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European Productivity in the Global Context: analysis, comparison with Emerging Economies, and Selective Industrial Policy Models for a New European Competitiveness

TESI DI LAUREA MAGISTRALE IN

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Abstract

Over the past two decades, a persistent divergence in economic performance has reshaped the global landscape. While the United States has remained at the technological frontier and China has sustained rapid industrial upgrading, the European Union has experienced a prolonged productivity slowdown. This thesis investigates the structural and institutional drivers of Europe's productivity problem, assessing whether a selective industrial policy can be a viable response under EU governance and market fragmentation constraints.

The study combines a comparative diagnosis with a prescriptive design. It first documents the evolution of the EU-US-China productivity gap, relating it to sectoral dynamics and a European "middle-technology trap." It then disaggregates the European case by comparing the institutional models of Germany, France, and Italy, which condition firm behavior and diffusion capacity. The analysis is complemented by an examination of China and India as benchmark cases of techno-industrial strategy.

The thesis argues that the binding constraint is not the absence of technologies but weak diffusion and scale-up in a fragmented environment. Productivity gains are concentrated among a thin frontier of firms, while a long tail adopts innovations slowly. The post-2019 shock sequence has exacerbated these frictions, reinforcing divergence across firms and regions.

Building on this diagnosis, the thesis develops an operational framework for a selective industrial policy that is disciplined, testable, and resistant to capture. It proposes a three-level architecture: macro reforms, a Strategic Positioning and Selection Matrix with conditionality and exit rules, and a delivery layer to coordinate ecosystems and accelerate diffusion at scale. The core contribution is a policy operating system that links selectivity to measurable upgrading outcomes rather than to spending volumes.

Key-words: European productivity slowdown, middle technology trap, innovation diffusion and scale up, market fragmentation, selective industrial policy

Abstract in italiano

Negli ultimi due decenni, una persistente divergenza nelle performance economiche ha ridisegnato il panorama globale. Mentre gli Stati Uniti hanno mantenuto la leadership alla frontiera tecnologica e la Cina ha sostenuto un rapido upgrading industriale, l'Unione Europea ha attraversato un prolungato rallentamento della produttività. Questa tesi analizza i driver strutturali e istituzionali del problema europeo di produttività, valutando se una politica industriale selettiva possa rappresentare una risposta credibile, date le condizioni di governance dell'UE e la frammentazione del mercato.

Lo studio combina una diagnosi comparata con una proposta prescrittiva. In primo luogo, documenta l'evoluzione del divario di produttività tra UE, Stati Uniti e Cina, collegandolo a dinamiche settoriali e all'emergere di una "middle technology trap" europea. In secondo luogo, disaggrega il caso europeo confrontando i modelli istituzionali di Germania, Francia e Italia, che condizionano il comportamento delle imprese e la capacità di diffusione dell'innovazione. L'analisi è completata dall'esame di Cina e India come casi di riferimento di strategia tecno industriale.

La tesi sostiene che il vincolo principale non sia l'assenza di tecnologie, ma la debolezza dei meccanismi di diffusione e di scale up in un contesto frammentato. I guadagni di produttività si concentrano in una fascia ristretta di imprese di frontiera, mentre una lunga coda adotta le innovazioni lentamente. La sequenza di shock successivi al 2019 ha aggravato tali frizioni, rafforzando la divergenza tra imprese e territori.

Su questa base, la tesi sviluppa un framework operativo di politica industriale selettiva, pensato per essere disciplinato, verificabile e meno esposto alla cattura. Propone un'architettura a tre livelli: riforme macro, una Strategic Positioning and Selection Matrix con condizionalità e regole di uscita, e un livello di delivery volto a coordinare gli ecosistemi e accelerare la diffusione su larga scala. Il contributo centrale è un sistema operativo di policy che lega la selettività a risultati misurabili di upgrading, più che ai volumi di spesa.

