the EU: 42.3% versus 18.7%.

One key factor underlying this phenomenon is the structure of corporate financing in Europe, which is predominantly based on debt financing. This model is poorly suited to support both (i) R&D and innovation-enhancing activities, and (ii) other intangible investment, which are critical to the productivity return of ICT investments. By contrast, firms in the United States benefit from substantially greater access to equity financing and venture capital[19], which are more appropriate for funding high-risk, intangible-intensive innovation: indeed, being able to raise equity finance makes firms 13 percentage points more likely to innovate.[20] (see **Appendix A**)

This gap becomes even more striking when focusing the R&D-intensive digital sectors - specifically ICT hardware and software. In terms of private sector investment, US companies account for 53% of total global digital R&D, while the combined contribution of EU-based digital firms amounts to only 8.9% (**Figure 3**). China has markedly strengthened its position, increasing its share of global digital R&D from 7.1% in 2014 to 19.4% in 2023. During the same period, the EU's share declined from 13.7% to 8.9%, highlighting a persistent and widening digital innovation gap. [21]

Figure 3 – R&D investment shares by global region and EU countries in digital sectors, 2023



Source: The 2024 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I

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priorities. Thus, funding directed towards specific, predefined socio-economic objectives within EU governments accounts for 47.53%. In contrast, the US allocates a staggering 92.15% to such predefined mission-oriented objectives, while China, Japan and South Korea allocate 69.46%, 68.98% and 79.51% respectively. See, Benoit F., Karvounaraki A., Stevenson A., Ravet J. (2025) EU R&D Investments explained – EU commission – R&I paper series.

[19] The average market capitalisation of US companies has historically been much higher than that of European companies, with the gap having widened significantly since 2010. In 2022, US companies achieved, on average, a market capitalisation that was 3.3 times higher than that of EU companies. See Gati Z., Lambert C., Ranucci D., et al, (2024), Examining the causes and consequences of the recent listing gap between the United States and Europe, European Central Bank, available at: https://www.ecb.europa.eu/press/fie/box/html/ecb.fiebox202406_07.en.html.

[20] European Investment Bank (2025) Investment Report 2024/2025: Innovation, integration and simplification in Europe

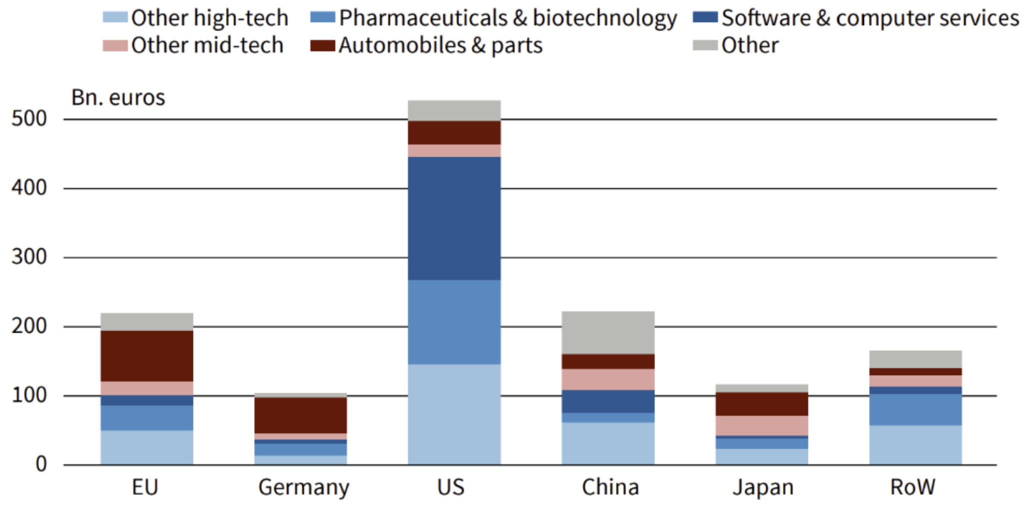
[21] See, Nindl E., Napolitano L., Confraria H., Rentocchini F., Fako P., Gavinan J. and Tuebke, A. (2024) The 2024 EU Industrial R&D Investment Scoreboard, EU Joint Research Centre.

World's top four R&D investors are US-based digital companies - Alphabet, Meta, Apple, and Microsoft - whereas the only two EU companies among the top 20 are in the automotive sector (Volkswagen and Mercedes-Benz).[22] Among the top 50 digital companies, only three are headquartered in the EU: SAP, Siemens, and Ericsson, with Nokia and ASML closely following.

This pattern reflects, firstly, the significantly larger size of US (tech) firms; however, it also points to a broader structural difference in the propensity to invest in R&D across economic sectors. Indeed, the fundamental distinction between Business Expenditure on R&D (BERD) in the two regions is not only quantitative but also sectoral. The United States tends to concentrate its investments in "high-tech" sectors, notably software, computing, and biotechnology, whereas European firms invest more heavily in "medium-tech" industries such as automotive, chemicals, and transportation. [23]

This imbalance may itself represent a challenge, as it suggests that Europe could be facing a so-called "mid-tech trap" — discussed in greater detail in **Appendix A**. This condition describes economies and firms that remain concentrated in mature industries with limited potential for high-growth innovation[24] (**Figure 4**).

Figure 4 - BERD by technology level, top 2500 companies



Source: Dietrich et al (2024) based on data from Industrial R&D Investment Scoreboard (2023)

Due to the mid-tech trap, the relatively lower aggregate business R&D expenditure in Europe can be explained, in the first instance, by a "structural composition effect". This effect arises because R&D-intensity (R&D expenditure as a percentage of revenues) is much higher in those high-tech sectors that are under-represented in the European economy compared to the United States. [25]

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[22] In 2023, the automotive sector accounts for 34.2% of total EU business R&D expenditure, representing approximately €73 billion annually, which makes Europe the world's largest investor in automotive, surpassing Japan (€33.6 billion), the US (€33.6 billion), and China (€22.2 billion).

[23] Meyers Z. (2025) A framework for understanding EU competitiveness – CERRE Report.

[24] Fuest, C., Gros, D., Mengel, P., Presidente, G. and Tirole, J. (2024) How to Escape the Middle Technology Trap - A Report by the European Policy Analysis Group.

[25] For example, in 2023, private-sector R&D intensity stood at 4.8% in the automotive industry, 8.2% in ICT hardware, and 10.9% in ICT software. See WIPO (2024), Global Innovation Index 2025: Innovation at a Crossroads; and Nindl E., Napolitano L., et al. (2024) cit. A more granular analysis reveals that Cellular and IoT technologies display particularly high R&D intensity

However, beyond this structural explanation, there is also evidence of an “intrinsic effect”[26]: EU firms within each industry are characterised by a lower R&D intensity in comparison with their US counterparts.[27] A rational and empirically robust explanation for this is that the R&D stock has a positive impact on productivity that differs markedly between the EU and the US across all macro sectors, as European firms that do invest in R&D tend to face greater difficulty in converting those investments into productivity gains.[28]

As a result, US firms not only benefit from a greater concentration in high-tech industries, which supports the structural effect, but also demonstrate superior efficiency in leveraging R&D investments - not only in high-tech sectors but across the board, even though in the high-tech this gap is much more pronounced.[29]

Thus, the EU faces two intertwined challenges: (i) a lower overall level of business expenditure in R&D, and (ii) weaker productivity returns from R&D spending, regardless of industry. While much of the policy debate has so far concentrated on increasing R&D[30], it must be considered that lower R&D investment may just be a rational response by firms to a lower expected return due to a limited ability to convert R&D into productivity gains. So, merely pushing for more R&D investment by the private (or public) sector - even if probably necessary - may be insufficient.

Importantly, the relatively lower R&D stock among EU firms may be even more significant at the firm level than at the aggregate level. If R&D effectiveness is subject to a “threshold effect”, only large-scale investments are likely to yield substantial productivity gains.[31] This consideration also underscores structural constraints within the EU, such as the smaller average scale of firms and the fragmented nature of both public and private R&D funding and industrial policies.[32]

2.2 R&D, Patents and the Innovation Chain

The concentration of EU R&D investment in the automotive and other medium-technology industries, combined with the relatively lower effectiveness of this spending, has a compounding negative effect

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- approximately 19.8% - second only to biotechnology. This is highly relevant from an innovation and competitiveness perspective, given Europe’s strong position in Cellular and IoT technologies, where firms such as Ericsson and Nokia rank among the leading global vendors.

[26] The basic difference is that structural effects relate to the relative size of industries within the economy, while intrinsic effects focus on how much companies in those industries invest in R&D in each economy.

[27] Ortega-Argilés R., Brandsma A. (2010) EU-US differences in the size of R&D intensive firms: do they explain the overall R&D intensity gap?, Science and Public Policy, Volume 37, Issue 6, Pages 429–441; Moncada-Paternò-Castello P., Grassano N. (2022), The EU vs US corporate R&D intensity gap: investigating key sectors and firms, in Industrial and Corporate Change, Volume 31, Issue 1, 19–38; Adilbish O-E, Cerdeiro D., et al. (2025) Europe’s productivity weakness: Firm-level roots and remedies – CEPR VOXEU Colums , available at: https://cepr.org/voxeu/columns/europes-productivity-weakness-firm-level-roots-and-remedies

[28] Ortega-Argilés R., Piva M., Vivarelli M. (2014) The transatlantic productivity gap: is R&D the main culprit? Can. J. Econ. 47, 1342–1371.; Nindl E., Napolitano L., Confraria H., Rentocchini F., Fako P., Gavinan J. and Tuebke, A. (2024), cit.

[29] See, Castellani D., Piva M., Schubert T., Vivarelli M. (2019) R&D and productivity in the US and the EU: Sectoral specificities and differences in the crisis, Technological Forecasting and Social Change, Volume 138, 2019, Pages 279-291.

[30] Also, the Draghi report emphasises that "*failure to meet the 3% target for R&D expenditure set by EU leaders over two decades ago is a fundamental reason why the EU lags behind the US and China*".

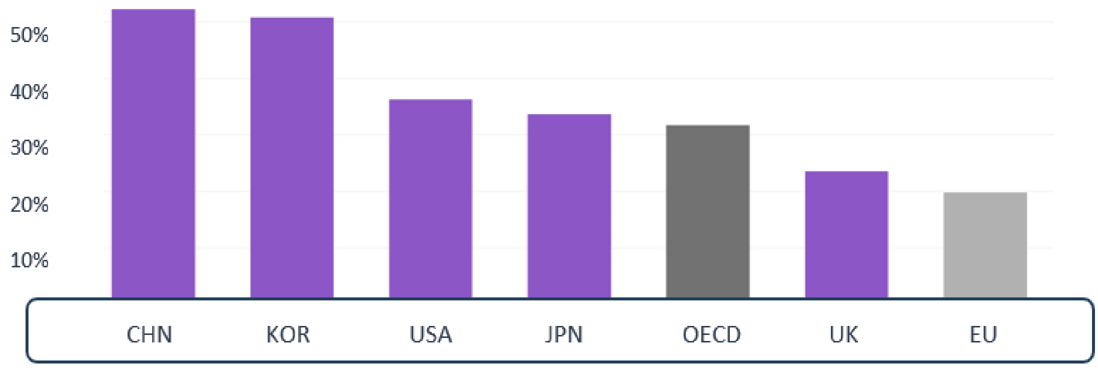
[31] See, Castellani D., Piva M., Schubert T., Vivarelli M. (2019), cit.

[32] See, Bianchini N., Ancona, L. (2023) Artificial intelligence: Europe needs to start dreaming again. Schuman Papers n°728.

on innovation performance and widens the technological gap in productivity-enhancing technologies, particularly in digital domains.[33]

Beyond its impact on productivity, the contribution of R&D to innovation-based competitiveness is typically assessed by examining how efficiently private and public organisations transform R&D investments into viable "new ideas," notably patents.[34] Looking specifically at the percentage of ICT-related patents[35] (**Figure 5**), it is evident that the EU, with 19.7% of its total IP5 patent families,[36] lags significantly behind other major economies, as well as the OECD average.

Figure 5 – ICT patents as a share of total IP5 patent families – 2020 data



Source: elaboration on OECD STI Micro-data Lab

The EU's weaker performance in ICT patenting, consistent with the "mid-tech trap" narrative, may point to a broader and persistent weakness in innovation-driven competitiveness. As previously noted, since ICT and digital technologies serve as multi-layered general-purpose technology (GPT), the EU's underperformance in ICT-related patenting is likely to have wider repercussions, affecting its position in advanced technologies and deep-tech domains.

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[33] European Commission (2024) Science, Research and Innovation Performance of the EU 2024. A competitive Europe for a sustainable future

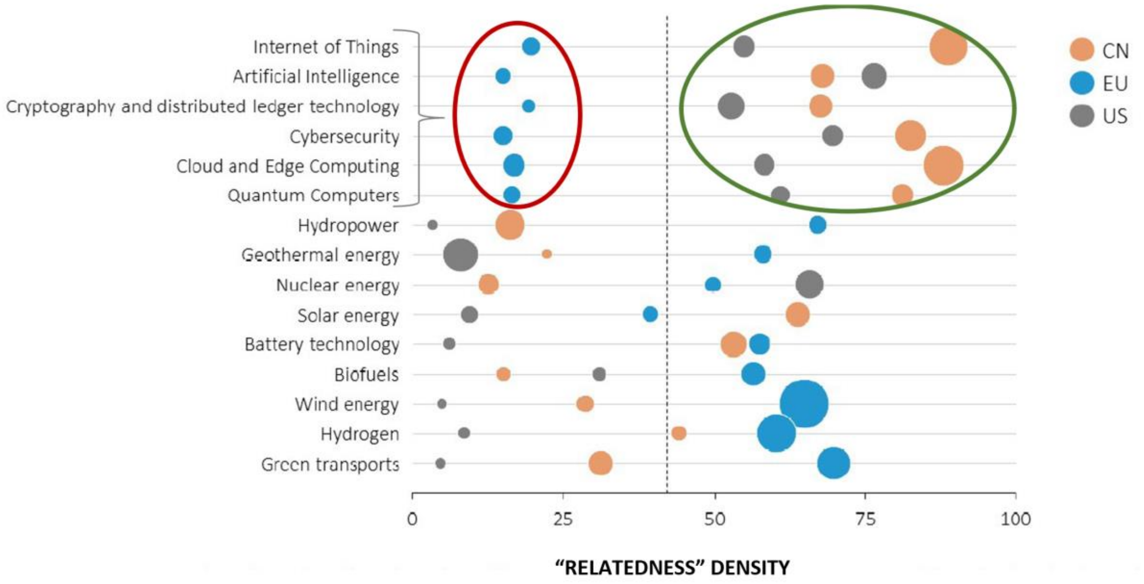
[34] See, Nindl E., Napolitano L., Confraria H., Rentocchini F., Fako P., Gavinan J. and Tuebke, A. (2024), cit. Although patents, as well as labour productivity assessed in the previous section, is imperfect output indicators of R&D effectiveness (since not all ideas and inventions are patented) they serve as useful proxies for the expected results of R&D investment. More broadly, patents are constantly used as one of the main indicators for "innovation intensity" both in academic research and policy reports. As mere examples: OECD (2009) Patent Statistics Manual; Griliches, Z. (1990) Patent Statistics as Economic Indicators: A Survey, in Journal of Economic Literature, 28, 1661-1707; Acemoglu D., Akcigit U., Kerr W. (2016) Innovation Networks, NBER Working Paper 22783; Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P. (2005) Competition and Innovation: An Inverted-U Relationship, in Quarterly Journal of Economics, 120(2), 701-728;

[35] ICT patents are identified using International Patent Classification (IPC) codes that encompass thirteen areas: (i) high-speed networks, (ii) mobile communication, (iii) security (e.g. encryption), (iv) sensors, (v) high speed computing, (vi) high capacity data storage, (vii) large capacity information analysis (e.g. big data analytics), (viii) Cognitive computing, (ix) Human interface technologies, (x) Imaging and sound technology, (xi) Information and communication processing technology, (xii) Electronic measuring (e.g. radio navigation), and (xiii) Others (e.g. hybrid computers).

[36] A patent family is a group of patent applications filed in multiple jurisdictions for the same invention, usually based on the priority date of the first filing. An IP5 patent family means the invention has been protected in all five major jurisdictions (EPO – European Patent Office; USPTO – United States Patent and Trademark Office; JPO – Japan Patent Office; KIPO – Korean Intellectual Property Office; CNIPA – China National Intellectual Property Administration). Filing in all IP5 offices is expensive and usually indicates high strategic and commercial value and thus reserved for technologies with large potential markets and long-term strategic importance.

This dynamic is at the basis of the meaningful illustration of the competitive positioning of different economies across technological domains, based on patents data (**Figure 6**). In addition to capturing the degree of existing specialisation in patenting for each technology (depicted by bubble size), the analysis gives primary emphasis to the ease with which a country can develop comparative advantage, measured by a "relatedness density" index: the extent to which a technology is related to others in which the country is already competitive. The visualisation clearly shows that, while the European Union maintains strong leadership in clean energy technologies, it exhibits notable weakness in digital and ICT innovation - a gap further amplified by low "relatedness" density. As a result, the EU significantly lags behind the United States and China in these strategic domains.

Figure 6 – EU position in complex technologies and "relatedness density" – 2019/2022



Source: Industrial R&D Investment Scoreboard (2023)

Indeed, also when examining artificial intelligence (AI), data on patent applications in AI-related technologies[37] reveal a pronounced geographical concentration of innovation, with the United States and China accounting for the overwhelming majority of filings. By contrast, both Japan and the European Union lag considerably behind[38] (**Figure 7**). Between 2020 and 2023, inventors from China and the United States accounted for almost 60% of all AI patents. China's share has risen sharply since the early 2010s, making it the global leader with 30.6% of total AI patents. By contrast, the United States had a small decline from 33% in 2010–13 to 27% in 2020–23. Japan's contribution fell

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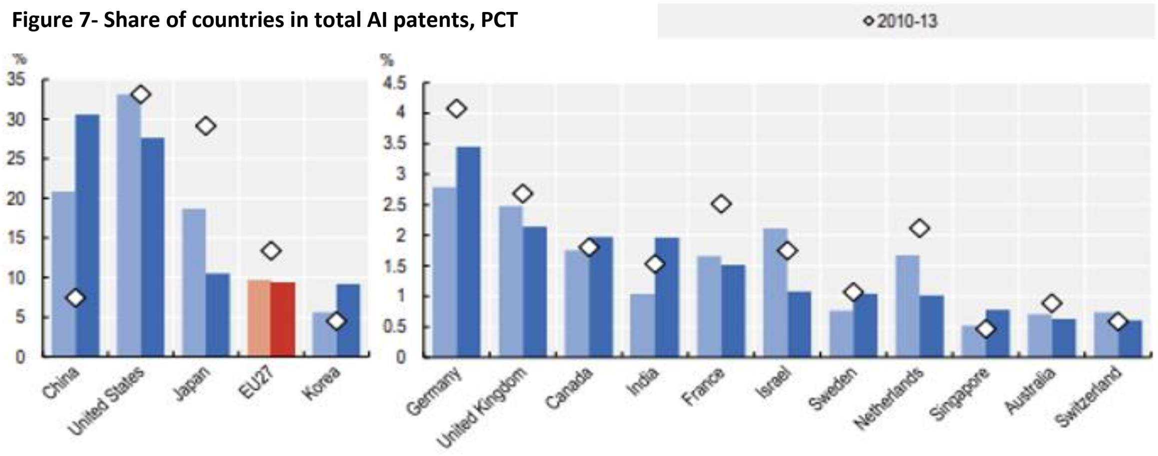
[37] Only filling under the Patent Cooperation Treaty (PCT) are considered, in order to eliminate jurisdictional misalignments. The Patent Cooperation Treaty (PCT), administered by the World Intellectual Property Organisation (WIPO), is an international treaty that streamlines the process of seeking patent protection in multiple countries. Rather than filing separate national or regional patent applications, inventors and applicants can submit a single "international" application under the PCT, which is legally recognised by over 150 contracting states. This simplifies the initial procedural and administrative requirements for protecting an invention globally.

[38] OECD (2025) Identifying emerging AI technologies using patent data: a semi-automated approach – Technical Paper - September 2025; Filippucci F, Gal F, Jona-Lasinio C, Leandro A, Nicoletti G (2024) The impact of Artificial Intelligence on productivity, distribution and growth: Key mechanisms, initial evidence and policy challenges - OECD Artificial Intelligence Papers n 15.

significantly, from 29% in the early 2010s to 10.5% in the most recent period. The EU27 experienced a decline of about four percentage points compared with 2010–13.

Figure 7- Share of countries in total AI patents, PCT



Source: elaboration on OECD, STI Micro-data Lab

This pattern highlights an expanding technological divide in AI innovation further reinforcing the impression that sustained ICT R&D investment is associated with a stronger ability to generate new frontier patents.