Parole chiave: Rallentamento della produttività europea, Trappola della tecnologia intermedia, Diffusione dell’innovazione e crescita dimensionale, Frammentazione del mercato, Politica industriale

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Introduction

Context & Thesis Aim

Over the past two decades, a profound divergence in economic performance has reshaped the global landscape. While the United States has reinforced its position at the technological frontier and China has achieved an unprecedented economic ascent, the European Union has experienced a persistent productivity slowdown, leading to a widening prosperity gap and raising fundamental questions about its long-term competitiveness. This trend, described by former ECB President Mario Draghi as a potential path to "slow agony," is not a cyclical phenomenon but a structural one, rooted in Europe's difficulty in adapting to the twin pressures of American technological dominance and Asian industrial ambition. Europe appears caught between two competing models: a market-driven, scale-intensive US model that excels in generating frontier innovations, and a state-led Chinese model that has proven exceptionally effective at mobilizing resources for rapid technological catch-up and industrial upgrading.

This thesis aims to dissect the structural and institutional foundations of Europe's productivity problem and to explore the viability of a selective industrial policy as a strategic response. It moves beyond a simple diagnosis of the productivity gap to investigate why Europe has struggled to generate high-growth firms, diffuse innovation, and scale up production in critical sectors. Specifically, the study examines whether a new European competitiveness model is possible, one that leverages the continent's unique institutional arrangements without resorting to either pure laissez-faire or heavy-handed state control. The central analytical question is not whether Europe should mimic the US or China, but whether it can forge a distinct and effective path to renewed industrial dynamism.

Definitions & Typologies

To analyse this challenge, the thesis relies on a set of core concepts. The **Productivity Gap** is defined not merely as a shortfall in output per worker, but more fundamentally as a lag in **Total Factor Productivity (TFP)**, which captures the efficiency with which an economy combines capital and labour, reflecting its innovative capacity and allocative efficiency. This distinction is critical, as Europe's gap is primarily a TFP problem, indicating a deeper failure in innovation and diffusion.

A second key concept is the **"Middle-Technology Trap,"** a term used to describe Europe's industrial predicament. It characterizes an economy that is losing its competitive edge in traditional, medium-technology manufacturing sectors to emerging economies, while simultaneously failing to transition effectively into high-technology, knowledge-intensive industries where the United States dominates. This trap suggests that Europe's industrial structure is misaligned with the primary drivers of global value creation.

Finally, **Selective Industrial Policy** is defined as a set of targeted government interventions designed to accelerate the development of specific sectors, technologies, or firms deemed critical for long-term competitiveness. This approach is distinguished from horizontal policies by its explicit focus on "picking winners" or, more accurately, "letting winners run" in strategic domains such as digital technologies, green energy, and advanced manufacturing. In this thesis, selectivity is treated as a **governance proposition** rather than a slogan: it is defensible only if it can be **embedded in credible discipline devices** (conditionality, performance criteria, and time-bounded support with exit rules) that limit rent extraction and avoid preserving persistently unproductive capacity.

A further concept introduced by the thesis is **BESNI (Business Ecosystem for Sustainable Network Innovation)**, defined as a delivery architecture designed to operationalise selective industrial policy at scale. BESNI targets the ecosystem complements that condition diffusion and upgrading, such as skills pipelines, testing and certification capacity, interoperable standards, data and digital infrastructure, and organisational know-how. This distinction between selection and delivery is central: the thesis separates the analytical problem of prioritisation (what to support) from the institutional problem of diffusion-throughput (how support translates into adoption and productivity gains), thereby **reducing capture risk** and **increasing evaluability within the EU's multi-level governance framework**.

Theoretical Lenses Used in Prior Work

Scholarly analysis of Europe's economic performance is grounded in several conceptual approaches that help explain the continent's complex and heterogeneous landscape. The first approach focuses on the **diversity of national economic models**, recognizing that countries like Germany, France, and Italy possess distinct **institutional logics**. These logics shape how

coordination occurs between firms, financial institutions, and government agencies. Understanding these deep-seated institutional differences is essential for explaining why a one-size-fits-all policy is likely to fail in Europe and why each country exhibits different strengths and weaknesses in productivity and innovation.

A second perspective examines the **national systems that support innovation and the diffusion of technology**. This view emphasizes that a country's ability to translate new knowledge into productivity gains depends on a complex network of public and private institutions, including universities, research centres, and financial markets. This framework is crucial for understanding the blockages that prevent new technologies from spreading from **frontier firms** to the broader economy of **laggard firms**, a particularly acute problem in Europe.