The results of this international benchmark on AI patents contrast sharply with another typical indicator of innovation - namely, the number of scientific publications related to AI. In this respect, the European Union demonstrates a strong research base, ranking second worldwide in AI-related scientific output, between China (leading) and the United States (third).[39]

This asymmetry indicates, as widely recognised, that the innovation pipeline in the EU's digital and ICT sectors weakens in subsequent stages of development, since much of the knowledge generated by European researchers fails to translate into patents and/or remains commercially underexploited.[40] This is consistent with the EU relatively low 'R&D-to-patent' elasticity, indicating a weaker conversion of R&D investment into patentable inventions compared to firms in other global regions.[41]

A key factor behind this dynamic is that high-tech R&D in Europe tends, on average, to be less integrated into "innovation clusters" able to enhance capacity to transform research first into patents and then into marketable outcomes as it happens in the US. Such clusters typically include large tech firms, networks of smaller innovators and start-ups, as well as universities and venture capital actors, which play a pivotal role in supporting commercialisation and scaling.[42] Moreover, as described in the following section, US tech firms tend to have much larger in scale and to be vertically integrated, facilitating both an easier transition of innovation to market and its widespread diffusion.

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[39] European Commission (2024) Science, Research and Innovation Performance of the EU 2024. A competitive Europe for a sustainable future.

[40] Draghi (2024); Letta (2024).

[41] See, Nindl E., Napolitano L., Confraria H., Rentocchini F., Fako P., Gavinan J. and Tuebke, A. (2024), cit.

[42] Draghi (2024); Letta (2024).

In partial contrast to this general trend, between 2000 and 2023, the EU ranked second worldwide in quantum patenting with around 16% of the total, behind the US (32%) but ahead of Japan (13%) and China (10%). This strong performance likely reflected the prioritisation and coordination at EU level of investments in quantum technologies - €7 billion of public money allocated so far, second only to China's public funding. However, private investment remains a critical weakness. In sharp contrast to the US and China, where corporate funding drives much of the momentum, none of the world's top ten technology companies by quantum investment are based in the EU: five are American and four are Chinese.

Another innovative yet consolidated industrial segment, where Europe has been traditionally leading, is advance connectivity, cellular and IoT technology. As stressed by both Draghi and Letta, this industrial segment is crucial for the EU due to a few reasons. Firstly, advanced connectivity is a foundational GPT and thus is one of the core drivers and multipliers for innovation and economic growth. Moreover, leadership in connectivity technologies and equipment matters not only in economic terms, but also under public interest and geopolitical viewpoints, as it is key for cyber-resilience and protection of citizens' data as well as strategic to Europe's collective security. Finally, EU-based technology firms, such as Nokia and Ericsson, are very well positioned in the innovation development and global supply of telecom equipment. They devote a very high share of their revenue to R&D – around 19-21% R&D intensity, highlighting that cellular and IoT technology is one of the few high-tech sectors where Europe has maintained a global competitive positioning. Each of these is crucial for innovation-based competitiveness as well as fundamental for securing Europe's competitive edge in such a crucial standard-based industry.[43]

This overall context underscores the need to maintain an intellectual property rights (IPR) framework that enables firms to invest in research and development and foster innovation in such a crucial sector. This is even more critical in the EU, because, as noted above, European innovators have lower expected returns on R&D investments compared to US; and the EU financial system does not adequately support high-risk, long-term innovation projects.

Moreover, main EU technology innovators are not vertically integrated, implying that they cannot directly deploy and commercialise their innovations downstream, free or at low cost, like non-EU large, vertically integrated conglomerates, which can remunerate their investments through sales of products and services to end-user markets.

In such a setting, trade-offs between the upstream and downstream layers of the innovation pipeline may emerge[44]: in order to be more competitive for widespread commercial diffusion and for incremental product innovation, downstream deployers - in the EU, particularly automotive and mid-

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[43] "*Europe's competitiveness, technological sovereignty, ability to reduce dependencies and protection of EU values … will also depend on how successful European actors are in standardisation at the international level.*" See European Commission (2022) An EU Strategy on Standardisation – COM (2022) 31 final. Standards definition in the ICT sector is necessary to develop and take advantage of strong economies of scale and network effects. Nevertheless, ICT standardisation has become a core geopolitical lever and European leadership in global standard-setting has been one of the continent's few enduring advantages in digital technologies, particularly in mobile communications, although China has embraced a strategic state-led approach to broaden its influence. See, Mi-jin Kim, Doyoung Eom, and Heejin Lee (2023) The geopolitics of next generation mobile communication standardisation: The case of open RAN, 47 Telecommunications Policy 102625; Faaborg-Andersen S., Lindsay Temes L. (2022) The Geopolitics of Digital Standards.

[44] For a general reference to innovation dynamics in a vertically integrated setting, see Liu X (2016), Vertical integration and innovation, in International Journal of Industrial Organisation, Volume 47, 88-120.

tech sectors players - may seek short-term cost reductions, while upstream technology developers need to rely on stable licensing revenues to recoup R&D investments and sustain future innovation. [45]

Depending on the specific industrial segment, downstream deployers and product innovators are highly diversified. In the case of smartphones, they are almost exclusively large technology companies based in the United States or China which, as noted in the previous section, invest heavily in R&D.[46] However, such investments do not *per se* contribute to increasing EU R&D intensity or to developing EU-specific comparative advantages in competitiveness.[47]

Differently, the R&D downstream investments by EU large deployers in the automotive sector and other mid-tech industries has a twofold effect: on one side, increase the overall EU R&D intensity, but, on the other side, nurture the mid-tech trap. (see **Appendix A**, with regards also of the VC percentage by EU-based companies that is directed to US-based startups). Consequently, maintaining effective incentives for upstream innovation in those high-tech sectors where EU is well-positioned may provide with one element for counteracting its mid-tech path dependency.[48]

In contrast, the downstream R&D investments made by major EU players in the automotive sector and other mid-tech industries have a dual effect: on one hand, they do contribute to raising the overall R&D intensity within the EU; on the other, however, they reinforce the “mid-tech trap.” (See **Appendix A**, including data on the proportion of venture capital from EU-based firms directed toward US-based startups.) As a result, sustaining effective incentives for upstream innovation - particularly in high-tech sectors where the EU holds competitive advantages - may offer a crucial means of counteracting this path dependency toward mid-tech specialisation.

That said, given the high number of SMEs in Europe - particularly within the Internet of Things (IoT) sector - fostering their active engagement and participation as EU-based implementers, and potentially as upstream innovators, would significantly strengthen Europe’s innovation-driven competitiveness. Such efforts could also help counter the current trend of EU start-ups and scale-ups expanding into the US market (see **Appendix A**), while at the same time promoting incremental

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[45] A description and assessment of this composite balance (that in standard-based industry revolves around the FRAND – fair, reasonable and non-discriminatory - concept) falls outside the scope of this report. In very general economic terms, it depends on quite a few factors, at the different levels of innovation chain, e.g., the magnitude and variety of positive spillover into the economy; the different risk and time-horizon of investments; the intensity of R&D (percentage of revenues); the differentiation of revenues, i.e., possibility of remunerating R&D with downstream sales. Overall, all these contribute to determine the different elasticity of the “invention supply” - Shapiro C. (2007) Patent Reform: Aligning Reward and Contribution, in Innovation Policy and the Economy Volume 8, yet in light of the different type of complementarities among innovations and substitutabilities between different complementors - Teece D.J. (2018) Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world, in Research Policy 47.

[46] See De Coninck R., von Muellern C., Zimmermann S., Mueller K. (2022) SEP Royalties, Investment Incentives and Total Welfare – CRA report for Fair Standards Alliance ASBL.

[47] These R&D investments are predominantly made outside Europe, with innovation diffusing downstream on a global scale. Analytically, it would be highly relevant - though empirically challenging - to isolate any share of this R&D spending that yields competitive advantages specifically for the EU. This would include R&D investments explicitly tailored to EU contexts or channelled through EU-based firms via targeted R&D programs. By contrast, infrastructure investments - discussed in more detail in the section below - allow for more straightforward attribution, as they are geographically anchored and more directly linked to downstream technological diffusion. Indeed, as elaborated in Sections 2.3 and 3, the dynamics shift considerably when examining downstream diffusion: once innovations are embedded in globally marketed products and services, the inability of EU firms to adopt or effectively utilise these technologies results in significant competitive disadvantages.

[48] Of course, this mechanism alone is insufficient to break path dependency without complementary policies addressing venture capital gaps, innovation governance, single market fragmentation, and direct support for breakthrough innovation in high-tech sectors. See Fuest, C., Gros, D., Mengel, P., Presidente, G. and Tirole, J. (2024), cit.

innovation and diversification. These dynamics are crucial if Europe is to effectively "capitalise on further waves of digital innovation." [49]

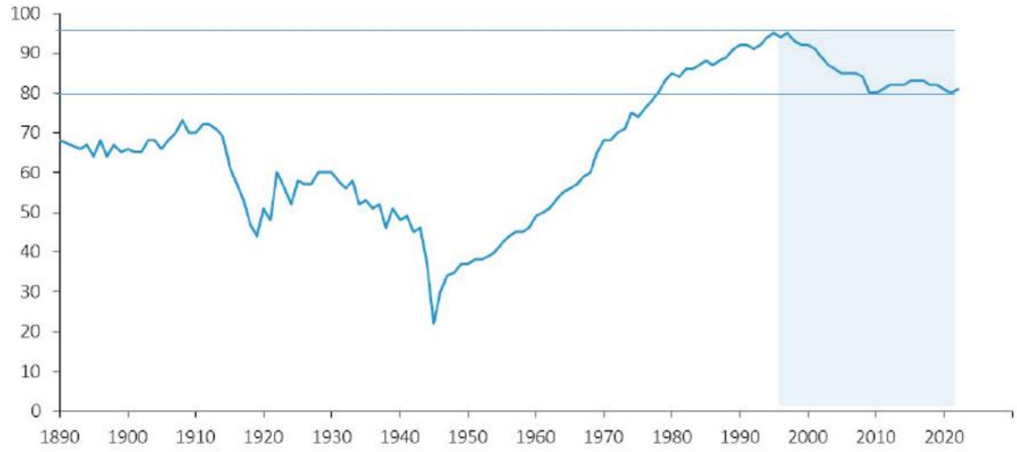
In this regard, the EU could consider promoting industry-led initiatives aimed at integrating innovative SMEs into ecosystems "orchestrated" by its largest technology companies. Such a composite coordination framework could combine: (i) innovation capacity-building, through mentorship, technical training, and intellectual property support; (ii) downstream R&D coordination, via pilot projects, co-innovation spaces, and structured commercialisation pathways; and (iii) network coordination and interoperation. This approach would help strengthen synergies between leading industry actors and SMEs, fostering a more cohesive and dynamic European innovation ecosystem. (see **Appendix C**)

In sum, maintaining an appropriate balance that effectively align incentives along the entire innovation pipeline is crucial for enhancing Europe's competitiveness. On one hand, as discussed in the following section, it is very important to ensure efficient and inclusive pathways from research to market—also by promoting downstream incremental innovation and diversification; on the other hand, it is crucial that this balance does not shift too far toward cost reduction — for instance through a weakening of patent protections, as such tilt would risk undermining the very innovation ecosystem and the innovation-based competitiveness that the EU seeks to reinforce.

2.3 Productivity, Scaling of Tech Companies and ICT Diffusion

In this innovation context, EU's labour productivity (LP) (as well as total factor productivity - TFP) is approximately 20% lower than that of the United States, reflecting a downward trend that began in the mid-90s.[50] (**Figure 8**)

Figure 8 – EU versus US labour productivity 1890 . 1995-2022 (US=100)



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[49] Draghi Report.

[50] Bergeaud A. (2024) The past, present and future of European productivity, in European Central Bank Forum report. Moreover, in 1990, the European Union (then comprising 12 member states) accounted for 26.5% of global GDP. Today, despite expanding to 27 member states, the EU's share has declined to 16.1%, while the United States has maintained a stable share of approximately 26%.

Source: Draghi Report (2024)

This productivity gap has been considered the long-tail of "*Europe's failure to capitalise on the first digital revolution led by the internet – both in terms of generating new tech companies and diffusing digital tech into the economy*".[51] As underscored in the Draghi Report, over the past two decades, when the ICT sector (i.e., the manufacturing of computers and electronics and information and communication activities) is excluded, labour productivity growth in the EU has largely mirrored that of the US.

The resulting EU-US productivity balance reflects, in part, the US stronger performance both in sectors where ICT is produced and in sectors that make intensive use of ICT, such as professional, administrative, and support services, as well as finance and insurance. In these industries, the U.S. benefited from an earlier, more widespread, and more effective adoption of ICT technologies, and thus benefits from higher productivity multipliers.[52] On the other hand, as detailed in **Appendix A**, the EU outperforms the US in terms of productivity within mid-tech sectors.

Altogether, this evidence suggests that the EU-US productivity gap is primarily concentrated in two closely related dimensions of the ICT sector: one within the ICT sector - representing the supply side of technologies and digital services - and another in the demand side. The former dimension relates to the creation and scaling of technology-driven firms, an area in which the EU has significantly lagged behind the US in producing globally dominant tech and digital companies (with the few upstream exceptions described in the previous section). The latter dimension, by contrast, is related with the diffusion and effective exploitation of digital technologies across the broader economy, where EU companies (particularly SMEs) have been less successful in translating digital adoption into labour productivity gains.[53]

Regarding the supply-side ICT dimension, the shortage of European digital and technology companies that successfully scale to a global level is a matter of concern for several reasons:

- Weaknesses in EU R&D capacity—both upstream and downstream, depending on the specific ICT segment—and in the commercialisation of key digital innovations, which are critical drivers of productivity. [54]
- Reduced generation of localised spillover effects, which limits the reinforcement of regional innovation clusters and technological hubs.[55]
- Fewer opportunities for the emergence of EU-based "orchestrators" capable of building and coordinating broad-based ecosystems that foster and accelerate technological advancement and diffusion (see **Appendix C**).[56]

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[51] Draghi Report.

[52] Indeed, in the OECD, an exogenous $10 billion increase in value added within high-tech sectors has been estimated to lead, over the subsequent three years, to an average productivity gain of 0.22%, compared with a modest 0.02% in low-tech sectors. See Cerra R., Crespi F. (2025) High Tech Economy, Annual Report – CED.

[53] Bergeaud A. (2025), cit.

[54] Marcus S., Rossi M.A. (2024), Strengthening EU digital competitiveness Stoking the engine – RSCAS paper.

[55] Matray A. (2021) The local innovation spillovers of listed firms, in Journal of Financial Economics 141.2 (2021): 395- 412. Financial economics literature shows that geography of firms that are focal for innovation matters: there is a Causal identification of a link between spatial concentration of innovative activities and increases in innovation. Activities of listed firms' research labs have a direct effect on innovation of local private firms.

[56] European Commission (2024) White Paper: How to master Europe's digital infrastructure needs? - COM (2024) 81 final.

- A lack of technological and digital leadership, which diminishes the EU's ability to shape the trajectory of technological and digital developments—and their applications—in ways that reflect European values and principles. This, in essence, strikes at the core of what is meant by "digital or technological sovereignty". [57]

In sum, although digital technologies and services are obviously globally accessible, where technology-driven firms are based and invest brings significant economic and geopolitical meaning - currently the EU depends on foreign countries for over 80% of its digital products, services and infrastructure.[58] In this regard, Draghi and, consequently, the Competitiveness Compass point at the need to reduce EU external dependencies which "could become vulnerabilities in a situation where trade fragments along geopolitical lines."[59]

This notion of "strategic autonomy" is examined in greater details in the **Appendix B**; however, it is important to highlight here some inherent and crucial trade-offs – points also emphasised by Draghi, who noted that any such policy should be:

- "*based on careful, case-by-case analysis*", targeting industry segments with genuine strategic value and security needs; and
- balanced, meaning that "*the EU must find a middle way between promoting its domestic [cloud] industry and ensuring access to the technologies it needs*".[60]

First, non-EU providers are not only selling digital services within the European market but are also actively building their own digital ecosystems, across multiple levels of the material–immaterial continuum.[61] This includes investments in tangible assets such as data centres, content delivery networks, research facilities, and workforce development. [62] In particular, investments in EU-localised digital infrastructures involve significant irreversible location-specific investments[63] - which are potentially stranded costs[64], creating exit barriers. In other words, the greater the investment, the stronger the interdependence between US tech and digital companies and the European digital economy, and, consequently, the lower the risk of "geopolitical weaponisation".

In this regard, according to BEREC, total global investment in internet infrastructure – comprising hosting, transport and delivery - by major user-facing US tech companies amounted around 751 billion euros over the period 2011–2021. This includes 75 billion euros in 2011-2013; 260 billion euros in

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[57] Indeed "sovereignty" is a political concept that finds its foundation into the factual capacity of making political visions and legal provisions effective. EU digital sovereignty thus refers to the political capacity to decide how the technology would impact on EU people and EU core values and principles, without being conditioned externally by being dependent technically and/or economically.

[58] European Commission (2024) Report on the state of the Digital Decade 2024.

[59] Draghi Report (2024).

[60] Ibidem.

[61] Manganelli A., Nicita A. (2022) Regulating digital markets. The Eu approach.

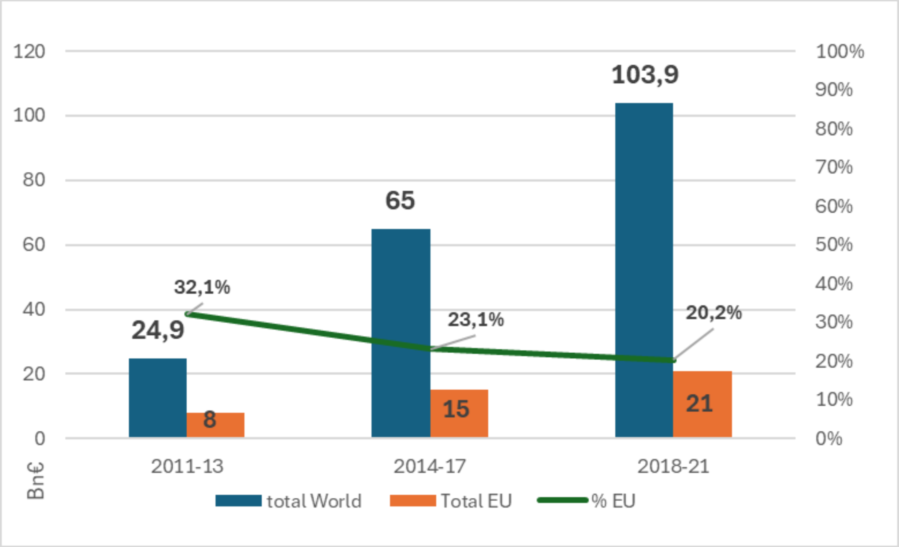
[62] Bauer M., Pandya D. (2024) ICT Beyond Borders: The Integral Role of US Tech in Europe's Digital Economy, ECIPE Policy Brief 06/2024; BEREC (2024) Report on the entry of large content and application providers into the markets for electronic communications networks and services – BoR (24) 139.

[63] Differently from classical hold-up theory, where the anticipation of opportunistic behaviour ex post discourages ex ante relationship-specific investments, which in most cases do not take place, in this context such investments have already occurred.

[64] Note that these stranded costs are "potential" not definitively stranded costs. This distinction is important since these costs become stranded only if geopolitical weaponisation occurs. Under normal market conditions, the company continues operating profitably. Thus, this is all about risk reduction through the creation of "interdependence" - the investments reduce the probability that either side would pursue weaponisation, because both sides would face significant costs from doing so.

2014-2017; and 416 billion euros in 2018-2021.[65] Specifically, within Europe, the average annual investment in internet infrastructure for these firms was around 170 billion euros over the same period 2011-2021, representing roughly 23% of their global spending (**Figure 9**).[66]

Figure 9 - Average annual expenditure by large global CAPs for internet infrastructures (hosting, delivery, transport)



Source: Elaboration on BEREC (2024) from Analysys Mason (2022) data

Second, any limitation on the supply of digital services from non-EU providers requires careful consideration, given their current pivotal role in Europe's digital transformation. Achieving greater independence too rapidly in the short term could entail significant risks—such as slower diffusion of digital technologies, lower service quality, and reduced consumer choice. This trade-off underscores the inherent complexity of the EU's industrial and digital policy landscape[67]: striking the right balance is therefore crucial to ensure that efforts to enhance strategic autonomy do not inadvertently undermine the very innovation cycle that the Competition Compass seeks to accelerate.

Regarding the demand-side, namely, the diffusion of ICT and digital services across the broader economy, the causal relationship between ICT investment and labour productivity gains is well established, yet it encompasses two interrelated key dimensions: (i) level of adoption and (ii) effectiveness of usage. Achieving productivity enhancement therefore depends on progress in both areas. Equally, for policymakers, it is essential to monitor not only the extent of ICT adoption but also how effectively these technologies are used to generate tangible economic outcomes.

This distinction is supported by econometric evidence showing that, even when European firms invested in ICT, the resulting productivity gains achieved were more modest than those recorded in the United States over the entire period 1995-2019.[68] Recent empirical analysis further reveal that

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[65] BEREC (2024), cit. - based on Analysys Mason (2022) The Impact of tech companies' network investment on the economics of broadband ISPs.

[66] The decreasing percentage, from 32.1% to 20.2%, does not seem to be indicating a gradual decoupling, yeti t seems the effect of increasing investment trends in other part of the world. However, it would be interesting to see updated data for the following period.

[67] Mayers Z. (2025), cit.

[68] Cette, G., Devillard, A., & Spiezia, V. (2022). Growth factors in developed countries: A 1960–2019 growth accounting decomposition. Comparative Economic.Studies, 1-27.

the marked transatlantic productivity divergence observed between 1995 and 2005 stems not only from differences in the volume of ICT investment, but more importantly from EU firms' limited ability to effectively exploit ICT infrastructure, and this inefficiency is estimated to account for approximately 80% of the observed productivity gap.[69]

Indeed, while digitalisation and the diffusion of GPTs offer substantial potential benefits to economy and society, these benefits are neither automatic nor immediate.

Realising productivity gains from ICT adoption requires strategic commitment of resources, and development of complementary skills and investments, both at the firm and workforce level, moreover organisational and sectoral restructuring around the new technological capabilities is often necessary. All these can be categorised as investments in non-R&D intangible assets (which are often partially measured in national accounts).

Therefore, ICT diffusion boosts productivity primarily among firms that also invest in complementary capabilities and intangible capital that enhance the effectiveness of ICT adoption - such as organisational expertise, human capital and training, software, brand equity, data assets. [70] Firms lacking such complementarities may fail to translate digital investments into productivity improvements. [71]

There is, again, a structural dimension related to firm size since the productivity gains from digitalisation vary significantly across companies of different scales. Larger firms are generally better positioned to realise productivity gains from digital technologies because they have more resources for complementary investments and can spread the fixed costs of digital adoption over a broader revenue base.[72] This dynamic helps to explain the greater difficulties faced by European firms in adopting digital technologies: SMEs constitute 99.8% of all EU businesses, with micro-enterprises (those with fewer than 10 employees) alone accounting for 93.3%. In contrast, only 0.2% of EU firms have more than 250 employees. [73]

In the context of the EU–US comparison, intangible assets represent approximately 20% of total assets in the EU, compared to 50% in the United States. When the asset boundary is extended to include intangible assets not captured in national accounts—primarily non-R&D-related intangibles—the share increases for both regions, yet a substantial gap remains - intangibles account for about 40% of total assets in the EU versus 60% in the US. This persistent disparity may represent an additional structural factor contributing to the long-standing transatlantic productivity gap.[74]

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[69] Gordon R.J., Sayed H. (2020) Transatlantic technologies: The role of ICT on the evolution of U.S. And European productivity growth, in International Productivity Monitor, 38 (2020), pp. 50-80; Bloom N., Sadun, R., Van Reenen J. (2012) Americans Do IT Better: US Multinationals and the Productivity Miracle, in American Economic Review 102, 167-201.

[70] Corrado C., Haskel J., Jona-Lasinio C., Iommi M. (2016) Intangible investment in the EU and US before and since the Great Recession and its contribution to productivity growth - EIB Working Papers 2016 / 08; Nikolov P., Simons W., Turrini A., Voigt P. (2024) Mid-Tech Europe? A Sectoral Account on Total Factor Productivity Growth from the Latest Vintage of the EU-KLEMs Database – EU commission Discussion Paper 208, July 2024.

[71] Nucci F., Puccioni C., Ricchi O. (2022) Digital Technologies and Productivity: a firm-level investigation for Italy, MEF WP N°3 - April 2022; Anghel B, Bunel S.et al. (2024) Digitalisation and Productivity - ECB Occasional Paper No. 2024/339.

[72] Anderton R., Botelho V., Reimers P. (2023) Digitalisation and productivity: gamechanger or sideshow?, ECB working paper series, No 2794.

[73] See, Draghi Report.

[74] Corrado C., Haskel J., Jona-Lasinio C., Iommi M. (2016), cit.

Finally, it is important to emphasise that productivity gains from ICT adoption, even for firms undertaking complementary investments, are not immediate but instead require time to materialise.[75] In the short term, even negative effects on productivity may emerge because of these "digital disruption costs".[76] Indeed, such transformations - encompassing workforce upskilling, organisational restructuring, and process reengineering - are often time-consuming and complex, characterised by high uncertainty and significant resistance to change.

Delays in obtaining positive outcomes from diffusion and adoption of ICT and digital technologies have been always empirically observed: firms making significant digital investments tend to improve both labour productivity (LP) and total factor productivity (TFP), yet, typically with a lag of several years, on average, five years post-adoption.[77] This enduring phenomenon of misalignment between sustained investment in digital technologies and the slower-than-expected growth in productivity indicators is known as the "productivity paradox" of information technology.[78]

Building on this background, the following section 3 carries out and in-depth assessment of the diffusion of ICT and digital services in the EU, focusing on three foundational pillars of the digital transformation: advanced connectivity, cloud infrastructures, and artificial intelligence.

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[75] Brynjolfsson E., Rock D., Syverson C. (2021) The Productivity J-Curve: How Intangibles Complement General Purpose Technologies, in American Economic Journal: Macroeconomics vol. 13, no. 1, January 2021, (pp. 333–72).

[76] Pérez C.J., Ponce C.J. (2015) Disruption costs, learning by doing, and technology adoption, in International Journal of Industrial Organisation, Volume 41, 64-75.

[77] E.g., Brindusa A, Bunel S (2024) Digitalisation and productivity, ECB Occasional Paper Series n. 339; Brynjolfsson E., Hitt L.M. (2003) Computing Productivity: Firm-Level Evidence. Review of Economics and Statistics 85, 793-808.

[78] Brynjolfsson E. (1993) The productivity paradox of information technology - Communications of the ACM. 36 (12): 66–77.

3. Diffusion of ICT and Digital Technology

3.1 The Dynamic of Digital Technology Diffusion

The transformation of innovation into sustainable productivity growth and welfare gains ultimately depends on the broad-based adoption and effective utilisation of technologies by firms, public institutions, and individuals. Such adoption often occurs not through radical breakthroughs, but through successive waves of incremental innovation. Moreover, without a clear pathway from research to market, even the most advanced innovations may fail to yield economic returns, weakening both the business case for innovation and the dynamic efficiency of the broader system.

Digitalisation transformation, referring to the process of using ICT and digital technologies and embedding them into everyday economic and social activities, is one of the main forces driving structural and organisational changes in the global economy. Digital technologies and services, by changing business models, creating new revenue streams, and transforming operations or social interactions, can generate positive effects both at micro (productivity gains) and macro (GDP growth) levels. In the meantime, digitalisation generates endogenous vast amounts of complementary innovation and opportunities for cross-fertilisation among previously separate fields.[79]

Therefore, all ICTs should be viewed as a unique networked, multi-layered GPT ecosystem, in which foundational layers support the emergence of successive, higher-order GPTs. Each of these layers satisfies the classic criteria of general-purpose technologies - pervasiveness, potential for continuous improvement, and facilitation of complementary innovations - across various points on the material-immaterial continuum. [80]

Conceptualising ICT in this layered manner helps to explain the cumulative and mutually reinforcing dynamics of digital transformation, where advancements in one layer unlock new possibilities in others. This interplay creates positive feedback loops that can significantly amplify structural productivity growth across the economy.

Indeed, innovation generates positive externalities and scope economies, with new technologies serving as stepping stones for further innovation: for instance, it has been empirically demonstrated that artificial intelligence (AI) innovation exhibits strong dynamic returns, through learning effects, and builds on complementarities with prior developments in network and communication technologies.[81]

Digital transformation encompasses a broad set of changes across sectors, services and technologies. To provide a focused and meaningful analysis, this paper concentrates on three foundational enablers: advanced connectivity, cloud computing, and artificial intelligence – which currently form the core infrastructure and intelligence layer of digital and ICT ecosystems.

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[79] Rossi, M. A. (2024) EU technology-specific industrial policy. The case of 5G and 6G, in Telecommunications Policy, 48.

[80] Manganelli A., Nicita A. (2022) Regulating digital markets. The Eu approach.

[81] Igna I., Venturini F. (2023) The determinants of AI innovation across European firms, Research Policy Volume 52, Issue 2, March 2023.

In the subsequent sections, the economic impact and diffusion level of those key ICT and digital technologies are assessed, in view of the Digital Decade Policy Programme (DDPP) targets, and in constant reference to international benchmarking, particularly vis-à-vis the United States, to gauge the European Union's competitive performance.

Given that these technologies constitute integral components of a multilayered digital ecosystem, it is essential to examine the distinct functional relationships that shape their dynamic interplay in driving productivity gains and fostering economic growth. First, particular attention is devoted to the interaction between the deployment of connectivity networks (connectivity supply) and the adoption of connectivity (connectivity demand) - a relationship that is critical also for the financing and long-term sustainability of infrastructure investment. Equally important is the nexus between connectivity adoption and the diffusion of advanced digital services, such as cloud computing and artificial intelligence, where strong complementarities and feedback effects emerge.

3.2 Impact of BB and Ultra BB Connectivity

Broadband Internet has probably been one of the key priorities for policy makers around the world in the two decades across the last decades since it has been considered as a primary engine for innovation and economic growth.

Over the past two decades, the EU has progressively raised its digital connectivity ambitions: the 2010 Digital Agenda[82] aimed for universal basic broadband (30 Mbps) and coverage for 50% of households at 100 Mbps, while the 2016 Gigabit Society [83] set Gigabit connectivity (i.e., 1 Gbps = 1000 Mbps) as goal of for all main socio-economic drivers (e.g., education, government services, transport hubs, digitally intensive enterprises) and a universal access to at least 100 Mbps - extendable to 1 Gbps, for all European households even in rural and remote areas.

Most recently, the 2021 Digital Compass states that "*it is our proposed level of ambition that by 2030 all European households will be covered by a Gigabit network, with all populated areas covered by 5G*".[84] These targets have been confirmed and coupled with a compelling enforcement system by the Digital Decade Policy Programme (DDPP 2030), which also calls for the deployment of 10,000 secure edge computing nodes and investment in quantum computing infrastructures. (see the **Annex**)

The evolving EU industrial policy rests on the foundational assumption that the increased deployment of fixed and mobile broadband is positively associated with economic development. This principle underpins much of the European Union's digital and industrial strategy, which recognises broadband infrastructures not merely as utility assets, but as a general-purpose technology (GPT) — characterised by wide applicability, and by their ability to generate pervasive positive externalities, productivity gains, and broad-based economic growth across both the digital ecosystem and the wider economy.

As with all GPTs, the transformative potential of ultra-broadband (UBB) arises primarily from its complementarity with other innovations, enabling both process improvements and the creation of new digital products and services. Today, advanced network connectivity is considered essential not

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[82] European Commission (2010) Communication on A Digital Agenda for Europe—COM (2010) 0245.

[83] European Commission (2016) Communication on Connectivity for a Competitive Digital Single Market—Towards a European Gigabit Society— COM (2016) 587 Final.

[84] European Commission (2021) Digital Compass 2030, The European way for the Digital Decade – COM 2021/118 final.

only for communications but also for next-generation digital activities — including artificial intelligence (AI), virtual and augmented reality (VR/AR), commercial and industrial Internet of Things (IoT) applications. These technologies are progressively migrating toward edge-cloud architectures, thereby requiring ubiquitous, robust and secure high-speed fixed and mobile connectivity.

As for general efficiency enhancement, BB has always considered a driver to stimulate productivity by lowering costs and facilitating more efficient business processes while enabling innovation and new business models through, for example, e-commerce, big data analytics, and remote collaboration.[85] The extensive use of the Internet reduces the cost of information, enables remote working, cuts production and distribution times, optimises business processes, increases innovation capacity and provides access to training channels to improve the quality of the workforce. [86] For consumers and workers broadband access supports digital skill acquisition, lowers barriers to ICT services, and improves access to information, education, and employment opportunities.

Generally speaking, the economic literature agrees on the positive impact of broadband and ultra-broadband on economic growth: quite a few seminal analyses recognised a strong positive causal effect of the deployment of telecommunications networks and services on GDP growth. [87] However, most of this first wave of literature does not refer to fibre /Very High-Capacity Networks (VHCN) connectivity and/or do not consider the level of adoption of connectivity as a crucial variable.[88]

The most recent studies, specific to UBB and fibre investments, have confirmed those positive results, yet with some limitations. In summary, (i) UBB and fibre investment have a positive incremental effect on economic growth, however (ii) returns on such investments decrease as installed speed/capacity and coverage increases - potentially meaning that 100% fibre coverage may not be the socially optimal choice; and (iii) adoption of connectivity services to substantial proportions of the population is more important in driving economic growth than the mere network deployment.[89]

There is a further new strand of economic literature that examines the relationship between ultra/broadband access and business development and productivity, showing that technological innovation and high connection speeds have a positive effect on (i) productivity of firms, both in terms of total factor productivity (TFP) and labour productivity (LP);[90] and on (ii) the entry of new firms in

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[85] Bakhshi H., & Mateos-Garcia J. (2012) Rise of the Datavores: How UK Businesses Can Benefit from Their Data. London: Nesta.

[86] Briglauer W., Cambini C., Gugler K., Sabatino L. (2025), Economic Benefits of High-Speed Broadband Network Coverage and Service Adoption: Evidence from OECD Member States, In Industrial and Corporate Change, pp. 1-40.

[87] Roller L. e Waverman L. (2001) Telecommunications Infrastructure and Economic Development: A Simultaneous Approachin American Economic Review. 91(4): 909-923; Czernic N., O. Falk, T. Kretschmer e L. Woessmann (2011), Broadband Infastructure and Economic Growth, in The Economic Journal, 121, 505-532; Gruber H., J.Hätönen, P.Koutroumpis, (2014), Broadband access in the EU: An assessment of future economic benefits, in Telecommunications Policy, 38(11), 1046-1058.

[88] Most of analysis relates to instances in which end users were unconnected or connected to very low bandwidth connections and are ulteriorly connected to functional broadband (still <100Mbps). Most of them are empirical studies based on data up to 2012 and therefore are not directly related with the current connectivity targets, as connectivity targets are not aiming to increase broadband penetration but rather achieve full EU-wide coverage to gigabit-capable networks.

[89] Briglauer, W. e Gugler, K.P. (2018), Go for Gigabit? First Evidence on Economic Benefits of (Ultra-)Fast Broadband Technologies in Europe, in Journal of Common Market Studies, 57(5), 1071–1090; Koutroumpis, P. (2019) The economic impact of broadband: Evidence from OECD countries, in Technological Forecasting and Social Change, 148, 119719; Briglauer W., Cambini C., Gugler K., Sabatino L. (2025) Economic Benefits of High-Speed Broadband Network Coverage and Service Adoption: Evidence from OECD Member States, In Industrial and Corporate Change, pp. 1-40.

[90] Cambini C., Grinza E. Sabatino L. (2023) Cambini, C., Grinza, E., & Sabatino, L. (2023) Ultra-fast broadband access and productivity: Evidence from Italian firms, in International Journal of Industrial Organisation, 86, 102901.

those sectors with greater use of digital technologies and large proportions of highly skilled workers.[91] However, as with the impact on economic growth, the productivity-enhancing effect of broadband is substantial but subject to diminishing returns once a certain quality threshold is reached. In addition, the positive socioeconomic effects materialise only when broadband is actively adopted and utilised on the demand side, rather than through mere availability on the supply side. [92]

Importantly, all these findings align with studies indicating that investments in ICT yield productivity gains only or mainly when accompanied by complementary measures and non-R&D intangible assets, such as staff training, adoption of new organisational practices and software adoption.[93] This indirectly confirms again that the uptake and effective utilisation of broadband services are critical to generate economic impact, compared to the mere availability of the technology itself (that represents however a pre-requisite).

3.3 Diffusion of Connectivity and the Role of EU Targets

In 2024 Europe's FTTH households coverage reached an estimated 69.2% - better than South Korea's 67.4% and the USA's 54.8% - and with a significant annual growth of 8.4%; while, the overall Europe's gigabit-capable coverage (≈VHCN[94]) reached an estimated 82.5% in 2024, with an annual growth of 4.5, as compared to the higher figures in China with 99.0%, in South Korea with 97.6%, in the USA with 90.3%, and in Japan with 93.9%.[95]

As for mobile networks, EU 5G average coverage is 94% of the population in 2024, which is comparable with other regions of the world; however, the actual 5G take-up in Europe (35.6%) is currently much lower compared to the US (96.5%) and China (73.1%). Furthermore, when looking at the coverage of 5G stand-alone (SA),[96] it covers only a fraction of the EU population: at the end of 2024, 5G SA coverage

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[91] Cambini, C., Sabatino, L. (2023) Digital highways and firm turnover, in Journal of economics & management strategy, 32(4), 673-713.

[92] Briglauer, W., Krämer, J., Palan, N. (2024) Socioeconomic benefits of high-speed broadband availability and service adoption: A survey, in Telecommunications Policy, 48(6).

[93] Brynjolfsson E., Rock D., Syverson C. (2019) Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics, in A. Agrawal, J. Gans, & A. Goldfarb, The Economics of Artificial Intelligence (pp. 23-60); Nucci F., Puccioni C., Ricchi O. (2022), cit.; Corrado C., Haskel J., Jona-Lasinio C., Iommi M. (2016), cit.

[94] One of the main objectives of the European Code of Electronic Communication - Directive UE 2018/1972 - is to "promote connectivity and access to, and take-up of, very high-capacity networks, including fixed, mobile and wireless networks, by all citizens and businesses of the Union". Consistently with the technological neutrality principle, the definition of VHCNs, at art 2(2) of the Code - serves the purpose of defining minimum performance standards that ensure adequate levels of connectivity: those standards are today more easily achievable through fiber-optic technologies, but it does not exclude the use of alternative technological solutions, provided that these are capable of guaranteeing "similar network performance in terms of available downlink and uplink bandwidth, resilience, error-related parameters, and latency and its variation". From this perspective, Article 82 of the European Code entrusts BEREC with the task of issuing guidelines to specify the technical criteria that a network must meet to be classified as a Very High-Capacity Network (VHCN).
See BEREC, Guidelines on Very High-Capacity Networks (2023) - BoR (23) 164.

[95] Analysis Mason (2024) Report for Connect Europe.

[96] 5G Standalone (SA) refers to the full deployment of 5G infrastructure, including both the radio access network and a new 5G core, enabling advanced features such as ultra-low latency, network slicing, and improved energy efficiency. Unlike 5G Non-Standalone (NSA), which relies on existing 4G infrastructure, 5G SA delivers the complete performance benefits envisioned for next-generation networks and is essential for industrial and mission-critical applications.

of the population reached only 40% in Europe, against 91% in North America and 45% in the Asia-Pacific area, despite the EU almost doubling the number of its commercial 5G SA networks in 2024.[97]

According to the latest "State of the Digital Decade"[98], there is a small delay in the deployment of VHCNs to be able to meet the connectivity target in 2030. Furthermore, while 5G (non-standalone) coverage already exceeds the target trajectory (94.3% in 2024 and expected to reach 100% by 2027, three years ahead of schedule), no specific target exists for 5G Standalone (SA).

Regardless of the EU's performance against the DDPP targets, the economic and econometric evidence presented in the previous section suggests that those targets themselves may be somehow arbitrary, marked by an inefficient supply-side bias rooted in a rationale mixing-up industrial policy and "universal service" type of considerations.

A key effect of very ambitious networks deployment objectives, that are far beyond what market forces can autonomously deliver, is the increase in the scope for public investment and support to fulfil the presumed investment gap.[99] This implies a re-allocation of public funds from other socially desirable objectives, [100] which, under an economic viewpoint[101], should take place only if (i) a significant portion of existing positive externalities are not reflected in the current ultrafast BB demand level, or (ii) there is a willingness to pay (WTP) unmet by current supply.[102]

Analysis in the previous section raised some doubts about point (i), and consequently on the overall social impact deriving from the Commission's connectivity targets and whether this justifies the costs, public and private, of achieving such objectives, particularly when it comes to remote and rural areas.[103]

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[97] Analysis Mason (2024), cit.

[98] European Commission (2025) State of the Digital Decade 2025: Keep building the EU's sovereignty and digital future -COM (2025) 290 final. This is the latest annual assessment of Member State progress and identification of gaps requiring targeted action. See the **ANNEX**.

[99] For example, a 2023 study estimated that the share of public funding required to complement private investment to achieve the EU's connectivity targets amounts to approximately 35% for FTTH networks and 29% overall. See WIK-Consult (2023) Investment and Funding Needs for the Digital Decade Connectivity Targets – Study for the European Commission. Similarly, the European Parliament (2024) Future-Proof Network for the EU: Full Fibre and 5G, underlined the scale of the investment challenge and the crucial role of public funding in bridging the gap. More broadly, the Recovery and Resilience Facility (RRF) has allocated €13.6 billion to digital connectivity initiatives across 21 Member States. The Connecting Europe Facility (CEF) Digital programme provides an additional €2.07 billion for the period 2021–2027. At the Member State level, between 2014 and 2023, the European Commission approved, under State aid decisions, a total aid amount of €61.97 billion for broadband deployment. During the same period, Member States also communicated, under the General Block Exemption Regulation (GBER), an overall budget of €28.84 billion, bringing the total approved aid to €90.70 billion. Out of this total, €22.78 billion (in current prices) was actually spent between 2014 and 2023. See European Commission (2025) State Aid Scoreboard 2024.

[100] Manganelli A., Nicita A. (2020) The governance of Telecom markets.

[101] Beneath a socio-political perspective lies an even more complex challenge: allocating resources among various public spending priorities - such as education, healthcare, social security, and family benefits, which vary significantly across EU member states.

[102] Parcu P. L., Rossi M. A. (2020) State Aid Policy in the Broadband Sector: Public Announcements, Investments and Crowding Out, in P. L. Parcu, G. Monti, & M. Botta (Eds.), EU State Aid Law (pp. 99–120).