Finally, a third body of work offers insights into the mechanisms that have powered the rise of emerging economies, particularly China. This research highlights the role of a strong, **techno-industrial state** in guiding investment, nurturing strategic industries, and coordinating a national growth strategy. While Europe's institutional context is fundamentally different, this perspective provides a critical benchmark for evaluating the tools and strategies available to policymakers seeking to shape economic outcomes through **industrial policy**.

Why Compare Europe with the US, China, and India

A comparative approach is central to this thesis, as Europe's competitiveness challenge can only be understood in a global context. The comparison with the **United States** is essential because the US represents the global productivity and technology frontier. Its success in creating and scaling tech giants provides a stark contrast to Europe's "scale-up shortage" and highlights the importance of deep capital markets, a unified consumer market, and a culture of entrepreneurial risk-taking.

China serves as the primary counterpoint, representing a highly effective, state-directed model of industrial and technological development. China's ability to dominate entire value chains, from solar panels to electric vehicles, through a combination of subsidies, strategic investment, and administrative guidance, poses a direct competitive threat to Europe's manufacturing heartland. Understanding the mechanics of China's techno-industrial state is crucial for designing any effective European response.

India is included as an alternative model of an emerging economy. Its growth has been driven more by services and a state-built digital public infrastructure than by manufacturing scale. India's trajectory suggests a different path to development, one that may hold important lessons for Europe as it seeks to digitize its own economy and service sectors.

Finally, the internal comparison between **Germany, France, and Italy** is critical to deconstruct the "European average." These three countries embody different institutional logics and expose the deep-seated heterogeneity that complicates any unified EU-level industrial strategy. Their divergent responses to global pressures reveal the national-level frictions that any European policy must overcome.

Existing Literature on the Productivity Gap

A substantial body of literature, produced by institutions like the European Central Bank, the OECD, and the European Commission, has documented the widening transatlantic productivity gap. This research consistently finds that the EU's underperformance relative to the US since the mid-1990s is primarily attributable to a slowdown in TFP growth, particularly in the ICT-producing and ICT-using sectors. Seminal reports, such as the one recently prepared by Mario Draghi, have synthesized this evidence and issued urgent calls for a European competitiveness overhaul.

Academic research has further explored the underlying causes, pointing to factors such as lower investment in intangible assets (software, data, R&D), a fragmented single market for services, and a less dynamic business environment that slows down the reallocation of resources from low- to high-productivity firms. While this literature provides a robust diagnosis of the problem, it often stops short of offering a detailed, politically feasible roadmap for a solution, particularly regarding the controversial domain of industrial policy.

Limitations of Current Comparative Evidence

Despite the richness of the existing literature, several limitations persist. First, many studies treat "Europe" as a monolith, using aggregate EU-level data that masks the critical institutional differences between member states. This approach fails to explain why some European countries have performed better than others and what lessons can be learned from these internal divergences.

Second, while the role of industrial policy is increasingly discussed, the analysis often remains at a high level of abstraction. There is a lack of granular, cross-country research that systematically compares the effectiveness of different policy instruments and governance models. Most studies focus on the what (the existence of the gap) rather than the how (the specific institutional and policy mechanisms that could close it).

Third, comparative analyses of Europe versus China often focus on trade and macro-level competition, with less attention paid to the micro-institutional foundations of China's success. There is a need for a deeper understanding of how China's state-led system shapes firm behavior, investment, and innovation at the sectoral level, and what specific competitive pressures this creates for European firms.

Research Gap

This thesis addresses these limitations by bridging three interrelated gaps in the literature. First, it moves beyond an aggregate diagnosis by systematically comparing the distinct socio-economic models of Germany, France, and Italy, linking their institutional structures to their specific productivity and innovation outcomes. This provides a more nuanced understanding of the "European problem."