[103] In the case of fibre deployment, however, a more pragmatic factor must be considered: existing copper networks are nearing the end of their operational life and will need to be anyway replaced. From the supplier's perspective, fibre offers a more efficient alternative, with lower maintenance requirements and significantly reduced labour costs due to fewer faults — even if the immediate benefits to end users are limited. In any event, these operational considerations suggests that decisions on how and when to upgrade infrastructure may, in many cases, be best driven by the market upon commercial considerations rather than public mandates. This is also why the transition from copper to fibre networks ought to be largely led by the market

By setting high uniform standards (e.g., symmetrical 1 Gbps connectivity) across vastly diverse territories, the EU framework imposes challenging financial burdens on Member States, especially in rural or sparsely populated areas. Indeed, uniform targets do not reflect differences in: (i) local industrial structure and productivity potential; (ii) demographic patterns and population density; (iii) existing infrastructure and baseline digital maturity.[104]

In other words, the VHCN impact and the demand heterogeneity are not adequately addressed, possibly undermining cost-effectiveness. In addition, also allocative inefficiencies may arise when high-performance networks are rolled out in areas with low adoption potential, while economically strategic zones may still lack targeted high-bandwidth infrastructure or more advance connectivity needs, especially for mobile connectivity, as for example 5G stand-alone or 6G. Therefore, very high supply-side targets could also induce intensification of trade-offs, particularly between coverage and performance.

As for point (ii), empirical studies suggest that while final consumers exhibit significant WTP for a basic-to-high-speed broadband upgrade, their WTP for ultra-high-speed services (e.g., 1 Gbps FTTH) is often marginal. [105] This implies that supply-led infrastructure expansion may outpace effective demand, at least in the short-medium term.

Indeed, connectivity demand in the EU has remained relatively low in comparison to the coverage already provided by existing VHCN infrastructures, particularly in certain national markets. In 2024, only 22.3% of fixed broadband subscriptions were at speeds of 1 Gbps or higher (up from 18.5% in 2023), against a coverage of 82.5%. As such, as evident in the following **Figure 10**, there is still need for significant progress in this area: great majority of EU countries (as well as EU average) in the down-left quadrant, indicating a good deployment associated with a scarce take-up.

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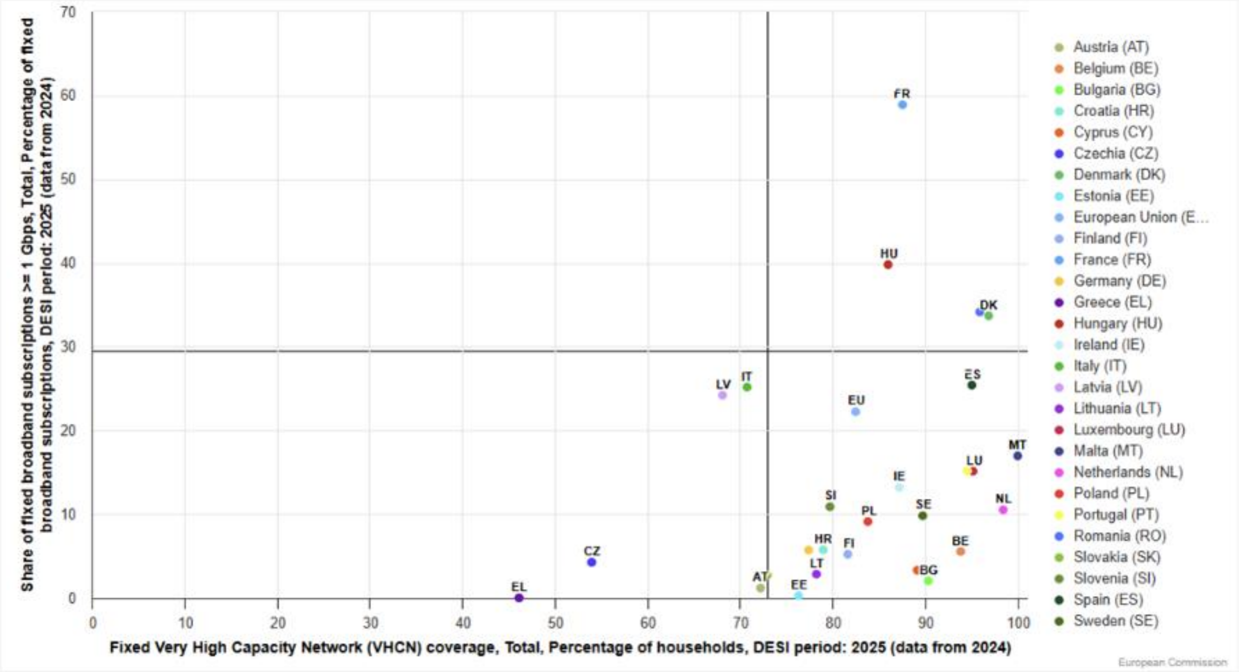
dynamics, encompassing users' demand, and not necessarily by defining an EU-wide copper switch-off date, as envisioned in the consultation of the forthcoming Digital Network Act – see European Commission (2025) Call for evidence for an impact assessment for a Digital Networks Act (DNA).

[104] Emergence of Fixed Wireless Access (FWA) as a pragmatic deployment alternative across rural and remote areas provides empirical evidence that uniform gigabit connectivity targets were insufficiently calibrated to local economic and demographic realities. FWA delivers lower performance than gigabit fibre infrastructure—typically offering 100-300 Mbps rather than symmetric 1 Gbps—yet achieves deployment costs substantially below fibre, particularly in sparsely populated territories where per-household infrastructure costs become prohibitively high under universal gigabit mandates. FWA adoption suggests that differentiated technology standards calibrated to local demand, cost structures, and productivity potential would have achieved broader connectivity objectives at significantly lower public and private expenditure, while respecting the revealed preferences of end-users and infrastructure investors.

[105] For example, also Liu Y.-H., Prince J., Wallsten S. (2018) find that "households' valuation of bandwidth is highly concave, with relatively little added value beyond 100 Mbps", and Fackler, T., Falck, O., & Krause, S. (2022) found that there is decreasing marginal willingness to pay for speed, at least once a desired broadband speed level is reached, i.e., upgrades to 30 Mbit/s and 50 Mbit/s are valued less than 16 Mbit/s. See, Liu Y.-H., Prince J., Wallsten S. (2018) Distinguishing bandwidth and latency in households' willingness-to-pay for broadband internet speed, in Information Economics and Policy, 45, 1–11, and Fackler T., Falck O., Krause S. (2022). High-speed broadband Internet and real estate prices, in Journal of Urban Economics, 127.

Figure 10 – Giga-connectivity adoption and VHCN deployment



Source: EU commission DESI INDEX (2025)

Nevertheless, the DDPP does not set explicit targets for connectivity adoption - even though such metrics are regularly monitored. This asymmetry may have tilted public interventions and investments toward infrastructure deployment, at the expense of stimulating demand,[106] which is now arguably the more pressing constraint. Demand for connectivity is not only a matter of socio-economic diffusion and productivity growth, but also a key determinant of financial returns on past and future investments. As noted, in well-functioning markets, these returns are vital signals that incentivise private investment, R&D, and innovation. [107]

In this context, greater attention should be given to understanding the wide disparities in adoption rates across Member States, and this analysis should inform efforts to remove barriers to adoption. This may also justify setting adoption-related targets at both EU and national levels.

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[106] For example, revisiting the state aid guidelines on broadband networks to ensure that (a) recipients of public funds have the appropriate incentives to meet ultrafast BB adoption targets, as well as roll-out targets; (b) state aids are used to provide users with demand-side incentives to adopt new technologies more quickly and in greater numbers. See Feasey R., et al. (2024) Ideas for the future of EU Telecommunications regulations, CERRE Report. In that policy paper is expressed a general preference to use public funds to support 'demand pull' measures to extend network coverage over 'supply push' subsidies since the main benefits of a new network are driven by usage rather than by its deployment. Or also exploring the use of collective purchasing programmes, organised and administered by local authorities or non-profit bodies, to promote collective adoption of ultrafast BB in areas where such infrastructures have already been built (as well as to promote deployment in areas where they have not). See, Bourreau M., Feasey R., Hoernig, S. (2017) Demand-Side Policies to Accelerate the Transition to Ultrafast Broadband, CERRE Report.

[107] As also the European Commission has acknowledged: "[the] perception of attractiveness of advanced digital networks by private investors is of crucial importance for the future of connectivity. Certain investors have underlined that the mobilisation of private investments requires a clear business case that is predicated on profitability and higher margins. Profitability depends on the take-up of enhanced fixed and mobile networks, which is itself linked to the development and increased take-up of data intensive applications and use cases, e.g., based on edge computing, AI, and IoT." European Commission (2024) WHITE PAPER How to master Europe's digital infrastructure needs? - COM (2024) 81/2.

Despite these critiques, EU connectivity targets in the last decade have been instrumental in steering investments, fostering long-term technological ambition, and (once the DDPP has been in force) promoting coordination across Member States. While concerns about their uniformity, supply-side bias, and weak linkage to effective demand are valid, they should not obscure the rationale for targeted “anticipatory (public or publicly-incentivised) investment”.

As previously noted, research shows that productivity gains from broadband and general-purpose technologies (GPTs) often materialise with a time lag. This is because adoption and complementary capabilities tend to follow infrastructure deployment only after an adjustment period. Hence, early investment in infrastructure can be economically justified, in high-potential areas where tipping point[108] and adequate return on investment could be reached. Moreover, infrastructure inertia, high fixed costs, and “regulatory bottlenecks” make a completely “reactive deployment” unfeasible or anyway not easily and quickly responsive to market demand.

This argument is especially strong for so-called “transformational infrastructure” - technologies that enable entirely new services, rather than just improving the quality of existing ones by providing incremental upgrades. In fact, the latter can be more easily driven by current demand. For instance, this seems to be the case for 5G SA, or edge-cloud micro-infrastructure, that are not merely enabling faster or better versions of previous services but represent a functional shift in digital infrastructure and associated services.

That said, this logic does not justify homogeneous deployment or uniform performance thresholds across all geographies and sectors. For “anticipatory investment” to be effective, it must reflect differentiated productivity effects, externalities, and absorption capacity. In other words, a market-led dynamic remains essential since signalling where value is likely to emerge and where infrastructure early building can translate into long-term economic returns. For example, 5G SA deployment in suburban residential areas may yield limited benefits, while in industrial corridors, transport hubs, or industrial and logistics nodes, it can function as a transformational productivity enabler.

Viewed through this lens, the current trajectory of gigabit connectivity deployment, while below DDPP targets, likely reflects a realistic absorption pattern considering current adoption gaps. Rather than accelerating this path indiscriminately, it would be more efficient to encourage the deployment and diffusion of advanced technologies such as 5G Standalone — and prospectively, 6G — in areas where their economic and societal returns can be maximised. This of course draws a clear distinction between end-users’ services, and B2B and tailored industry services.

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[108] Tipping points are not only those at end-users’ level, i.e., critical mass and economies of scale on the demand-side. Very often they could emerge within supply chains or enterprise ecosystems, for instance (i) when enough enterprises adopt private 5G, then vendors, device makers, and developers align to support it; (ii) once cloud-native 5G SA cores are deployed at scale, the cost and risk of launching new services (e.g., network slices) drop significantly.

3.4 Impact of Cloud and AI

Cloud computing and artificial intelligence are increasingly seen as key enablers of productivity, innovation, and competitiveness in the digital economy. Their combined effects are expected to reshape how firms operate, scale, and compete across sectors.

In particular, cloud computing can enable significant cost savings by exploiting scale economies in the provision of computing resources, thus avoiding inefficient under-utilisation of on-premises IT capacities. In particular, cloud computing drastically reduces the need for upfront fixed capital investments as it can be provisioned on a variable cost basis proportional to the utilisation of computing resources.[109] These characteristics allows firms to quickly and flexibly scale up and allow for organisational agility as well as flexibility to quickly adapt to changes in customers' demand.[110] Therefore, cloud usage can increase the productivity of firms, as it allows them to quickly customise IT to their specific needs.[111]

Considering all these elements, cloud appears to be different from earlier IT technologies that mainly reinforced the scale advantages of incumbents,[112] since it may allow startups to grow by reducing their IT fixed costs. Nevertheless, empirically, the likelihood of using cloud computing is anyway positively related to the size of firms - this is not a direct causation, yet it depends on presence of in-house IT personnel, and the share of firm's turnover generated via the Internet.[113] These results confirm again a clear complementarity between technology and knowledge, suggesting that the use of cloud technologies improves productivity, but without knowledge the new technology may not be adopted at all.

Cloud services and infrastructures are also a key enabler of digital services and an important driver of innovation for the entire economy, for example, with regards to Artificial Intelligence (AI). In turn, AI is perceived as the most transformative general-purpose technology (GPT) of our time: AI is likely to represent a catalyst for productivity across several sectors by, inter alia, the automation of routine tasks, process optimisation, and support to data-driven decision-making.[114] Moreover, AI may facilitate access to new markets, since products and services can be more customised, varied and of higher quality.

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[109] Gal P., Nicoletti G., Renault T., Sorbe S., Timiliotis C. (2019) Digitalisation and productivity: in search of the holy grail - firm-level empirical evidence from EU countries - OECD Economics Working Papers No. 1533 (2019).

[110] De Stefano T., Kneller T., Timmis J. (2023) Cloud Computing and Firm Growth, in the Review of Economics and Statistics; Marston S., Li Z., Bandyopadhyay S., Zhang J., Ghalsasi A. (2011) Cloud computing—The business perspective, in Decision Support Systems, 51(1), 176-189; Makhlouf R. (2020) Cloudy transaction costs: a dive into cloud computing economics, in Journal of Cloud Computing, 9(1), 1-11.

[111] Duso T., Schiersch A. (2025) Let's switch to the cloud: Cloud usage and its effect on labor productivity, in Information Economics and Policy, Volume 70, June 2025.

[112] Lashkari D., Bauer A., Boussard J. (2019) Information Technology and Returns to Scale, in American Economic Review, vol. 114, no. 6, June 2024 (pp. 1769–1815).

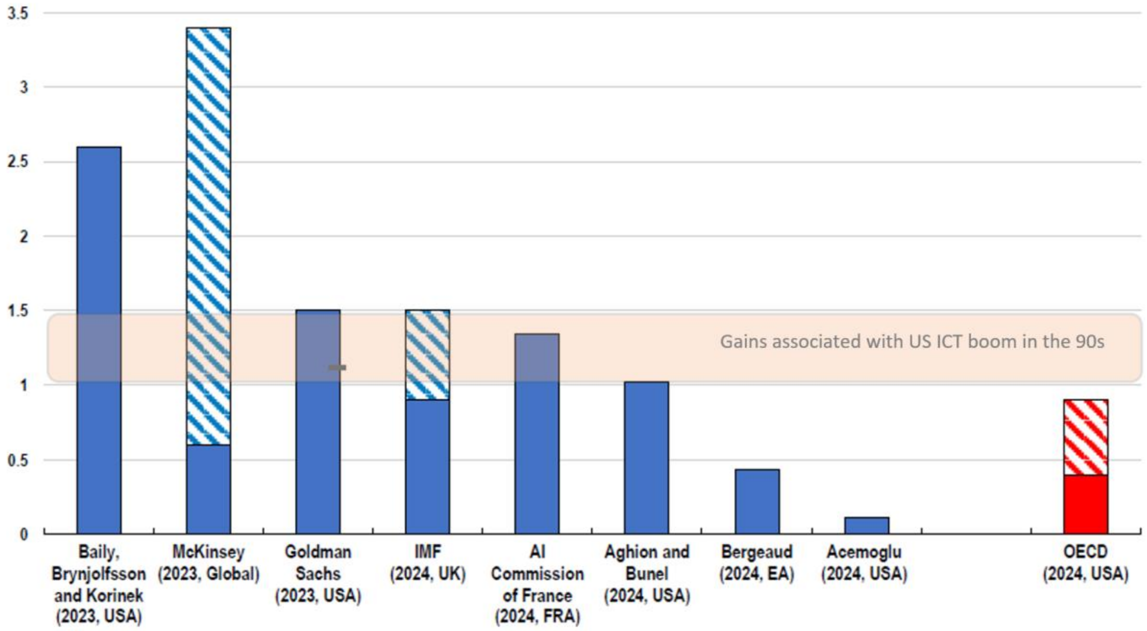
[113] T. Duso, A. Schiersch (2025), cit.

[114] Szczepański M. (2019) Economic Impacts of Artificial Intelligence (AI) - EPRS | European Parliamentary Research Service.

Nevertheless, while AI demonstrates remarkable potential to enhance productivity at individual level, it should not be presumed that these micro-level gains will necessarily translate into equally large aggregate benefits. Several factors suggest that the macroeconomic impact may be more limited.[115]

As a matter of fact, there are quite a few different recent studies trying to quantify the expected macroeconomic impact of gen-AI on productivity: results, reported below (**Figure 11**), are very heterogeneous.[116]

Figure 11 – Comparing AI's predicted macro-level productivity gains across studies



Source: OECD (2024) Note: Predicted increase in annual labour productivity growth over a 10-year horizon due to AI (in percentage points). The estimates refer to the countries shown in brackets. When the source presents a range of estimates as the main result, the lower and upper bounds are indicated by striped areas.

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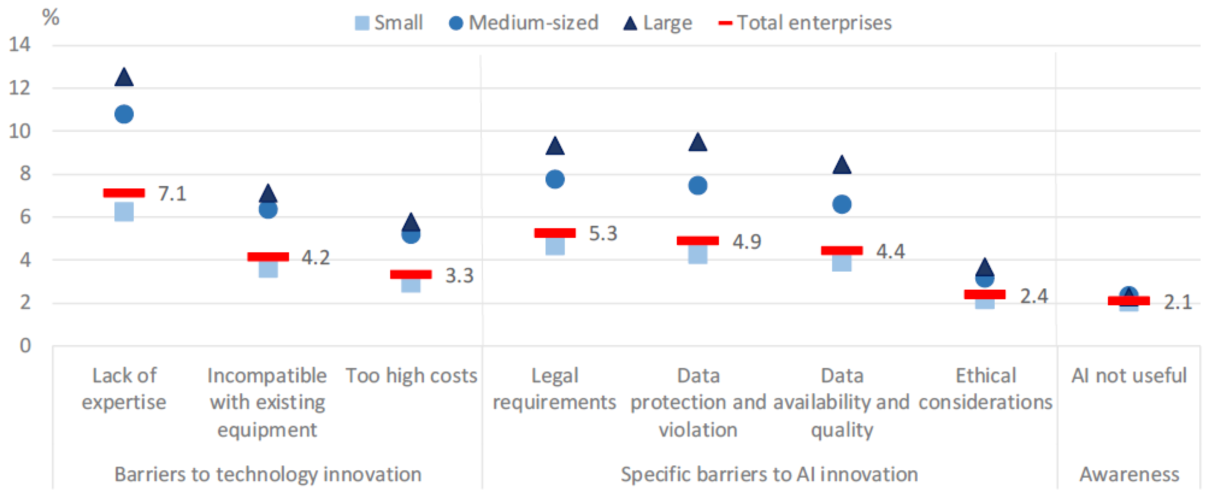
[115] First, AI's transformative effects are concentrated in cognitive and knowledge-intensive activities, such as information and communications technology, finance, and professional services, whereas tasks with a substantial physical component (e.g., construction, much of manufacturing, and personal services) remain relatively unaffected unless complemented by advanced robotics. Second, because of general equilibrium dynamics and the complex interdependencies within production networks, aggregate productivity gains cannot simply be calculated by summing improvements across individual sectors. For instance, if efficiency gains from AI lead to lower prices but are not matched by a proportional increase in demand, the market may reach saturation quickly. In such cases, labour and capital may shift toward sectors where AI has less impact on productivity, thereby diluting the potential economy-wide benefits and limiting the net effect on overall output. See, Filippucci F., Gal P., Schief M. (2024) Miracle or Myth? Assessing the macroeconomic productivity gains from Artificial Intelligence - OECD Artificial Intelligence Papers, n 29.

[116] For instance, Briggs and Kodnani (2023) suggests an optimistic view based on their large aggregate productivity growth estimates, amounting to 1.5 percentage point (p.p.) labour productivity boost per year, comparable to the size of total productivity growth observed over the past decades. In contrast, Acemoglu's (2024) assessment is much more cautious, based on the small growth effects (on the order of 0.1 p.p. labour productivity gains per year) he projects using a task-based aggregation framework and Hulten's (1978) theorem. Aghion and Bunel (2024) use the framework in Acemoglu (2024) but rely on different assumptions from the literature to arrive at numbers that are in between but closer to the optimistic end of the spectrum (around 1 p.p. point boost).

Indeed, to fully leverage AI's productivity potential - especially at macro level - still requires complementary digital infrastructure and skills, as for earlier digital technologies.[117] Therefore, bad predictions (such as the recent MIT report[118]) should not be alarming per se. Like all general-purpose technologies (GPTs), according to the transformation hypothesis, full productivity-enhancing potential of AI will likely take time to materialise, as it requires not only widespread adoption but also the accumulation of significant complementary skills, organisational change and investments, often concentrated in intangibles, that take time to build and can be difficult to finance.[119]

In the case of AI, this includes data assets, cloud computing capacity, digitally skilled labour, and new business models. These factors in the short-term work as obstacles to AI adoption (**Figure 12**): in 2024 7.1**%** of all EU27 enterprises cited a lack of relevant expertise as the main reason for not having adopted AI (getting to more than 12% between large firms); 4**%** pointed to incompatibility with existing equipment, software, or systems, while 3% mentioned excessive costs.[120] Those are the same common barriers to innovation, which remain relevant for AI adoption.