Second, it takes the debate on industrial policy from the abstract to the concrete by focusing on the concept of a selective industrial policy. The thesis investigates which specific sectors and technologies could be realistic targets for such a policy in Europe and what governance mechanisms would be required to implement it effectively, avoiding the pitfalls of protectionism and inefficient resource allocation. The research gap is not only about identifying priority domains, but about specifying an operational design under governance constraints: a replicable framework that combines (i) explicit selection criteria, (ii) credible discipline and exit mechanisms, and (iii) a delivery layer capable of accelerating diffusion by coordinating the complements that underpin adoption.

Third, it places the European dilemma in a direct, structured comparison with the US and Chinese models, treating them not just as economic competitors but as distinct institutional systems for generating innovation and productivity. By doing so, it aims to identify the specific elements of their success that may (or may not) be adaptable to the European context. The core contribution of this thesis is to synthesize these three levels of analysis, internal European heterogeneity, the specifics of selective industrial policy, and the global competitive landscape, to offer a more integrated and actionable perspective on Europe's future competitiveness.

Structure of the Thesis

The remainder of this study is organised as follows. **Chapter 1** frames the research question within the main scholarly debates on productivity growth, structural change, innovation diffusion, and industrial policy. It synthesises competing explanations for Europe's slowdown, including frontier-innovation constraints, scale-up frictions, misallocation, market fragmentation, and institutional heterogeneity, and distils the core mechanisms and testable expectations that guide the empirical and prescriptive chapters that follow. **Chapter 2** establishes the empirical foundation by documenting the evolution of the productivity gap between the EU, the US, and China, with a focus on the sectoral drivers of this divergence and the emergence of the "middle-technology trap." **Chapter 3** disaggregates the European case by providing an in-depth comparative analysis of the socio-economic models of Germany, France, and Italy, linking their institutional structures to their respective productivity and innovation performance. **Chapter 4** shifts the focus to the emerging economies, examining the state-led industrial and technological strategies of China and India and assessing the competitive pressures they exert on Europe. **Chapter 5** provides a detailed analysis of recent developments in European industry between 2019 and 2025, a period of intense shocks and structural transformation, examining both sectoral trends and firm-level adaptation dynamics. **Chapter 6** moves from analysis to prescription, building on the preceding chapters to develop a conceptual model for a selective European industrial policy. It proposes a three-level taxonomy of intervention (Macro, Meso, and Micro) that integrates market-making reforms with targeted industrial strategy. At the core of this model is the **Strategic Positioning and Selection Matrix (SPSM)**, an analytical framework designed to guide the allocation of resources towards high-potential sectors through explicit, contestable prioritisation criteria. To make selectivity operational, Chapter 6 introduces **BESNI (Business Ecosystem for Sustainable Network Innovation)** as the delivery layer that coordinates ecosystem complements and enables diffusion across firms rather than only supporting champions. The chapter also specifies evaluative criteria that keep the framework testable: success is defined by accelerated diffusion among high-potential laggards, narrowing productivity dispersion through upgrading rather than protected persistence, and strengthened reallocation dynamics; failure is indicated by frontier-only gains, widening dispersion, worsening misallocation, or persistent support without measurable upgrading. **Chapter 7** concludes by outlining the main limitations of the thesis, discussing measurement and identification constraints, political-economy and implementation risks, and proposing a focused agenda for future research and policy experimentation (future activities) to refine and test the selective framework over time

1 Literature review

Based on what has been analysed in the past sections, the core puzzle of the thesis is no longer whether Europe faces a productivity and competitiveness constraint, but **why the constraint persists** despite sustained policy activism and high levels of technology availability. The recent academic literature converges on a diagnosis that is **structural rather than cyclical**: aggregate outcomes are shaped by (i) **heterogeneous national institutional logics** within the EU, (ii) a **diffusion regime** where productivity gains concentrate among **frontier firms** while a long tail of **laggards** fails to absorb new technologies, and (iii) an external environment characterised by **state-led techno-industrial competition**, led by the US and China, with India emerging as a distinct benchmark case. Within this framing, **"selective industrial policy"** becomes not a rhetorical choice but a **testable governance proposition**: it is effective only if it can **target binding constraints, discipline rent extraction and accelerate diffusion without eroding competitive selection**. This section positions the thesis within the most recent academic debates (2023–2026) and clarifies the conceptual scaffolding and synthesis protocol that culminate in the prescriptive model developed in Chapter 6.

1.1. Research Question and Analytic Sub-Questions

The thesis is organised around a main research question and two analytic sub-questions that discipline both the comparative strategy and the policy conclusions.

Main research question:

To what extent do Europe's heterogeneous institutional models and the competitive pressures from the US and China constrain or enable the effectiveness of a selective industrial policy aimed at closing the productivity gap?

This question reflects a shift in the recent literature on industrial policy from a binary debate (intervention versus non-intervention) to a conditional one focused on governance capacity, instrument choice, and political economy constraints. In this view, industrial policy is best understood as an attempt to reconfigure the allocation of resources and capabilities under constraints of information, lobbying, and administrative limits, rather than as a generic subsidy agenda[1]

Analytic sub-questions:

SQ1 – Institutional Heterogeneity:

How do the distinct institutional logics of Germany, France, and Italy mediate their respective performance in productivity, innovation, and technology diffusion?

Recent comparative political economy has increasingly treated the EU as a compound polity in which national models remain consequential for firm behaviour, skill formation, finance, and the organisation of production, even under a common market and shared regulatory constraints. The implication for this thesis is that "Europe" cannot be modelled as a single institutional equilibrium: cross-country divergences in diffusion capacity and industrial restructuring are expected outcomes of different coordination and governance arrangements.

SQ2 – Policy Effectiveness:

Under what conditions can selective industrial policy accelerate firm-level technology adoption and productivity growth within the EU's multi-level governance framework?

The new industrial policy literature emphasises that effectiveness depends on (i) selecting sectors and capabilities in ways consistent with comparative advantage dynamics, (ii) embedding support in credible performance criteria and ex post evaluation, and (iii) maintaining competitive pressures so that policy accelerates upgrading rather than preserving low-productivity capacity[2]

[1] Juhász et al., 2024
[2] Juhász & Lane (2024); Bruzzone (2024)

1.2. Conceptual Frameworks Mobilised

This thesis mobilises three complementary frameworks. They are not treated as competing paradigms but as analytically separable lenses, each addressing a different layer of the productivity problem.

Framework 1: Comparative Institutional Analysis of National Models

The first framework is a comparative institutional analysis of Germany, France, and Italy, centred on the concept of **"institutional logics"** shaping economic governance and coordination. The recent literature has updated this approach by focusing less on static typologies and more on how institutional arrangements mediate adjustment under shocks and technological transitions. The key claim is that productivity outcomes depend not only on technology availability, but on the **institutional capacity to reallocate resources** toward higher-productivity uses, **coordinate complementary investments** (skills, intangibles, organisational change), and **sustain competitive selection**.

Germany is frequently analysed as an economy whose competitiveness historically relied on export performance and coordinated adjustment mechanisms, but where recent research highlights growing stress from energy and cost shocks and a rebalancing problem for its demand and growth regime.[3] France is increasingly examined through the lens of state capacity and strategic steering, including how national administrations shape EU-level rules and policy space, producing a distinctive form of state-enabled industrial orientation.[4] Italy is commonly characterised in the recent micro- and meso-level literature by persistent structural fragmentation, a high prevalence of SMEs and family ownership, and diffusion bottlenecks, with productivity dynamics closely tied to governance quality, managerial capabilities, and the ability to pair technology adoption with organisational upgrading.[5]

In the thesis, these national logics matter because they condition the feasibility and likely incidence of selective policy instruments. The same instrument, for example a subsidy for automation or a green investment tax credit, will have different effects depending on (i) the

[3] Campana & Hein (2025)
[4] Benoît (2025)
[5] Brambilla & Lavista (2025); Peruzzi (2025)

financing structure of firms, (ii) the availability of skills and managerial complements, and (iii) the strength of competitive selection that forces inefficient firms to exit rather than persist.

Framework 2: Firm-Level Heterogeneity and Technology Diffusion

The second framework centres on **firm-level heterogeneity** and **diffusion failures**. The recent productivity literature has substantially strengthened the micro-foundations of the productivity paradox by linking weak aggregate performance to the coexistence of highly productive **frontier firms** and a long tail of **laggards** that either cannot or do not adopt new technologies effectively.