Figure 12 – Share of Enterprises not using AI technologies by main reason and firms size (%), EU27 2024



Source: OECD (2025)

In this context, the role of digital platforms has become increasingly crucial, particularly through their ability to seamlessly integrate digital technologies by creating, orchestrating, and coordinating digital ecosystems. As technology becomes more advanced and is built upon multiple interconnected layers, the effective use and coordination of diverse technologies and layers - often developed by different

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[117] Corrado C. et al. (2021), New evidence on intangibles, diffusion and productivity - OECD Science, Technology and Industry Working Papers, No. 2021/10. In addition to previous ICT technologies, a widespread productive usage of AI could be influenced also by infrastructural bottleneck as availability of fixed and mobile VHCN, storage capacity and enormous computing power as well as the deployment of edge computing capacity.

[118] https://fortune.com/2025/08/18/mit-report-95-percent-generative-ai-pilots-at-companies-failing-cfo/.

[119] Corrado C., Haskel J., Jona-Lasinio C. (2021) Knowledge Capital and Productivity Growth in the EU, in Economics of Innovation and New Technology, 30(5), 455–483; Brynjolfsson E., Rock D., Syverson C. (2019) Artificial Intelligence and the Modern Productivity Paradox, in A. Agrawal, J. Gans, and A. Goldfarb (Eds.), The Economics of Artificial Intelligence: An Agenda (pp. 23-57).

[120] Kergroach S., Hériter J. (2025) Emerging Divides in the Transition to Artificial Intelligence - OECD Regional Development Papers No. 147; Eurostat (2024). Statistics on the Use of Artificial Intelligence by Enterprises.

firms/complementors - becomes essential for enhancing productivity. This could be observed also in the diffusion of AI and reduction of structural barriers that traditionally slowed the adoption of earlier digital technologies. (see **Appendix C**)

As for the digital skills gap, it has become evident across most sectors and is particularly pronounced, exceeding 11%, in high-tech industries such as computer and electronics manufacturing, and in knowledge-intensive services. This likely reflects the more advanced and intensive use of digital technologies in these sectors.

More broadly, indeed, Europe still lacks the deep pool of digitally trained workers that mass adoption requires; just over 10 million ICT specialists, which is about 5.0% of the labour force, are available today. As for consumer utilisation, basic digital skills are lacking among nearly half the adult population, leaving 44.4% of citizens unable to use common online tools or protect themselves from cyber-risks.[121] This area should be a top priority for policymakers, deserving focused attention and substantial allocation of resources.

3.5 Diffusion of Cloud and AI and the Role of EU Targets

In 2023, 38.97% of enterprises reported using intermediate or advanced cloud computing services. [122] However, uptake varied significantly by enterprise size: while nearly 38% of small and medium-sized enterprises (SMEs) adopted cloud solutions, the rate was much higher among large enterprises, at nearly 70%. Considerable disparities also exist across EU Member States, with adoption rates ranging from 73% in Finland to below 20% in Greece, Bulgaria, and Romania.

It is important to note that these figures offer limited insight into actual productivity growth and competitiveness. Cloud computing encompasses a broad and heterogeneous range of services, typically categorised by functionality.[123] Notably, the Software-as-a-Service (SaaS) ecosystem is highly diverse and varies significantly in terms of complexity and functionality. [124] Consequently, the impact of cloud services on productivity and economic growth depends heavily on the specific type of service adopted, but also – crucially - on how effectively these services are integrated and utilised within firms.

Despite these crucial differentiations, the Digital Decade Policy Programme (DDPP) defines cloud adoption in overly broad terms - as the percentage of enterprises using at least one “intermediate or sophisticated” cloud computing service. [125] This reflects an ongoing emphasis on surface-level

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[121] European Commission (2025) State of the Digital Decade 2025: Keep building the EU's sovereignty and digital future - COM (2025) 290 final.

[122] European Commission (2025), cit.

[123] A primary distinction lies between Infrastructure-as-a-Service (IaaS), which provides access to computing infrastructure and requires customers—usually businesses—to build or implement significant components of their final services, and Software-as-a-Service (SaaS), which offers ready-to-use applications with minimal need for additional development or integration by the end user. See Manganelli A., Schnurr D. (2024) Competition and Regulation of Cloud Computing Services - CERRE Report.

[124] As a matter of fact, in terms of economic function, SaaS applications are services delivered via the cloud rather than services of a generic “cloud market”.

[125] Defined as one among the following: finance or accounting software applications, enterprise resource planning (ERP) software applications, customer relationship management (CRM) software applications, security software applications, hosting

indicators, rather than on the deeper economic and societal implications of cloud adoption. However, even by this lenient definition, the EU's current pace of cloud adoption falls short of the DDPP's stated objective of achieving 75% adoption by 2030. Not necessarily being a meaningful information.

Likewise, AI is currently used by just a small fraction of enterprises: only 13.5% of EU enterprises deploy any form of artificial intelligence in 2024.[126] The mismatch is starkest among small businesses, where AI adoption lingers at just 12.6%, compared with 41% in large firms, reinforcing scale-based productivity divides. At the same time, uptake differs greatly among Member States, from 27.6% in Denmark to about 3.1% in Romania.

Currently, the adoption of AI is neither universal nor uniform. Many firms and workers have not yet found it worthwhile or feasible to integrate AI into their operations, whether due to cost, lack of expertise, insufficient perceived benefits or also an overestimation of the risks involved. This trend is not exclusively European, as official statistics indicate that adoption rates remain relatively low in all OECD area, 13.9% with US at 8.3%, confirming that AI adoption is still at an early stage compared to other ICT technologies.[127]

Specifically, in the EU the generic percentage of enterprises using AI is well below the expected DDPP trajectory, supposed to get to 75% by 2030. The target of 75% of enterprises using AI is expected to be reached in 2042 if no further actions are taken.

It is important to highlight that several "consumer-oriented" and "user-friendly" AI applications have instead experienced remarkably rapid adoption. For example, as widely known, ChatGPT reached 100 million users within just two months - faster than any previous internet application.[128] As a result, the uptake of AI among EU and global firms has accelerated significantly since 2024.

However, while the swift diffusion of AI may be partly attributed to its usability and accessibility, the technology's real impact depends heavily on how it is deployed—specifically, for which tasks, by whom, and what is level of expertise and trust in generative AI.[129] Off-the-shelf AI tools can be quickly adopted to automate routine or "easy-to-learn" tasks. Yet, achieving a deep and transformative integration of AI into production systems remains a long-term endeavour requiring significant adaptation, investment, and organisational change.

In sum, although AI and cloud targets are inherently demand-side measures and reflect how technologies are being leveraged within the economy, setting absolute numerical targets for adoption may offer limited economic insight. Firstly, adoption targets focus on means rather than on outcomes. For example, evidence suggests that (i) many EU firms use cloud and AI services in superficial ways,

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the enterprise's database(s), and computing platform providing a hosted environment for application development, testing or deployment.

[126] EU enterprises utilised various AI technologies, with no single technology dominating. In 2024, 6.88% used AI for written language analysis (text mining), followed by 5.41% using natural language generation. Other technologies, such as speech recognition, machine learning for data analysis, workflow automation, and image recognition, were used by 3.23% to 4.78% of enterprises. Only 1.01% used AI for autonomous machine movement.

[127] Kergroach S., Héritier J. (2025) Early Divides in the Transition to Artificial Intelligence - OECD Regional Development Papers No. 147; Filippucci, Gal, Jona-Lasinio, Leandro, Nicoletti (2024), cit.

[128] From its commercial introduction, it took 75 years for the telephone to reach 100 million users; 16 for mobile phones; 7 for the World Wide Web; 2.5 years for Instagram; 9 months for TikTok; and only two months for Chat GPT.

[129] Calvino F., Reijerink J., Samek R. (2025) The effects of generative AI on productivity, innovation, and entrepreneurship – OECD Artificial Intelligence Papers n 39.

with little operational impact, and (ii) often lack managerial capacity or complementary skills to achieve productivity gains.[130] In a nutshell, current quantitative targets largely neglect the quality, relevance, or depth of digital transformation, and this extends also to the other targets regarding skills and public service.[131]

Secondly, the homogenous, formalistic, and quite arbitrary setting of targets can be a source of inefficiencies in the focus of policy makers and public funding: expecting 75% of all EU businesses to adopt cloud or AI technologies ignores sector-specific use cases, opportunity costs, and variation in technology spillovers. Indeed, the uptake of cloud and AI services as well as related challenges differ from sector to sector, and it has been widely recognised that Europe should develop AI for specific use cases and vertical applications, especially in industrial sectors where it could hold competitive advantages – which is "even more critical than raw supercomputing power".[132] This is also aligned with the Apply AI Strategy[133], recently published by the EC, which has sector-by-sector targeted measures to boost AI adoption across 10 key industry sectors and the public sector (see **Annex**).

Therefore, a recalibrated approach should: (i) introduce ex-ante rigorous impact assessments to inform target setting; (ii) adapt goals to sectoral and regional economic logic; and (iii) shift from headline adoption rates to depth, quality, and productivity of use.

In this perspective, a more economic approach would: (i) differentiate adoption across sectors and industry segments according to their expected impact; (ii) prioritise the timing of adoption in sectors with the highest multiplier effects; and (iii) geographically reflect both complementarities in technology development (e.g., between industrial AI, edge computing, or 5G SA/6G) and differentiated regional capabilities. Such an approach would ensure that the EU focuses not on symmetry for its own sake, but on the strategic allocation of resources where returns to public and private investment are highest.

By refining its framework in this way, the Digital Decade could evolve from a mere ICT and digital checklist into a *coherent industrial strategy*, aligned with Europe's economic structure, policy capabilities, and long-term growth potential.

A complementary and pragmatic step would be to (also) adopt dynamic targets, benchmarking progress against the United States to assess whether the EU is lagging or leading. Accordingly, EU policy frameworks - particularly the Digital Decade targets - should integrate a dynamic competitiveness dimension by institutionalising some form of "yardstick competition":[134] adoption

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[130] Bencivelli L., Formai S., Mattevi E., and Padellini T. (2025) Embracing the digital transition: the adoption of cloud computing and AI by Italian firms – Bank of Italy occasional paper n. 946.

[131] For example, (i) technology depth: firms may report cloud adoption but lack integration into workflows; (ii) skill alignment: not all ICT training meets actual labour market needs; (iii) Public service quality: public e-services may be technically online, yet fragmented, insecure, or user-unfriendly.

[132] "*Sectoral AI applications are even more critical than raw supercomputing power. Here, Europe has a real advantage: its firms hold more than half the global market in industrial automation solutions, a cornerstone of industrial AI. Yet only around 10% of manufacturing firms used AI last year*". See Mr. Draghi intervention at High Level Conference – "One year after the Draghi report: what has been achieved, what has changed" 16 September 2025.

[133] European Commission (2025) Apply AI strategy – COM(2025) 723 final.

[134] The concept of yardstick competition was originally introduced by Shleifer (1985) to describe a regulatory mechanism whereby firms' performances are compared against each other to incentivise efficiency and discourage rent-seeking. See Shleifer, A. (1985), A Theory of Yardstick Competition, in The RAND Journal of Economics, Vol. 16, No. 3, pp. 319–327. For

indicators should be adjusted periodically (e.g., once every two years) in line with US performance trajectories, ensuring that EU targets consistently exceed concurrent US achievement levels.

Indeed, while current levels of AI adoption among European firms appear broadly comparable to those in the United States, [135] as previously described, the EU faces persistent structural constraints stemming from industrial composition and firm-size distribution. These disadvantages create a dynamic handicap: even when adoption rates temporarily converge, Europe's underlying capacity to translate adoption into productivity gains and competitive advantage remains constrained relative to US peers operating at greater scale and with superior access to capital. Recognising these systemic disadvantages, the EU should aspire to consistently outperform the United States in the diffusion and targeted adoption of digital and advanced technologies to overcome its structural disadvantages and progressively narrow the innovation and productivity gaps that have accumulated over the past two decades.

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more recent discussion of yardstick competition in innovation policy contexts, see OECD (2010), Measuring Innovation: A New Perspective, and OECD Competition Committee (2023), Competition and Innovation: A Theoretical Perspective, which discusses how benchmarking and comparative performance mechanisms can support innovation objectives.

[135] According to the 2024 AI Index Report, the proportion of European firms reporting the use of AI technologies saw a significant rise in 2023, nearly matching that of North America (57% compared to 61%). See, Maslej, N., Fattorini, L., et al. (2024) The AI Index 2024 Annual Report – at AI Index Steering Committee, Institute for Human-Centered AI, Stanford University.

4. Conclusions

4.1 Key Findings

This paper has examined the European Union's innovation ecosystem and digital transformation through the lens of competitiveness, revealing a complex interplay between structural constraints and policy design shortcomings that continue to hinder EU innovation and productivity growth.

To this end, section 2 assessed the EU's performance on the principal drivers of innovation-led competitiveness and benchmarked these outcomes against those of the United States. Section 3, in turn, has expanded the analysis of adoption and diffusion of ICT across Member States, with particular attention to connectivity, cloud infrastructures, and artificial intelligence.

In pursuing this analysis, the paper addressed crucial cross-cutting policy questions, including:

- What are the principal causes of the EU's innovation gap, and to what extent are current EU policies contributing to close it?
- To what degree are the creation and scaling of EU-based technology firms essential to competitiveness, and what trade-offs might this entail for broader digital diffusion?
- How effectively is the EU is performing in the diffusion and productive utilisation of digital technologies, and how robust and meaningful is the contribution of the DDPP targets?

Before addressing each specific questions, it is important to acknowledge that, although this paper does not directly engage with the implementation of the Single Market, the effective integration and consolidation of a unified EU Single Market - comprising 440 million consumers and 23 million companies – emerges as a fundamental structural condition for enabling all core drivers of innovation-based competitiveness.

The Single Market is pivotal for multiple dimensions of competitiveness, e.g., enhancing frontier innovation capacity, also through EU-level coordination of public R&D spending; allowing the scaling-up of young, innovative companies and large industries capable of competing globally; mobilising greater volumes of private finance; fostering broader technology adoption across sectors; stimulating intangible investment to unlock productivity potential of ICT investments; and strengthening domestic demand and overall investment.

Accordingly, the answers to the cross-cutting policy questions, as well as the recommendation in the next section, are premised on the progressive implementation of the Single Market reform agendas proposed in Letta and Draghi policy paper, which are fundamental for building a sustained innovation-driven competitiveness in the EU.

On the first core policy question— the innovation gap—this paper finds that EU competitiveness deficit stems not only from the lower quantity of R&D investment, but more importantly from its limited capacity to translate research and innovation into productivity-enhancing outcomes. Large-scale investments are likely to yield more substantial productivity gains, which is calling for consolidating the fragmented nature of both public and private R&D funding and industrial policies. In addition, the weaker performance in ICT patenting may underscore a broader perspective weakness in innovation-driven competitiveness, which should be addressed by maintaining an effective and balanced IPR framework system that incentivise innovation and support competitiveness. While the Competitiveness Compass offers a broad and ambitious policy agenda, for the moment it still falls short of adequately addressing the chronic failure to convert R&D efforts into measurable productivity gains.

On the second question—the creation and scaling of EU-based tech companies— the evidence highlights structural impediments that also underlie the innovation gap. These include Europe's mid-tech industrial base, fragmented digital markets, a firm landscape dominated by SMEs, and shallow capital markets—conditions that hinder the emergence of globally competitive technology firms. As a result, the EU has struggled to foster digital champions. However, it is worth stressing that not all the US productivity advantage is directly derived from its major tech platforms, while these may instead also be one of its results. So going trying to emulate a "US-model" without addressing the underlying problems could be ineffective and very inefficient. Thus, attempting to replicate the US model may be neither feasible nor desirable. Instead, a polycentric digital architecture, where telecom providers and ICT manufacturers play a more active role, may represent a more adequate and balanced path for the EU. In this regard, the Competitiveness Compass includes promising initiatives - such as the proposed "28th regime" and measures to deepen venture capital markets - though actions related to reducing strategic dependencies must be carefully designed to avoid creating complex trade-off between fostering the scale up of EU companies and ensuring broad-based digital diffusion.

On the third question—the achievement and effectiveness of digital diffusion targets— the EU performs well in terms of basic digital infrastructure and digital services, aligning broadly with other major jurisdictions. However, it continues to lag in both the development and usage of some of the more advanced infrastructures and services. Moreover, like at higher levels of the innovation chain, European firms exhibit a lower capacity to translate ICT investments into productivity gains. This is primarily due to smaller average firm size and limited capacity to invest in the complementary intangible assets—such as skills, software, and organisational capital—required for effective digital transformation. Therefore, those disadvantages should be addressed, also through mechanisms for enhancing financing for companies' intangible investments. Yet, in any case, Europe should aim to outperform the US in the diffusion and productive use of ICT and digital technologies across its broader industrial ecosystem. These structural weaknesses are currently not meaningfully addressed by the Digital Decade Policy Programme (DDPP), which retains a strong supply-side and homogenous target-setting bias. By prioritising coverage over adoption, and adoption over economic performance, the DDPP overlooks the critical importance of demand heterogeneity and sectoral context in driving digital impact.

4.2 Policy Recommendations

Drawing on the key findings and the overall analysis, the following policy recommendations are proposed:

Recommendation 1 - Rebalance public R&D funding toward high-impact innovation in high-tech sectors
To address current funding patterns that disproportionately benefit established, medium-technology sectors, the EU should:

- reallocate public R&D subsidies toward mission-oriented innovation in high-tech sectors, and
- strengthen coordination of R&D efforts among member states, concentrating funding to support breakthrough innovation with greater systemic and cross-sectoral impact.

Recommendation 2 - **Foster cross-sectoral financing partnerships for market-oriented high-tech R&D**

Facilitate structured partnerships between EU mid-tech and EU high-/deep-tech firms to develop joint financing vehicles, such as corporate venture funds or co-investment platforms, dedicated to market-oriented R&D in Europe.

Recommendation 3 – **Maintain a balanced intellectual property rights (IPR) framework to foster innovation-driven competitiveness**:

Maintain a balanced intellectual property framework able to support EU innovation, especially in sectors with high R&D intensity and where R&D is inherently market oriented. Given the peculiar characteristics of EU innovation ecosystem and critical role of licensing revenues in financing European innovation, the EU should preserve IP protection, while promoting industry-based solutions to encourage involvement, upstream and downstream, of EU innovative SMEs in order to further stimulate incremental improvements and differentiation in the innovation ecosystem.

Recommendation 4 - **Enhance the productivity yield of R&D through stronger innovation–deployment alignment**
To increase the effectiveness and productivity impact of R&D investment, the EU should:

- Ensure that R&D support is tied to downstream adoption incentives, including demand-pull levers like tax credits, and
- Foster cohesive innovation ecosystems, by promoting partnership among large market actors (upstream and downstream), start-ups, public research institutions, universities, and financing entities.

Recommendation 5 - Strengthen regulatory impact assessment to support competitiveness and innovation

Ensure that ex-ante impact assessments for digital/ICT policymaking and regulation systematically include:

- Profitability analysis of EU ICT-intensive firms, recognising that declining profitability can discourage capital reallocation toward high-tech sectors, thereby reinforcing the “mid-tech trap.”
- Appraisal of the orchestration function within a contestable, fair digital ecosystem—as a source of value creation, a bridge from R&D to market, and a catalyst for the adoption and diffusion of digital technologies.

Recommendation 6 - Apply proportional and risk-based principles to strategic autonomy measures: When strategic autonomy actions are deemed necessary, they should be defined and implemented in accordance with proportionality and risk-based principles, by:

- Assessing the impact of strategic autonomy measures on the diffusion and uptake of ICT and digital technologies.
- Concentrating autonomy efforts and associated costs where security considerations or systemic dependencies clearly justify intervention, while distinguishing between measures targeting service for private entities and those for governments and public administrations;
- Framing tread-offs and proportionality assessments to differentiate (where feasible) between “enabling” measures aimed at fostering EU-based alternative supply chains, and “restrictive” measures designed to directly limit the presence of non-EU providers.

Recommendation 7 - Adopt differentiated target-setting aligned with economic potential and regional characteristics

Implement differentiated digital targets that reflect regional economic potential and structural characteristics. Rather than pursuing uniform “universal service” coverage, policy should prioritise high-impact deployments in economically strategic areas, those most likely to generate transformational productivity gains and broader spillover effects.

Recommendation 8 - Institutionalise ex-ante impact assessments for digital infrastructure investment

Introduce systemic ex-ante impact assessments for digital infrastructure investment, particularly where anticipatory public (or publicly incentivised) investments are envisaged. Such assessments should account for market absorption capacity, heterogeneous returns, and regional economic logic, externalities, and productivity multipliers, ensuring that investments are both demand-responsive and economically justified.

Recommendation 9 - Redesign digital adoption targets toward outcome-based, dynamic benchmarking

To shift from uniform, quantity-based digital adoption targets toward differentiated, outcome-oriented objectives, including skills acquisition, effective utilisation rates, and productivity impact metrics. Also, to establish a dynamic transatlantic benchmarking framework to align EU performance targets with U.S. trajectories, ensuring that EU consistently exceed concurrent US achievement levels.