Two recent strands are central. First, the **"intangible economy"** strand argues that intangible inputs (software, data, organisational capital) can generate rising **productivity dispersion**, increasing **market power** and dampening **dynamism**, thereby weakening aggregate productivity growth after an initial boost.[6] Second, recent firm-level evidence shows that intangible investment, while productivity-enhancing at the micro level, can amplify **divergence between frontier firms and the rest**, and that industries with larger intangible-driven gaps tend to experience lower average productivity growth.[7]

A crucial implication is that **diffusion is not an automatic process**. The laggard tail is not simply "behind" on a deterministic convergence path; it is often constrained by **absorptive capacity, skill mismatch, financing frictions, and the tacit knowledge requirements** embedded in advanced technologies. Recent evidence specifically attributes a meaningful part of the productivity slowdown to **diffusion barriers faced by laggard firms**, especially in digital- and skill-intensive sectors, and links these barriers to structural country characteristics.[8]

Within Europe, recent empirical work has further clarified that the productivity payoff of digital adoption is heterogeneous by firm type, sector, and adoption bundle. For Italy, firm-level evidence finds positive effects of digital technologies on TFP, with stronger effects when adoption involves advanced domains and technology bundles, and when complemented by organisational features that enable exploitation.[9] For Europe more broadly, recent work connects AI innovation to productivity gains and explicitly ties the magnitude of the premium

[6] De Ridder (2024)
[7] Le Mouel & Schiersch (2024)
[8] Berlingieri et al. (2024)
[9] Nucci et al. (2023)

to distance-to-frontier dynamics, implying that policy can influence whether AI becomes a diffusion technology or a frontier-only advantage.[10]

This framework directly underpins the thesis's policy orientation. If the central constraint is diffusion, then selective industrial policy cannot be evaluated primarily by its effect on frontier firms, which are often already investing. It must be evaluated by whether it (i) **relaxes adoption constraints for high-potential but capability-constrained firms**, and (ii) **accelerates reallocation away from persistently low-productivity firms** that survive through implicit or explicit protection.

Framework 3: State-Led Development and Techno-Industrial Strategy

The third framework analyses the US, China, and India as benchmark cases of **techno-industrial strategy**, not as models to replicate mechanically but as **external constraints shaping Europe's feasible policy set.**

Recent industrial policy research describes a global shift: advanced economies are increasingly using subsidies, procurement, regulation, and mission-oriented investment to shape technological trajectories, often justified by **security, resilience, and decarbonisation goals**[11] In the US, the policy mix associated with semiconductor and clean-tech strategies is widely interpreted as a **re-legitimation of industrial policy** under a competitiveness and national security rationale, with the academic debate focusing on implementation, distributional incidence, and spillovers.

China is treated in recent scholarship as a paradigmatic **techno-industrial** state in which industrial policy is not episodic but embedded in a dense apparatus of finance, regulation, experimentation zones, and target-based coordination. Recent work on China's data-driven and platform economy governance illustrates how industrial strategy can be implemented through institutional design in specific regional clusters, integrating technological upgrading with state steering capacity.[12] The green transition provides a particularly salient domain: recent scholarship links China's dominance in clean-tech sectors to **centralised and pragmatic**

[10] Marioni et al. (2024)
[11] Juhász et al. (2024); Veugelers (2024)
[12] Anguelov (2025)

industrial policy, and analyses the international trade and legal implications of this approach for other economies responding with their own green industrial policies.[13]

India is treated as an analytically distinct case because its state capacity is expressed through a different configuration: a **state-built digital backbone** that reduces transaction costs and enables formalisation, combined with **selective manufacturing and upgrading** policies aimed at reconfiguring its position in global value chains. Recent academic work explicitly situates India's industrial policy in a changing global environment and highlights the strategic logic of combining digital public infrastructure with targeted manufacturing incentives.[14]

For Europe, this framework does not imply imitation. Its analytical function is to clarify that Europe's industrial policy debate occurs under external competitive pressure where state-led strategies are already reshaping relative prices, investment allocation, and technological frontiers. Therefore, the relevant question becomes whether Europe can design a selective industrial policy **consistent with its institutional constraints**, while still being sufficiently strategic to avoid being locked into **follower positions** in key technology domains.