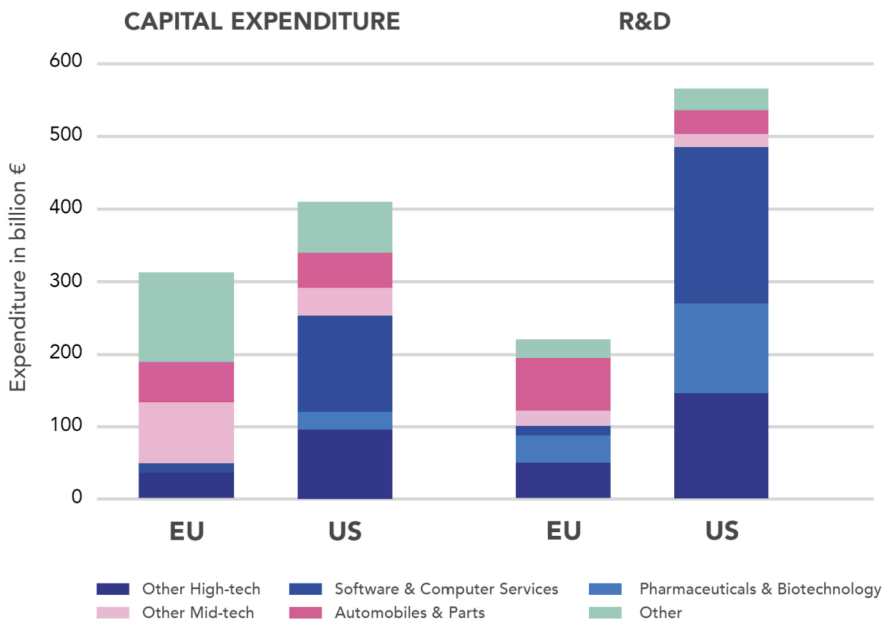
Recommendation 10 - Create EU-level financing instruments for intangible capital formation

To establish dedicated EU-level financing mechanisms to support intangible capital formation, including organisational innovation, software development, and workforce training. These instruments should address the structural limitations of Europe’s debt-based financing system, which insufficiently supports intangible investments—a crucial component in enhancing the productivity returns of ICT adoption.

Appendix A: "Mid-Tech Trap" and access to finance

US companies invest heavily in high-tech sectors such as software and biotechnology, where R&D intensity and profit margins are high, while European firms remain largely concentrated in mid-tech industries like automotive and mechanical engineering.[136]

Figure 13 - CAPEX and BERD by industry sector (2023)



Source: Gros et al. (2024) based on EU Industrial R&D Scoreboard.

In the US, high-tech sectors tend to generate a virtuous cycle: larger market shares lead to more R&D investment, which reinforces technological leadership and global competitiveness (**figure 13**). In contrast, Europe's path dependency on mid-tech sectors has led to what has been defined as "middle technology trap",[137] where innovation is mostly made of small incremental improvements and incentives for disruptive high-tech innovation remain weak, ultimately limiting the scale and dynamism of Europe's innovation ecosystem. This situation implies a misalignment between R&D investment and breakthroughs in sectors generating higher value added and where R&D has a higher impact on firms' productivity.[138]

Nor can Europe compete sustainably and profit from high-volume, low-tech manufacturing (textiles, basic consumer-goods assembly, commodity production) that relies on labour-intensive, standardised processes where low labour costs are decisive - sectors where European labour costs are 10-20 times

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[136] Meyers Z. (2025) A framework for understanding EU competitiveness – CERRE Report.

[137] Fuest C., D. Gros, Mengel P.-L., Presidente G., Tirole J. (2024) EU Innovation Policy - How to Escape the Middle Technology Trap - IEP@BU report.

[138] Ortega-Argilés, R., Piva, M., Vivarelli, M. (2015) The productivity impact of R&D investment: Are high-tech sectors still ahead?, in Economics of Innovation and New Technology, 24(3), 204–222; Czarnitzki D., Thorwarth S. (2012). Productivity effects of basic research in low-tech and high-tech industries, in Research Policy, 41(9), 1555–1564; Kancs, d'Artis, Siliverstovs, B. (2016) R&D and non-linear productivity growth, in Research Policy, 45(3), 634–646.

higher than Asian competitors. Europe has experienced sustained disinvestment from these industries without fully transitioning to high-tech, thus remaining “trapped” in the middle(-tech) where there is stable but slow growth as well as progressively declining profit margins.

Europe has seen sustained disinvestment from these activities without a full pivot to high tech, leaving it ‘trapped’ in the middle-tech segment: stable but slow growth, and steadily eroding profit margins.[139]

These EU-US divergent trajectories toward high-tech have developed over the past two decades: in 2003, the US and EU both counted automotive companies among their top R&D investors; however, while the US transitioned toward high-tech - by 2022 its top R&D spenders were all software companies, the EU, as well as Japan, remained anchored in mid-tech sectors like automotive. [140]

Figure 14 - Top-3 R&D spenders and their industries compared over time

	2003	**2013**	**2023**
EU	Mercedes-Benz (auto) Siemens (electronics) Volkswagen (auto)	Volkswagen (auto) Mercedes-Benz (auto) Bosch (auto)	Volkswagen (auto) Mercedes-Benz (auto) BMW (auto)
US	Ford (auto) Pfiser (pharma) GM (auto)	Microsoft (software) Intel (hardware) Merch (pharma)	Alphabet (software) Meta (software) Apple (hardware)
JPN	Toyota (auto) Panasonic (electronics) Sony (electronics)	Toyota (auto) Honda (auto) Panasonic (electronics)	Toyota (auto) Honda (auto) NTT (telecom)

Source: Data from the EU Industrial R&D Scoreboard (2024)

The US was able to shift its industrial base toward higher-growth and higher-margin sectors, counteracting the typical path dependencies that characterise innovation and industrial specialisation, [141] while the EU remained locked into its historical trends.

A key factor underpinning this divergence has been found in the profitability differential (**figure 15**): in the US, high-tech firms enjoy a roughly 7 percentage point margin advantage over mid-tech firms, creating a strong incentive for capital reallocation. In Europe, this margin is only about 3 percentage

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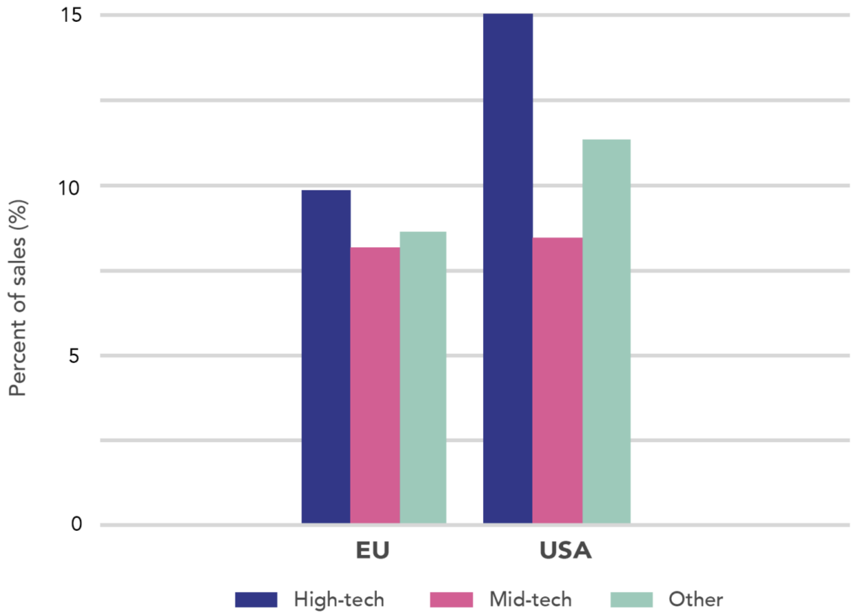
[139] Even the EU automotive sector - Europe's largest - industry now faces existential pressure. The EU export-oriented growth model confronts increasingly protectionist policies from both the US and China; moreover, the technological shift to electric vehicles, on one side, and the importance of in-vehicle and networked software applications, on the other side, is eliminating traditional European competitive advantages, based on mechanical engineering.).

[140] In 2023, the automotive sector accounts for 34.2% of total EU business R&D expenditure, representing approximately €73 billion annually, which makes Europe the world's largest investor in automotive, surpassing Japan (€33.6 billion), the US (€33.6 billion), and China (€22.2 billion).

[141] See, e.g., Acemoglu D. (2023) Distorted innovation: does the market get the direction of technology right?, AEA Papers and Proceedings, in American Economic Association 113; Aghion P., Antonin C., Bunel S. (2021) The power of creative destruction: Economic upheaval and the wealth of nations; Aghion P., et al. (2016) Carbon taxes, path dependency, and directed technical change: Evidence from the auto industry, in Journal of Political Economy 124.1 (2016): 1-51. Melitz M., Redding S. J. (2021) Trade and Innovation - NBER Working Paper No. w28945.

points, offering much weaker signals for industrial transformation and often not compensating (at least in the short term) the costs of transaction. [142]

Figure 15 – Average profit margin by sector (2003-2022)



Source: Gros et al. (2024) on data from Industrial R&D Investment scoreboard 2023

This transformation was also driven in the US by strong total factor productivity (TFP) growth in the ICT and software-producing sectors, further amplified by the positive externalities generated within R&D-intensive clusters. These clusters —comprising large corporations, startups, universities, and venture capital firms—played a pivotal role in fostering innovation. Not only did they stimulate entrepreneurship[143], but they also enabled firms to rapidly acquire cutting-edge technological capabilities, particularly in emerging fields often rooted in university research.[144]

Such a dynamic and integrated environment facilitated the rapid development and diffusion of digital technologies in the United States, in stark contrast to the more cautious and incremental innovation patterns observed in much of Europe. In contrast, Europe's innovation system lacks comparable scale-driven loops, constraining the emergence of global technology champions and dampening incentives for high-risk, frontier investment.

Moreover, the EU outperforms the US in terms of productivity within mid-tech sectors. This advantage reflects the higher concentration of EU firms (and larger firms) operating in mid-tech industries, and their higher physical capital expenditure (**Figure 13**). Capex has a greater impact on productivity in

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[142] Gros D., Mengel P-L, Presidente G. (2024) What Investment Gap? Quality Instead of Quantity - IEP@BU Policy Brief; Dietrich A., Dorn F., et al. (2024) Europe's Middle-Technology Trap, in EconPol Forum, 25(4), 33-39.

[143] Delgado, M., Porter, M. E., Stern, S. (2010) Clusters and entrepreneurship, in Journal of economic geography, 10(4), 495-518.

[144] Mohnen, P., Hoareau, C. (2003) What type of enterprise forges close links with universities and government labs? Evidence from CIS 2, in Managerial and decision economics, 24(2-3), 133-145; Valero, A., & Van Reenen, J. (2019) The economic impact of universities: Evidence from across the globe, in Economics of Education Review, 68, 53-67.

low- and medium-tech firms than in high-tech ones, as higher levels of output per worker (Labour Productivity) are often driven by tangible capital deepening, such as increased investments in machinery, equipment, and physical infrastructure aimed at enhancing workforce efficiency.

This pattern is also closely aligned with the structure of corporate financing in Europe, where firms rely predominantly on debt financing - an instrument naturally suited to supporting tangible, physical investments that can serve as collateral. By contrast, debt is inherently ill-suited for early-stage innovation and generally inadequate for large-scale, high-risk investment projects. This marks a significant transatlantic divergence in the financing of innovation[145]: compared with their U.S. counterparts, European firms face greater constraints in accessing equity financing and venture capital. As underscored by both Draghi and Letta, these structural disadvantages in accessing deep, long-term “patient capital” [146] have resulted in a persistent shortfall for Europe in developing and scaling new technologies to their full commercial potential.

As specified later for the automotive, the sector specialisation and the structure of financial system are interdependent self-reinforcing factors in the mid-tech trap: in facts, over 80% of venture capital investment by EU based large companies—which are unlikely to be financially constrained—finance US-based startup.[147] In addition, there is a huge gap in financing for later-stage growth between the EU and the US.[148]

EU scale-up firms have raised, on average, 50% less capital than their US counterparts in the last ten years. [149] As a result, many EU-originated innovative firms, especially start-ups and scale-ups, turn to U.S. venture capital and view expansion into the vast, unified American market as a more attractive and feasible growth strategy, rather than facing the substantial challenges of operating across the fragmented landscape of the European Union.[150]

The result, as well known, is a striking scale deficit: by their tenth year, European digital scale-ups have raised 50% less capital than their Silicon Valley peers and the number of “unicorns” established in the EU, in 2024, has reached 286 units, still lagging significantly behind China (397) and the US (1687).[151]

The EU automotive sector provides a complementary and instructive perspective on this dynamic. In response to the digital and technological transformation impacting the industry, companies are

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[145] Aghion L., Howitt P., Levine R. (2018) Financial development and innovation-led growth, in Handbook of finance and development (pp. 3-30); Garcia-Macia D. (2017) The financing of ideas and the great deviation - International Monetary Fund Paper No. 2017/176.

[146] In this context, “patient capital” refers to investment that is willing to accept longer payback periods and higher uncertainty in order to support breakthrough R&D and the scaling of innovative companies. This type of financing — prevalent in the US, where large venture funds and capital markets sustain multi-year innovation cycles, and in China, where state-backed investment plays a similar role — is far less accessible in Europe. The result is that promising European firms often struggle to secure the resources needed to compete globally, leading in some cases to relocation abroad or acquisition by non-European players.

[147] Gros D., Mengel P-L, Presidente G. (2024), cit.

[148] Quas A., Mason C., Compañó R., Testa G., Gavigan J. P. (2022) The scale-up finance gap in the EU: Causes, consequences, and policy solutions, in European Management Journal, 40(6), 833-844.

[149] Fratto C., Gatti M., Kivernyk A., Sinnott E., van der Wielen W. (2024) The scale-up gap: Financial market constraints holding back innovative firms in the European Union, at: https://doi.org/10.2867/382579; European Investment Bank (2025), cit.

[150] Weik S., Achleitner A-K., Braun R. (2024), Venture capital and the international relocation of startups, in Research Policy, Volume 53, Issue 7; Arnold, N. G., Claveres, G., & Frie, J. (2024) Stepping Up Venture Capital to Finance Innovation in Europe - IMF Working Paper No. 2024/146.

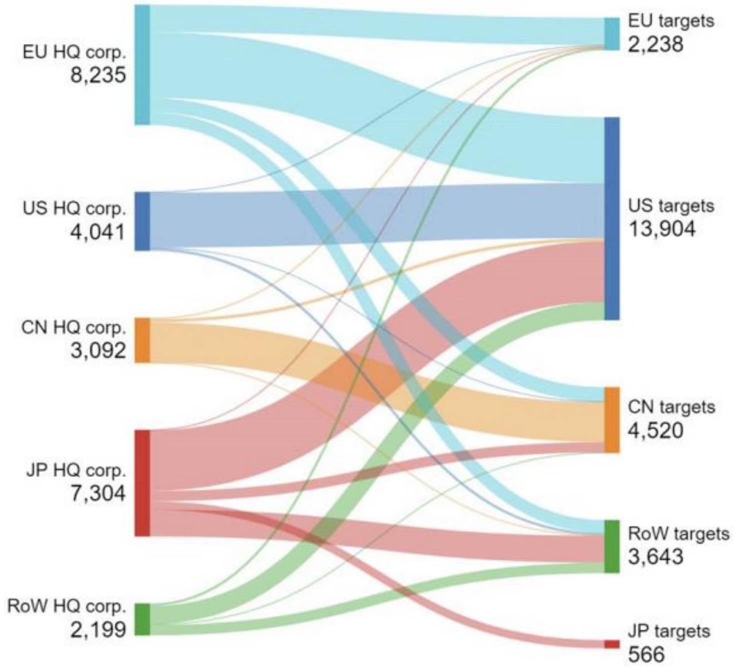
[151] European Commission (2025) Digital Decade in 2025: progress and outlook – Commission Staff Working Document, SWD (2025) 290 final.

directing investments toward the technological innovations reshaping the sector: autonomous driving, advanced sensor technologies, and related digital capabilities. This is done through several strategies, prominently including Corporate Venture Capital (CVC). [152]

EU automotive leaders are deploying CVC at levels comparable to their Japanese competitors and higher to US and Chinese ones. Notably, high-tech newcomers to automotive, such as Tesla and BYD (respectively headquartered in US and China), are primarily recipients of venture capital financing, including corporate VC, rather than themselves deploying venture capital into other startups – this also explains the reduced magnitude of US and Chinese VC financing from the automotive leaders.

A clear and meaningful pattern emerges when examining where automotive CVC investors, organised by their headquarters' regions, are allocating capital to fund startups. The overwhelming majority of global automotive CVC flows to US-based startups, including investments by both EU and Japanese automotive leaders (**Figure 16**). [153] In contrast, CVC from leading Chinese and US automotive firms is invested predominantly domestically.

Figure 16 - CVC investment flows between regions, EUR million



Source: Gavigan et al. (2024)

These geographic dynamics reveal two critical insights:

- First, consistency across sectors. The CVC-to-VC ratio between the US and EU for automotive mirrors the broader pattern across all sectors. From 2010 to 2023, automotive companies invested 6.21 times more CVC capital in the US than in the EU- virtually identical to the 6.27x ratio for total VC investment across the two economies during the same period. This suggests

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[152] Gavigan J., Fákó P., Compañó R. (2024) Corporate Venture Capital in the Automotive Sector - JRC Working Papers on Corporate R&D and Innovation (CoRDI) No 02/2024

[153] Gavigan J., Fákó P., Compañó R. (2024), cit. The analysis is carried out considering those VC deals involving the top five R&D investing automotive companies by corporate HQ location for EU, US, China, Japan and ROW (rest of the world)

the VC gap is not automotive-specific but structural, reflecting the EU’s problematic functioning of equity financing.[154]

- Second, reinforcement of the mid-tech trap. EU and Japanese automotive firms' decision to invest their CVC predominantly outside their home regions, rather than in their own innovation ecosystems, risks deepening their domestic mid-tech trap. By channelling capital to US-based ventures rather than funding domestic high-tech startups, European automotive companies (i) further incentivise the systemic transfer of EU innovative start-up to US; and (ii) cause a transfer abroad of those capitals that are specifically meant to reallocate resource from mid-tech to high-tech.

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[154] Ibidem.

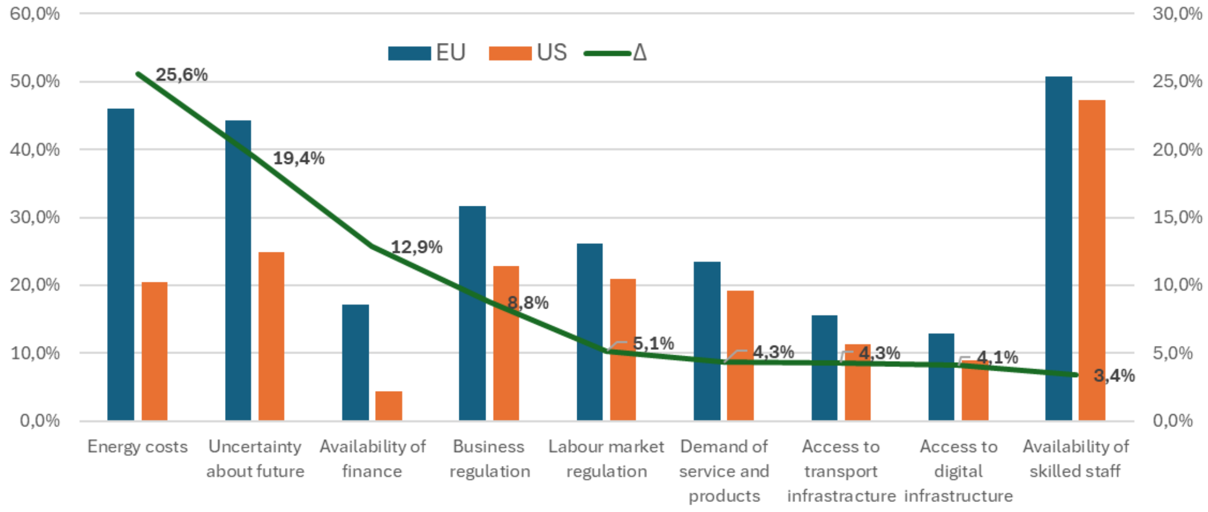
Appendix B: Strategic Autonomy and the Cloud and AI Development Act

I. EU digital companies scale and EU Strategic Autonomy

Draghi and Letta reports have markedly stressed that European companies remain overwhelmingly small: SMEs represent 99.8% of all EU firms - with micro-enterprises alone accounting for 93.3% of the total, while only 0.2% of businesses employ more than 250 workers.