1.3. Case Selection Logic and Introduction

The case selection follows a structured comparative logic designed to maximise explanatory leverage for both diagnosis and prescription.

Global relevance cases:

The United States is selected as the technological frontier benchmark and the reference point for global innovation rents and scale-driven diffusion in platform and intangible-intensive sectors. In recent literature, it is also treated as the key origin of the contemporary industrial policy reorientation among advanced economies, reinforcing the external competitive constraint facing Europe.[15]

China is selected as the strategic challenger that combines scale, state coordination, and techno-industrial steering, shaping global clean-tech and advanced manufacturing competition. The

[13] Li and Du (2025)
[14] Nayyar (2024); Parsheera (2024)
[15] Juhász & Lane (2024)

academic literature increasingly conceptualises China's industrial strategy as a systemic feature rather than a sequence of ad hoc interventions, with strong implications for Europe's industrial positioning.[16]

India is selected as an alternative emerging model whose economic upgrading is anchored in digital public infrastructure and selective industrial policy, offering a distinct contrast to China's finance- and capacity-intensive model. Recent scholarship frames India as a case where state capacity is expressed through infrastructural standard-setting and digital rails that potentially enhance diffusion and formal sector scaling.[17]

EU internal heterogeneity cases:

Germany, France, and Italy are selected to represent Europe's internal diversity in governance and coordination mechanisms, which is central to the thesis's argument that a single EU-wide policy instrument will have heterogeneous outcomes. These cases also capture analytically relevant variation: Germany's manufacturing and export orientation, France's state capacity and strategic steering tradition, and Italy's SME-dense structure with persistent diffusion gaps. The purpose is not to rank models normatively but to specify mechanisms through which institutional logics mediate the productivity effects of technological change and policy intervention.

1.4. Data Sources and Synthesis Protocol

Because the thesis is built on secondary data and comparative synthesis rather than a single original dataset, the credibility of the argument depends on transparent source selection and a disciplined synthesis protocol.

Primary academic sources:

1. Peer-reviewed academic literature.

   The core evidentiary base is peer-reviewed articles in economics, political economy, and innovation studies, complemented where necessary by working papers from

[16] Anguelov (2025); Li & Du (2025)
[17] Nayyar (2024); Parsheera (2024)

academic research networks when they represent frontier research later published in refereed outlets. The emphasis on 2023–2026 literature is intentional: it reflects the acceleration of both industrial policy scholarship and firm-level research on intangibles, AI, and diffusion.

2. Statistical data for descriptive grounding.

   For macroeconomic and sectoral trend description, the thesis relies on harmonised official statistics and widely used academic datasets, primarily Eurostat national accounts and structural indicators, productivity accounts where available, and cross-country productivity datasets used in the academic literature. These series provide descriptive discipline and reduce the risk of inferring structural mechanisms from narrative evidence alone.

Synthesis protocol:

The synthesis follows a two-step process designed to maintain a clear separation between (i) descriptive regularities and (ii) causal or institutional interpretation.

Step 1: Descriptive macro and sectoral mapping.

The thesis first maps productivity, investment, sectoral reallocation, and trade positioning patterns for the EU relative to benchmark economies, with attention to the sequence of shocks in 2019–2025. This step establishes what must be explained, but avoids claiming causal attribution from aggregate correlations.

Step 2: Institutional and micro-founded interpretation.

The thesis then uses the academic literature to interpret the descriptive patterns through the mechanisms emphasised by recent research: diffusion failures and firm heterogeneity; intangible-driven divergence and market power; and institutional constraints on policy effectiveness. This step is explicitly comparative: it treats Germany, France, and Italy as distinct institutional environments that shape diffusion capacity and the incidence of EU-level policy constraints.

This protocol is aligned with the recent industrial policy literature's insistence on measurement clarity and mechanism-based evaluation, which treats "industrial policy" as a heterogeneous bundle of instruments requiring careful classification and ex post assessment.[18]

1.5. Analytical Techniques

The thesis uses four analytical techniques, each aligned with one component of the research question and collectively enabling the transition from diagnosis to a prescriptive framework.