A recent survey by the European Investment Bank (EIB) [155] assesses firms' perceptions of investment barriers across the European Union that inhibit scaling. The findings (figure 17) show that the most significant obstacles to investment include the availability of skilled personnel, high energy costs, uncertainty about the future, and restrictive business and labour market regulations. When compared with the United States, these factors - apart from skill shortages, which are similarly reported overseas - remain major sources of competitive disadvantage for European firms: energy costs (25.6% EU-US gap), uncertainty about the future (19.6%), business regulation (8.8%), and labour market regulation (5.1%). In addition, limited access to finance represents one of the most substantial negative differentials relative to U.S. firms, with a 12.9% gap—equivalent to an approximately 3:1 ratio (see **Appendix A**)

Figure 17 - Major investment impediment (perceived) in the EU and in the US



Source: Elaboration on data from EIB Investment Survey 2025 - European Union overview

This skew is even sharper in the digital economy, where most EU players are start-ups, and where just four EU-headquartered tech firms (i.e., ASML, SAP, Siemens and Schneider Electric) make it into the global top-50 by market capitalisation, while the US-based "big tech" - Apple, Microsoft, Alphabet, Amazon, Nvidia, Meta - are the most capitalised companies in the world, each one dwarfing the combined EU largest ones. Notably, no European company established from the ground up in the past

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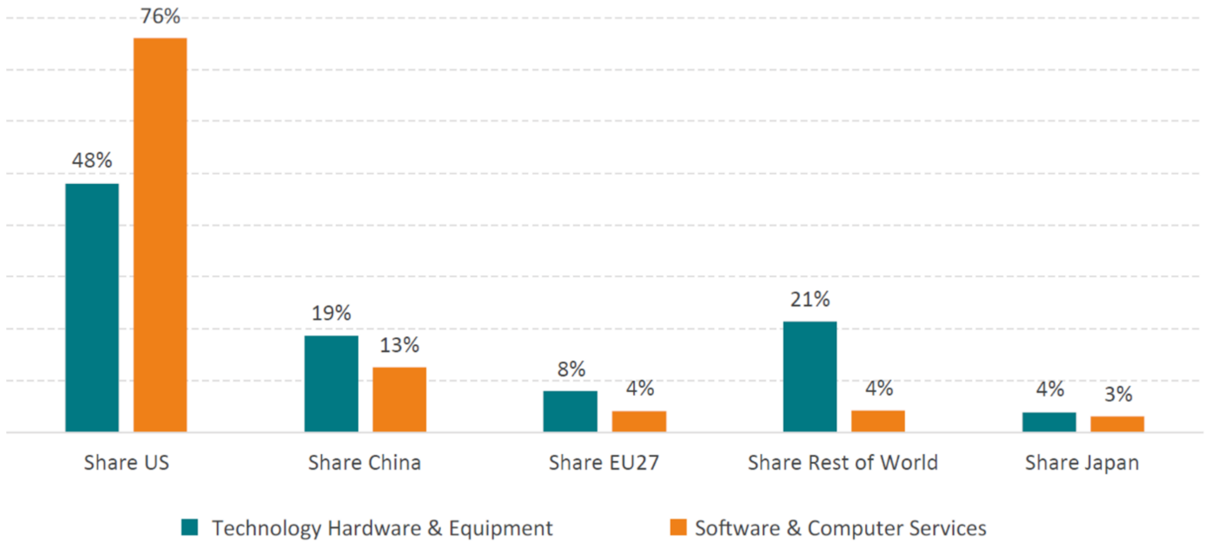
[155] European Investment Bank (2025) Investment Survey 2025 - European Union overview.

fifty years has reached a market capitalisation exceeding EUR 100 billion. In contrast, all six U.S. companies valued above EUR 1 trillion were founded within this same timeframe.

The largest US tech firms are also the heaviest investors, as for ICT capital expenditure and R&D. As noted, EU-headquartered companies represent a relatively low investment share in key global ICT investments – 8 % in technology hardware and equipment, compared to 48% of the US share, and 4 % in software and computer services, compared to 76% for US.

Figure 18 – Share of Capital expenditure and R&D in Global investments by leading Tech companies, 2022



Source: European Commission (2023) EU industrial R&D Investment Scoreboard

This situation, on one side, shows the importance of US technology solutions for Europe's digital economic transformation,[156] yet, on a different perspective, also underscores the fact that, currently the EU depends on foreign countries for over 80% of its digital products, services, infrastructure.[157]

In this regard, Draghi is of the opinion that EU ought to reduce its existing large external dependencies, as those "could become vulnerabilities in a situation where trade fragments along geopolitical lines."[158]

Following this line, the third pillar of the EU Competitiveness Compass - complementing the first pillar focused on closing the innovation gap (see **Annex**) - targets the reduction of strategic dependencies and the enhancement of security. Both pillars ultimately seek to bolster the EU's "strategic autonomy", but they do so from different angles and on distinct timelines. This divergence makes their coordination particularly important and complex.

The enduring concept of "strategic autonomy" [159] - initially meaningfully framed as "open" strategic autonomy - highlights the European Union's ability to act independently in key areas while maintaining

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[156] Bauer M., Pandya D. (2024) ICT Beyond Borders: The Integral Role of US Tech in Europe's Digital Economy, ECIPE Policy Brief 06/2024.

[157] Eu Commission (2023) Report on the state of the Digital Decade 2023.

[158] Draghi Report (2024), cit.

[159] Cagnin C., Muench S., Scapolo F., Stoemer E., Vesnic Alujevic L. (2021) Shaping and securing the EU`s Open Strategic Autonomy by 2040 and beyond - JRC paper; Kroll H. (2024) Assessing Open Strategic Autonomy - JRC paper.

constructive global partnerships. It entails the capacity to decide when and how to exercise such independence, reinforcing a vision of "interdependence" - rather than independence - supported by credible alternatives that reduce vulnerability to critical dependencies.

This objective can be pursued through policy responses that broadly fall into two types of action:

- Measures aimed at fostering EU-based alternative supply chains ("enabling"), and
- Measures designed to restrict or limit the presence of non-EU providers ("restrictive").

Although their boundaries are not always clear-cut, and may be not mutually exclusive, as policies may contain both elements, the distinction matters analytically and normatively.

Of these, the second approach, focused on limiting the supply from non-EU providers, requires careful evaluation – particularly if enforced in a short timeframe. Indeed, any dependency underlies a need, and whether alternative EU providers exist and can be supported to such an extent to provide the same variety and quality of service is not a trivial question and very much depends on the specific sector and service we are considering. A quest for greater independence in the short term always carries potential risks, including slower digital diffusion, lower service quality, and reduced consumer choice. Such trade-offs highlight the complexity of the current policy landscape[160]: striking the right balance is therefore essential to ensure that efforts to secure autonomy do not inadvertently hinder the innovation cycle that the Competition Compass aims to accelerate.

Instead, the first approach is increasingly viewed in a more favourable light, as it aligns with long-standing structural gaps in EU industrial policy and actively promotes the development of European industry. As Mario Draghi recently emphasised, in a shifting geopolitical context where all major powers are moving to reduce external dependencies and reclaim strategic autonomy, the EU must articulate a coherent industrial policy, centrally coordinated and strategically guided. [161]

An enabling approach can be understood, in terms of market outcome, as the industrial policy equivalent of pro-competitive regulation that counteract structural and economic advantages and boost competition. This approach can progressively enable European firms to compete more effectively, both in private markets and in public procurement. However, it should be carefully designed since, like pro-competitive regulation, enabling policies may face two constraints: (i) threshold effects - insufficient support fails to overcome structural disadvantages, yielding costs without competitive benefits; and (ii) dependency effects - excessive or prolonged support can create dependency on the public intervention rather than building genuine capacity.

In addition to the type of action ("enabling" versus "restrictive"), another dimension of a strategic autonomy policy contributes substantively to define and frame its potential trade-offs: the scope of the action, i.e., measures targeting service for private entities (consumers and businesses) as opposed

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[160] Mayers Z. (2025) A framework for understanding EU competitiveness – CERRE issue paper.

[161] While Member States have begun adjusting their strategies with more assertive industrial and strategic policies, these efforts at EU level are often uncoordinated and fragmented, diluting their collective impact. Coordination challenge is twofold: (i) between Member States: National-level interventions often lead to duplicated efforts, and divergent standards, and neglected cross-border externalities, weakening the effectiveness of Europe-wide action; and (ii) across policy domains: in leading global economies like the US and China, industrial policy is increasingly multi-dimensional, linking fiscal incentives, trade enforcement, and foreign economic tools into integrated national strategies, while replicating this in the EU context requires strong alignment between national priorities and EU-level governance.

to measures targeting services for governments and other public administrations ("private" versus "public").[162]

Policy options targeting services for public bodies do not necessarily imply smaller trade-offs in economic terms; rather, the analytical framework may be subject to a shift reweighing when national security enters the equation. In these domains, a precautionary approach could be considered more justified, in order to prioritise protection against low-probability but high-consequence risks (foreign surveillance, infrastructure disruption, coercive leverage) even when such risks cannot be precisely quantified. This contrasts with the proportionality principle, which is adopted in EU law as a regulatory principle and widely recognised to promote market efficiency. Therefore, invoking security to justify precautionary measures cannot be extended indiscriminately, but should be accurately evaluated and targeted.

In this context, the Draghi Report acknowledges that it is important that EU companies maintain a foothold in areas where "technological sovereignty" is possible and required, such as advanced connectivity, security, and encryption. While as for "cloud sovereignty" Draghi's opinion is that "*the EU should ensure that it has a competitive domestic industry that can meet the demand for 'sovereign cloud' solutions. To achieve this goal, the report recommends adopting EU-wide data security policies for collaboration between EU and non-EU cloud providers, allowing access to US hyperscalers' latest cloud technologies while preserving encryption, security and ring-fenced services for trusted EU providers. At the same time, the EU should legislate mandatory standards for public sector procurement.*"

Indeed, despite the expansion of EU cloud providers, US hyperscalers still accounts for about 70% of the market for infrastructure as a service (IaaS) and hosted private cloud. As noted, despite the pro-competitive cloud policies enacted by the EU,[163] this trend is expected to persist due to the economics of the sector.[164] Again, this signals both a large dependency as well as an investment gap for Europe (private and/or public funds) to fill in order to satisfy that need (or part of that need) in alternative ways.[165]This is even more complex considering that it is an objective for the EU to increase that need, by incentivising more EU companies to use different kind of cloud services and use it in a productive-enhancing way.

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[162] This distinction is generally clearer than the enabling/restrictive dichotomy, as the end-user category is more readily identifiable, though grey zones persist in public-private partnerships, critical infrastructure, and dual-use technologies.

[163] Specifically, the Data Act (Regulation 2023/2854) chapter VI and VIII – recently become effective and applicable, and the Digital and Markets Act (Regulation 2022/1925), which has been marked by conceptual and enforcement challenges as far as cloud services are concerned. See Manganelli A. (2025) Policy responses to competition concerns in cloud computing services, in Cloud Services and Competition Policy - Concurrences No 8-2025 On-Topic.

[164] See Manganelli A., Schnurr D. (2024) Competition and Regulation of Cloud Computing Services – CERRE Report.

[165] "It is too late for the EU to try and develop systematic challengers to the major US cloud providers: the investment needs involved are too large and would divert resources away from sectors and companies where the EU's innovative prospects are better." Draghi Report (2024).

II. The Cloud and AI development Act

One of the EU's key policy responses is the forthcoming Cloud and AI Development Act (CAIDA), a central legislative pillar of the Competitiveness Compass (see **Annex**).

The CAIDA legislative proposal, initially scheduled for Q4 2025, is now expected for Q1-2 2026 and is supposed to be structured around three main pillars: (i) Research & Development, (ii) Autonomy, and (iii) Deployment.

The first pillar, (i) Research & Development, focuses on strengthening data processing infrastructures, software, and related services, with a strong emphasis on fostering the widespread adoption of advanced digital technologies. As outlined above, although the European Union benefits from a long-standing tradition of scientific excellence - particularly within its universities and public research institutions - it continues to lag behind the United States and Asia in converting research outputs into market-ready products and achieving broad market diffusion.

The second pillar, (ii) Autonomy, aims to establish a secure, EU-based cloud infrastructure designed to support narrowly defined, highly critical use cases - particularly those requiring elevated levels of data security, such as in the public sector. This initiative seeks to create the conditions necessary for the EU cloud industry to develop sovereign and secure processing capabilities that can adequately serve these mission-critical and strategic needs.

The third pillar, (iii) Deployment, will be implemented through the adoption of concrete quantitative targets, most notably the objective of tripling the EU's data processing capacity within the next five to seven years. This expansion will be underpinned by the development of highly sustainable data centres, addressing a key shortfall in the Union's digital infrastructure. Currently, the EU hosts only about one-third as many data centres as the United States, which considerably constrains its capacity to support large-scale data storage and AI-related processing. [166]

As for Deployment, the objective of tripling the EU's data centre capacity within the next five to seven years is consistent with, and substantially reinforces, the Digital Decade Policy Programme (DDPP) targets. However, as discussed earlier in the context of connectivity, supply-side targets - such as infrastructure deployment - must be assessed against both current and projected demand to ensure a sound rationale for "anticipatory public (or publicly-incentivised) investment". In the case of data centres and AI factories, demand and willingness-to-pay trends are strictly linked with the increase for AI-related workloads, which require substantial data storage and processing capacity.

As noted in the discussion on connectivity, another important consideration in assessing anticipatory public investment relates to the presence of externalities not captured by existing market demand. In the context of cloud infrastructure, such externalities may also be negative, arising from the risk - actual or perceived - associated with the reliance on non-EU-based cloud infrastructure for highly critical use cases. If addressing these risks is necessary to ensure resilience, sovereignty, and trustworthiness of the EU's digital ecosystem, it is however essential to narrowly frame those risks and considering that those negative externalities are mainly internalised either by public subsidies,

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[166] Savills Research (2024) European Data Centres Navigating the new data-centric frontiers, available at: https://pdf.euro.savills.co.uk/european/european-commercial-markets/spotlight-european-data-centres---may-2024.pdf.

crowding-out private investments, or by business and end-users, through higher prices or lower quality. This is the "insurance cost" mentioned by Draghi, which should be, on one side, mitigated by cooperation and, on the other side, effectively minimised – i.e., defined trough a proportional and not precautionary kind of assessment.

Indeed, while CAIDA primarily appears to focus on promotional or "enabling" measures aimed at strengthening the EU's domestic cloud and AI industries, certain provisions about "Autonomy" may in operate as "restrictive" measures, limiting market access for non-EU providers. In this respect, the distinction between enabling and restrictive measures can often be highly blurred, raising questions about the balance between industrial policy objectives and the principles of open competition.

In this context, "cloud sovereign solutions" developed by major hyperscalers have emerged, triggering an ongoing debate on what truly constitutes sovereignty in the cloud domain: whether the mere localisation of infrastructure within the EU suffices, or whether genuine sovereignty requires that cloud providers be European-owned and operated. Alternatively, could transatlantic partnerships, if adequately governed and compliant with EU data protection and security standards, also align with the EU's sovereignty objectives?

This debate is primarily legal and jurisdictional in nature, [167] extending beyond questions of technical architecture or of adoption of technical and organisational requirements-based cybersecurity certification scheme. Therefore, a primary task for CAIDA would be to provide clear definitions avoiding uncertainty reducing fragmentation, as well as ensuring consistency with existing legislation, particularly looking at the interplay with data-related regulatory provisions included in the Data Act and the Digital Markets Act.[168]

For example, how would be framed the interplay with all the different interoperability and data portability obligations in the DMA, Data Act and also GDPR? Or, more generally, what would be the relationship with the Data Act provisions aiming at putting in place safeguards against unlawful international governmental access and transfer of non-personal data?[169] Answering these questions is not trivial, and therefore it calls for clarification and further caution about the effect of new provisions.

While these legal considerations about "restrictive" provisions are undoubtedly important, their substantive implications are even more important and can vary significantly in terms of impact on the market, demand satisfaction and evolution – all of which should always be taken into consideration within any policymaking regulatory assessment.

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[167] Companies may remain subject to the laws of their home jurisdictions, even when data or operations are physically located abroad. Namely, US cloud providers remain subject to American law regardless of where they operate their infrastructure, so to the Clarifying Lawful Overseas Use of Data Act ("Cloud Act"), enabling US authorities to compel companies to provide data regardless of its physical location, and "FISA Section 702" that allows surveillance of non-US citizens' data stored by American companies outside the US. Of course, all these procedures are constraint by legal substantive and procedural limitations and are not that different – in terms of impact on users' rights - from similar legislation active in EU member states.

[168] Respectively, Regulation 2023/2854 and Regulation 2022/1925.

[169] Art. 32 (chapter VII) of the Data Act states that: "providers of data processing services shall take all adequate technical, organisational and legal measures, including contracts, in order to prevent international and third-country governmental access and transfer of non-personal data held in the Union where such transfer or access would create a conflict with Union law or with the national law of the relevant Member State".

Appendix C: Digital and ICT Ecosystems Orchestration

I. The Role of "Orchestrator"

US tech companies are global "digital champions" by virtue of their global scale, massive investments in R&D and infrastructures and their constant industrial and commercial focus on the newest key technologies. (see **Appendix B**)

Nevertheless, their global prominence is also due to their role of de *facto* "coordinators" in broad digital ecosystems. Frequently positioned at the core of platform-based models, they orchestrate a vast array of complementors, including developers, users, and businesses, through tightly governed digital platforms. [170]

Unlike markets with a static structure, digital orchestrators actively structure and foundationally shape ecosystem interactions, by setting governance rules and procedures to ensure smooth internal interactions, reducing transaction costs, enabling complex multi-party collaboration, and aligning incentives of complementors to invest in quality enhancements and in specialised complementary services.[171]

This orchestration activity does not only leave substantial scope for complementors to innovate independently, but is aimed to enhance the quality, user experience, and ultimately the overall value of the platform ecosystem.[172]

Indeed, in the digital economy, those companies that combine very large scale and coordinating influence are usually able to:

- Advance in the innovation process by virtue of large investments in R&D, also absorbing some of the inherent risks of frontier innovation, particularly by investing in R&D where expected returns are highly uncertain;
- Enable a distributed model of innovation and value generation; and
- Support and stimulate technology advancement and widely spread its diffusion.

In practice, centralised control over the main key ecosystem assets retained by orchestrators (particularly those that are non-rival and scalable, e.g., data infrastructure, AI models, and algorithms) is pivotal for the well-functioning of the ecosystem.

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[170] See, Jacobides M., Cennamo C., Gawer A. (2018) Towards a Theory of Ecosystems, in Strategic Management Journal 39, no. 8 (2018): 2255–76; Kretschmer T., Leiponen A., Schilling M., Vasudeva G. (2022) Platform Ecosystems as Meta-Organisations: Implications for Platform Strategies, in Strategic Management Journal 43, no. 3 (2022): 405–24.

[171] They do so by establishing governance rules that preserve quality and incentivise investment, sharing data insights, and making available technology tools such as software development kits, i.e., provide the necessary tools, guidelines, and economic incentives for businesses or complementors to provide those services that align with the ecosystem's needs. See, Jacobides M., Cennamo C., Annabelle Gawer A. (2022) Externalities and Complementarities in Platforms and Ecosystems: From Structural Solutions to Endogenous Failures, in Research Policy 53, no. 1; Autio E. (2022) Orchestrating Ecosystems: A Multi-Layered Framework, in Innovation 24, no. 1 (2022): 96–109.

[172] Kretschmer T., Leiponen A., Schilling M., Vasudeva G. (2022) Platform ecosystems as meta-organisations: Implications for platform strategies, in Strategic Management Journal 43: 405-424.

On the other side, centralised control is also strategic, since it allows orchestrators to internalise a relevant portion of the value produced in the ecosystem and entrench their position at its core. [173].

This twofold effect and the consequent fundamental economic tension seem to be a defining physiological characteristic of the contemporary digital economy, rather than a pathological one. Therefore, the difficult policy and regulatory challenge is not to eliminate the centralised orchestration or nullify centripetal forces of value of attraction, which may be neither feasible nor desirable when that activity substantially contribute to incremental value creation,[174] but to ensure that digital ecosystems remain sufficiently open and contestable to sustain innovation while providing fair opportunities for all participants to capture a fair value from their contributions.[175]

EU public policy has progressively sought to address this trade-off, through regulatory interventions aimed at enhancing contestability and fairness, through data access, non-discrimination and interoperability obligations. [176] In this context, it has had very challenging (and not always successful) to strike an effective and efficient balance, requiring nuanced approaches that recognise both the physiological characteristics of digital value creation and the need for public intervention to shape governance mechanisms that prevent abusive and strategic behaviours that affect contestability and fairness, as well as, ultimately, the well-functioning of the ecosystem.[177]

II. The EU "3C Network Vision"

Given the growing significance of ecosystem economics, the European Commission has envisioned a market evolution that would extend platform dynamics to the connectivity sector. This transformation builds on the virtualisation of electronic communications network functions and their progressive migration to cloud and edge environments.[178] The proposed *"3C Network – Connected Collaborative Computing"* framework envisions transforming today's connectivity manufacturers and service providers into sophisticated orchestrators of collaborative computing ecosystems. [179] According to the

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[173] Helfat C., Raubitschek R. (2018) Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems, in Research Policy, Volume 47, Issue 8, 2018, Pages 1391-1399; Lei Shen, Qingyue Shi, Vinit Parida, Marin Jovanovic (2024) Ecosystem orchestration practices for industrial firms: A qualitative meta-analysis, framework development and research agenda, in Journal of Business Research, Volume 173, 2024.

[174] As noted above, asymmetric value distribution in digital ecosystems may serve important systemic functions: (i) Risk absorption; (ii) Coordination efficiency; (iii) Investment capacity; (iv) Quality assurance within the ecosystem. These functions also indicates that some degree of value concentration may be necessary for ecosystem stability and continued innovation. See Lei Shen, Qingyue Shi, Vinit Parida, Marin Jovanovic (2024), cit.; See, Jacobides M., Cennamo C., Gawer A. (2018), cit.

[175] Scott Morton F.M. (2025) Digital Platform Regulation: Making Markets Work for People; Crémer, J., de Montjoye, Y.A., Schweitzer, H. (2019) Competition Policy for the Digital Era. Report for the European Commission.

[176] Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector and amending Directives (EU) 2019/1937 and (EU) 2020/1828 (Digital Markets Act) OJ L 265/1

[177] See, with different perspectives: (i) Meyers Z. (2025) Which Governance Mechanisms for Open Tech Platforms? – CERRE Report; (ii) Cennamo C., Kretschmer T., Constantinides P., Alaimo C., Santaló J. (2023) Digital Platforms Regulation: An Innovation-Centric View of the EU's Digital Markets Act, in Journal of European Competition Law & Practice, Volume 14, Issue 1, January 2023, Pages 44–51; (iii) De Streel A., Feasey R., Kramer J., Monti G. (2021) Making the Digital Markets Act more resilient and effective – CERRE Report.

[178] The shift from proprietary, hardware-centric telecom infrastructure toward open, virtualised, and software-defined networks promises to revolutionise Electronic Communications Networks by enabling greater agility, flexibility, and innovation. See, BEREC (20023) Study on the trends and cloudification, virtualisation, and softwarisation in telecommunications - Report prepared for BEREC by Plum Consulting and Stratix, BoR (23) 208.

[179] Shared infrastructure and collaborative frameworks would lower individual capital requirements, while simultaneously amplifying collective innovation capacity. Moreover, this approach would serve as a strategic lever to secure Europe's global leadership in network equipment manufacturing, while fostering the development of complementary industrial capabilities across the broader digital value chain.

EU commission's white paper[180] , such an ecosystem would integrate the full spectrum of the digital value chain, ranging from semiconductors and computational capacity across edge and cloud environments, to radio technologies, connectivity infrastructure, data management, and applications. The ultimate and very ambitious goal would be to create a unified platform through which European companies can overcome long-standing scale disadvantages, and the fragmentation of the EU's digital landscape, which have hindered European digital competitiveness.

This policy vision is extremely challenging as today European industry relies heavily on non-EU cloud and digital platform providers, which are the *de facto* orchestrators of the EU digital ecosystems. At the same time, this represents a policy response to what is perceived to be a critical source of dependencies and incremental weakness with a view to the AI strategy, since, unlike the US or China, no large-scale EU tech companies currently animate the competition along the AI value chain. [181]

So far, this policy vision has not been operationalised. However, some untrivial obstacles can already be identified. First, while the risk-bearing function of an ecosystem can, in principle, be supported - or even fully undertaken - by public authorities through subsidies or strategic investments, the coordination function is far more challenging to replicate. Public bodies very often face substantial information asymmetries and misaligned incentives, which hinder their ability to deliver real-time orchestration or high-level strategic planning - essential in dynamic, fast-evolving digital ecosystems.

System orchestrators are often required to define non-negotiable or non-collaborative standards—such as API protocols, compliance frameworks, or security baselines—and enforce them in ways that do not constitute Pareto improvements, inevitably creating "winners and losers." Given the challenges posed by asymmetric information, the establishment of a publicly governed ecosystem appears both implausible and undesirable. Similarly, private collaborative governance models - such as the GAIA-X initiative[182] - tend to falter due to the absence of assertive steering by a private authority and the lack of a coherent private legal order.[183] These shortcomings typically manifest as: (i) the absence of a credible enforcement mechanism; (ii) the proliferation of vague or inconsistent standards/functioning rules; (iii) weak firm-level commitments, with participants easily exiting the ecosystem when it ceases to serve their interests; and (iv) unaddressed power asymmetries that undermine collective action.

The connectivity market may represent a partial exception, as industry-led collaborative standards continue to play a pivotal role. Nevertheless, identifying a clear *primus inter pares* among operators—and extending that influence across the broader digital ecosystem—remains highly challenging. Prominent European companies operating across various layers of the telecom value chain (e.g., Ericsson, Nokia, Deutsche Telekom, and Vodafone) are not inherently positioned as platform

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[180] European Commission (2024) White Paper: How to master Europe's digital infrastructure needs? - COM(2024) 81 final.

[181] From AI chips production to cloud computing infrastructures, passing through large application provider, which can deploy and integrate AI capabilities into end-user products and can leverage value from access to massive integrated datasets. See, Manganelli A. (2025) Foundation models and generative AI applications: what competitive concerns? , forthcoming in European Competition Journal - available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5242028.

[182] GAIA-X is a Franco-German-led European initiative launched in 2019 to develop a federated, secure data infrastructure for Europe aimed at promoting digital sovereignty and reducing dependence on non-European cloud providers. GAIA-X operates as an international non-profit organisation (AISBL) based in Belgium, developing (i) Standards and certification frameworks for data infrastructure compliance; (ii) Digital Clearing Houses (operated by providers like T-Systems and Aruba) to certify Gaia-X-compliant services; (iii) Sectoral "lighthouse projects" demonstrating practical applications in specific industries; (iv) Open-source principles ensuring transparency and interoperability.

[183] See Manganelli A., Nicita A. (2022), cit.

orchestrators, nor do they typically operate at-scale digital platforms. While some initiatives have emerged, [184] these efforts have not come close to rivalling U.S. platforms in terms of scale, user base, or ecosystem integration.[185]

That said, European telecom operators and upstream vendors and innovators are not necessarily destined to be passive complementors. Although they may not evolve into global platform orchestrators, they still have the potential to assume more balanced and strategic roles in shaping a polycentric digital ecosystem, particularly in domains where decentralised infrastructures remain critical assets. Their influence will ultimately hinge on how complementarities and substitutability evolve across connectivity, cloud services, and application layers. [186]

Indeed, the architecture of digital and ICT ecosystems is not fixed but shaped by the evolution of technology. The historical centralisation of the internet was driven by the need for massive compute power and data aggregation, favouring hyperscaler dominance. However, as compute becomes cheaper and more distributed, models like edge computing, on-device computing, edge-AI may be able to partially reconfigure the landscape toward latency-sensitive, decentralised architectures – that could also benefit in terms of cyber-resilience, and protection of citizens' and business data.

In this emerging cloud-edge continuum, EU telcos and vendors of telecom equipment have an opportunity to leverage their physical infrastructure and regional coverage to participate in new service delivery models. Rather than replicating the scale of hyperscalers, the strategic horizon lies in building differentiated, multi-actor ecosystems — where orchestration is shared, context-dependent, and possibly based on multiple equilibria, shaped by the specific configuration of technological and market complementarities and substitutabilities.[187]

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[184] For instance, Ericsson's Aduna: https://www.ericsson.com/en/press-releases/2025/7/ericsson-announces-completion-of-aduna-transaction, DT's T-Systems https://www.t-systems.com/de/en, and somehow also Vodafone's 5G slicing https://www.telecoms.com/5g-6g/vodafone-germany-launches-5g-slicing-tariffs.

[185] Real-world progress remains uneven and fragmented: most telco-cloud and NaaS (Network-as-a-Service) initiatives remain limited to internal, private and siloed infrastructure deployments and "specific functions such as 5G core" (with a limited 5G Stand Alone diffusion) rather than public, composable, service-oriented ecosystems. See, BEREC (2024) Report on Cloud and Edge Computing Services, BoR (24) 136.

[186] Since "the traditional boundaries between these various actors are increasingly blurred as they form part of what can be described as a computing continuum". European Commission (2024) White Paper, cit.

[187] The "traditional relationships" between telcos and digital platforms was one of complementarity, however an increasing two-sided substitutability is taking place. See BEREC (2024) Report on the entry of large content and application providers into the markets for electronic communications networks and services, BoR (24) 139; Manganelli A. (2024) End-users regulation, in The Future of European Telecommunications: In-depth Analysis – CERRE Report.

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Annex: Description of the Main EU Policy Actions

The EU pursuit of competitiveness and productivity-enhancing digital transformation is currently embodied in two pivotal and comprehensive policy frameworks: the Digital Decade Policy Programme 2030 and the EU Competitiveness Compass.

Digital Decade Programme 2030

To incentivise and monitor digitalisation across the EU, in 2022 the European Union has launched the Digital Decade Policy Programme 2030 (DDPP) [188] as a legally binding framework that represents the current EU's overarching digital transformation roadmap, and which aims to align digital progress with broader policy objectives of competitiveness, technological sovereignty, resilience, and inclusion.

The DDPP emerged from the Commission's 2030 Digital Compass Communication,[189] which laid out a vision for empowering citizens and businesses through digital transformation, by structuring Europe's digital ambitions along four cardinal axes: (i) Digitally skilled population and workforce; (ii) Secure and sustainable digital infrastructures; (iii) Digital transformation of businesses; (iv) Digitalisation of public services.

To translate these principles into actionable commitments, the Commission has established quantified targets, benchmarked against the Digital Economy and Society Index (DESI).[190] These include:

- Digital Skills and Professionals:
    - At least 20 million ICT specialists employed in the EU by 2030, with a focus on gender parity (from 7.8 million in 2019);
    - 80% of EU adults to have basic digital skills.
- Digital Infrastructures:
    - Gigabit connectivity for all households and 5G coverage in all populated areas;
    - 20% of global semiconductor production value to be based in Europe;
    - Deployment of 10,000 climate-neutral highly secure edge nodes;
    - Europe's first quantum-accelerated computer by 2025.
- Business Digital Transformation:
    - 75% of EU enterprises adopting cloud computing, big data, or AI technologies (from under 30% in 2020);
    - Ensuring over 90% of SMEs reach at least a basic level of digital intensity;

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[188] Decision (EU) 2022/2481 establishing the Digital Decade Policy Programme 2030.

[189] European Commission (2021) 2030 Digital Compass: the European way for the Digital Decade – COM (2021) 118 final.

[190] The DESI (Digital Economy and Society Index) is the set of indicators through which the European Commission has monitored the digital competitiveness of Member States since 2015. It was updated in 2021 to align with the Digital Decade Compass.

    - To double the number of European unicorns.

- Digital Public Services
    - Full digitalisation of key public services, including interoperable e-health systems and records and digital identity solutions.

The programme facilitates large-scale, cross-border multi-country Projects addressing strategic digital capacity gaps. These projects, involving at least three Member States, can leverage various implementation mechanisms including joint undertakings, European Research Infrastructure Consortia, and the newly established European Digital Infrastructure Consortia (EDICs).[191]

The Digital Decade Programme employs a sophisticated and unprecedented governance framework combining monitoring, cooperation, and implementation mechanisms. In particular, it requires Member States to submit digital decade strategic “National roadmaps” (the first ones by October 2023) through which they propose national projected trajectories and describe policy plans, measures, and actions for reaching the targets. These roadmaps ensure coordinated EU-level national efforts while allowing for some regional specificities and different starting points. After having identified the national trajectories the enhanced Digital Economy and Society Index (DESI) serves as the primary monitoring instrument, tracking progress toward digital targets through Key Performance Indicators (KPIs) established via implementing acts. This system enables annual assessment of Member State progress and identification of gaps requiring targeted action, which are described into the Commission annual Reports on the “State of the Digital Decade”.[192] Those are submitted to the European Parliament and Council, providing assessments of progress, identifying gaps, and recommending targeted actions. These reports feed into the European Semester process, ensuring integration with broader economic governance. The programme includes Adaptive Management and Cooperation Mechanisms: The European Commission is required to assess digital targets and definitions by June 2026, allowing for adjustments based on technical, economic, or societal developments. To this aim, a structured dialogue between the Commission and Member States ensures responsive governance, with mechanisms for peer review, joint commitments, and structured consultations when significant deviations from projected trajectories occur.

EU Competitiveness Compass

Considering the current geopolitical context and the EU’s economic and industrial position, the European Commission has recently designated competitiveness as a structural and strategic priority. In 2025 a European Commission’s Communication[193] introduced a Competitiveness Compass (CC): a guiding framework for the future EU industrial policymaking to address the EU’s persistent decline in productivity growth and its erosion of technological leadership in comparison with major global competitors such as the United States and China.

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[191] European Digital Infrastructure Consortia (EDICs) are EU-recognised legal entities that enable Member States to jointly develop and operate cross-border digital infrastructures. EDICs have capacity to enter contracts, own assets, hire staff, and manage funds. By pooling resources and expertise across the EU, EDICs are aimed to overcome the fragmentation and are typically used for large-scale projects such as quantum communication networks, federated cloud and edge systems, high-performance computing, blockchain-based public services, and cross-border digital identity.

[192] The most recent one is the 2025 Communication: European Commission (2025) State of the Digital Decade 2025: Keep building the EU's sovereignty and digital future - COM (2025) 290 final.

[193] European Commission (2025) A Competitiveness Compass for the EU - COM (2025) 30 final.

Several interlinked challenges are at the base of such a policy framework. First, Europe possesses strong assets, including a skilled workforce, a large single market, and a stable legal environment, yet it has remained constrained by long-standing structural barriers such as low levels of innovation commercialisation, fragmented markets, and high regulatory burdens.

At the same time, while the EU is confronted with intense global competition in innovation and industrial leadership from the United States and China, its position is further weakened by dependence on non-EU and highly concentrated parts of important supply chains, which leave it vulnerable to disruptions and geopolitical pressures.

Moreover, many of the key levers that shape competitiveness, such as taxation, labour policy, and industrial strategy, are still primarily in the hands of national governments. To match the scale and strength of other major global players, the CC aims to align EU and national policies.

The CC identifies three transformative imperative pillars: (i) closing the innovation gap, i.e., addressing Europe's productivity challenge through measures (ia) facilitating start-up creation and scaling, (ib) introducing a 28th legal regime for innovative companies,[194] (ic) enhancing venture capital markets, and (id) providing a targeted support for advanced technologies like AI, quantum computing, and biotechnology; (ii) a joint roadmap for decarbonisation and competitiveness, recognising that decarbonisation policies can drive growth when well-integrated with industrial and economic policies; (iii) reducing strategic dependencies and increasing Security, addressing supply chain vulnerabilities, promoting trade diversification, and strengthening defence industrial capabilities.

In addition, the Compass proposes five horizontal enablers to support competitiveness across all sectors: (i) simplification, aiming to reduce reporting burden by 25% for all companies and 35% for SMEs, as well as introducing comprehensive regulatory screening and modernisation efforts; (ii) Single Market Integration, aiming to remove residual barriers and preventing fragmentation to maximise continental scale benefits; (iii) financing, by developing a Savings and Investments Union and refocusing the EU budget through a European Competitiveness Fund; (iv) skills and quality Jobs, by creating a Union of Skills addressing labour market transformation and skills gaps; and (v) policy coordination, by implementing a Competitiveness Coordination Tool to align EU and national industrial and research policies.

From a broader perspective, the horizontal enablers in the Competitiveness Compass are crucial for enhancing both the efficiency and the effectiveness of the EU's economic and political systems. By targeting overregulation, Single Market integration, financing, skills, and policy coordination, the CC aims to address the main structural weaknesses that have long constrained Europe's competitiveness. Yet, these areas are marked by entrenched path dependencies and institutional inertia, which will make structural reform very difficult to achieve. It is nevertheless highly positive that the Compass not

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[194] In the EU policy context, the "28th regime" refers to a legal or regulatory framework offered at the EU level as an optional alternative to national laws, rather than replacing them. The term "28th" was coined back when the EU had 27 national regimes, so the EU framework was effectively the "28th option." Even after Brexit, the concept is still used metaphorically. Initially used in debates on the European Contract Law, European Company Statute, and EU-wide IP rights, etc. – the Letta report revived and reframed it for today's context. Letta argued for an EU-level optional legal framework (effectively a "28th regime") for sectors where fragmentation blocks competitiveness — especially in energy, capital markets, digital, and defence. In his framing, it's a tool for faster integration without waiting for unanimous harmonisation.

only recognises these systemic bottlenecks but also elevates them to core priorities alongside its three transformational imperatives.

Among the three pillars, the first one, i.e., closing the innovation gap, stands out as the main driver for achieving an innovation-led competitiveness, directly looking at economic growth, productivity, and the capacity to generate and scale cutting-edge technologies.

For this reason, the Competitiveness Compass and the Digital Decade Programme should be seen as complementary and mutually reinforcing frameworks that jointly try to address Europe's challenges to create a comprehensive innovation ecosystem. The Compass incorporates key digital initiatives to advance in the pursuit of the Digital Decade objectives, namely: (i) the AI Factories Initiative and Apply AI Strategy support the Digital Decade's targets for AI adoption across enterprises; (ii) the EU Cloud and AI Development Act contributes to digital infrastructure development; (iii) Data Union Strategy facilitates the data sharing essential for digital transformation; (iv) Digital Networks Act addresses connectivity targets by improving market incentives for digital infrastructure investment. Also, the third pillar of CC, i.e., reducing strategic dependencies and increasing security, relates closely to the deployment of ICT and the development of digital ecosystems, as it confronts Europe's reliance on extra-EU technology companies and seeks to strengthen digital sovereignty.

EU AI Policy Action Plan (and Apply AI strategy)

In spring 2025, both the European Union and the US issued comprehensive policy frameworks aimed at accelerating the adoption and governance of artificial intelligence, reflecting a shared recognition of AI as a transformative driver of economic growth, competitiveness, and societal change. The European Union's AI Continent Action Plan[195] and the Americas AI Action Plan[196] each articulate ambitious agendas to enhance digital infrastructure, foster innovation, develop human capital, and promote the ethical and trustworthy use of AI technologies, although they differ markedly in their underlying strategic orientations, governance mechanisms, and economic policy approaches.

The EU's strategic approach encompasses two complementary dimensions: frontier AI development and widespread sectoral AI application. The EU framework is embedded within a binding regulatory structure, centred on the AI Act, which establishes a harmonised and enforceable set of market rules intended to safeguard fundamental rights, ensure market integrity, and consolidate the Union's position as a global standard-setter. This legal architecture is paired with an explicit pursuit of technological sovereignty, manifest in large-scale public investments in centralised infrastructure such as AI Factories, AI Gigafactories, and the expansion of EuroHPC-based high-performance computing capacity.[197] These initiatives are further supported by the Data Union Strategy, which envisages sector-

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[195] European Commission (2025) AI Continent Action Plan, COM (2025) 165 final.

[196] The White House (2025) Winning the Race: Americas AI Action Plan.

[197] The EU has established 13 AI Factories as part of a €10 billion investment program, with the first facilities becoming operational by late 2025/early 2026. These facilities are built around Europe's world-leading EuroHPC supercomputers and serve as: (i) Open ecosystems providing AI startups, researchers, and industry with access to computing power (ii) One-stop shops for developing cutting-edge, trustworthy AI models and applications (iii) Platforms that more than triple the current EuroHPC AI computing capacity. Building on AI Factories, the EU announced AI Gigafactories as part of the €20 billion InvestAI initiative. These are: (i) Large-scale facilities equipped with approximately 100,000 state-of-the-art AI chips (four times more than current AI factories); (ii) Designed as the "largest public-private partnership in the world for trustworthy AI development"; (iii) Intended to enable development of the most complex AI models at unprecedented scale.

specific data spaces and specialised “Data Labs” to facilitate secure, standardised, and interoperable data sharing across the single market.

Complementing these infrastructure investments, the Apply AI strategy[198] (launched autumn 2025) shifts emphasis toward translating frontier AI capabilities into concrete sectoral applications where Europe possesses competitive advantages. Apply AI focuses on accelerating AI deployment across strategic industries—particularly manufacturing, automotive, healthcare, pharmaceuticals, and energy—through public-private partnerships, regional AI Factories with sectoral specialisation, and targeted innovation support. This approach recognises that while Europe may not lead in general-purpose Foundation models (FM), it can achieve proprietary competitive advantage through domain-specific AI solutions developed by leveraging Europe's abundant industrial data, manufacturing expertise, and world-leading positions in industrial automation and specialised sectors. The strategy operationalises this through sector-specific acceleration programs, skills development initiatives, regulatory sandboxes for high-impact applications, and public procurement mechanisms designed to create lead markets for European AI solutions, thereby embedding AI capabilities across Europe's industrial base rather than concentrating innovation in a narrow technology layer.

By contrast, the Americas AI Action Plan adopts a more decentralised and cooperative approach, prioritising regional interoperability, voluntary alignment of ethical frameworks, and flexible governance that accommodates diverse national regulatory environments. Its infrastructure strategy is driven by AI Innovation Zones and public–private testbeds, leveraging cross-border collaboration and market-led investment rather than centralised public provisioning. In the data domain, it favours privacy-preserving, interoperable frameworks that encourage, rather than mandate, participation, while in skills development it emphasises distributed training hubs and workforce retraining programmes tailored to national labour market needs.

Whereas the EU seeks to embed AI development within a cohesive legal and infrastructural ecosystem to assert regulatory leadership and strategic autonomy, the Americas approach reflects a more pluralistic, market-oriented model oriented toward fostering competitiveness, enabling policy experimentation, and maximising inclusivity across a heterogeneous regional landscape. These divergent models illustrate not only contrasting philosophies of economic governance but also differing geopolitical strategies which are also based on the different starting point in terms of scale and innovation rate of their tech and digital companies.

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[198] European Commission (2025) Apply AI strategy – COM (2025) 723 final.

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