1. Structured comparative analysis.

   The thesis applies a structured comparative method to assess national models and global benchmarks using common dimensions: governance and coordination mechanisms, technology diffusion capacity, industrial structure, and policy space constraints. The goal is to isolate mechanism-relevant differences, rather than to provide exhaustive country narratives.

2. In-depth case study analysis.

   Chapters 2 and 3 adopt case-study logic to analyse how national institutional logics shape firm incentives and policy feasibility. Case studies are used not to generate general laws but to refine causal hypotheses about diffusion constraints, state capacity, and policy implementation.

3. Historical process-tracing of shocks and responses (2019–2025).

   Chapter 4 traces the sequence of shocks (pandemic, supply-chain disruptions, energy crisis) and links them to shifts in firm behaviour, investment composition, and sectoral restructuring. This technique is essential because the productivity problem is not analysed as a stationary equilibrium. Recent work on diffusion barriers suggests that shocks can permanently alter diffusion trajectories by widening capability gaps between frontier and laggard firms, particularly where skills and finance constraints tighten.[19]

[18] Juhász et al. (2025)
[19] Berlingieri et al. (2024)

4. Conceptual model-building for selective policy design (Chapter 6).

   The thesis culminates in a prescriptive conceptual model that translates the empirical and institutional diagnosis into an operational policy framework. This model-building proceeds in two steps.

First, the thesis constructs a three-level taxonomy of intervention:

Macro level: EU-wide framework conditions that shape incentives and investment feasibility, including regulatory harmonisation, competition and state aid constraints, and capital market conditions. Recent scholarship on EU industrial policy highlights that the binding constraint is often not the absence of instruments but the governance tension between strategic autonomy objectives and preserving a competitive single market[20]

Meso level: sectoral and ecosystem interventions targeting shared bottlenecks, including skills pipelines, testing facilities, standards, and infrastructure that enable diffusion and upgrading across firms rather than only supporting champions. This level is grounded in the diffusion literature’s emphasis on complements and absorptive capacity.

Micro level: firm-targeted mechanisms designed to accelerate adoption among high-potential firms and to enforce discipline through conditionality, performance criteria, and exit mechanisms for persistently unproductive capacity. The recent literature reframes policy effectiveness as dependent on governance constraints and state capacity, implying that the key design problem is to align targeting with credible enforcement.[21]

Second, the thesis introduces the Strategic Positioning and Selection Matrix (SPSM) as an analytical tool to guide selectivity. The SPSM operationalises sectoral prioritisation by combining (i) strategic relevance under techno-industrial competition, (ii) domestic capability and diffusion potential, and (iii) vulnerability to external dependencies and input constraints. The purpose is to move beyond generic “strategic sectors” rhetoric and impose a consistent decision rule linking diagnosis to instrument choice.

[20] Mariotti (2025); Bruzzone (2024)
[21] Juhász & Lane (2024)

By construction, this conceptual model is disciplined by the literature reviewed above: it assumes that the central risk of selective industrial policy is not only mis-targeting, but also the political economy of support without discipline, which can preserve laggard firms and depress aggregate productivity through reduced selection. The SPSM and the macro-meso-micro taxonomy are therefore designed to embed selectivity within a governance architecture that maintains competition, accelerates diffusion, and ties support to measurable upgrading outcomes.

Third, the thesis proposes the Business Ecosystem for Sustainable Network Innovation (BESNI) as the delivery layer required to make selectivity operational at scale. The rationale is that diffusion constraints are rarely solved by financial support alone: they depend on complements such as skills, testing and certification capacity, interoperable standards, data and digital infrastructure, and organisational know-how. BESNI is conceived as an institutional mechanism that coordinates these complements across firms and regions, reduces transaction costs for adoption, and creates repeatable pathways for upgrading within priority ecosystems. In governance terms, it also provides a concrete locus for evaluation: performance is assessed through diffusion throughput and measurable capability accumulation, rather than through spending volumes or headline "supported projects."

Taken together, these techniques provide a coherent route from the empirical diagnosis of Europe's productivity paradox to a structured policy proposal. The literature reviewed in this section supplies the mechanism-based logic for why a selective approach is necessary, what it must target, and what governance conditions must hold for it to improve aggregate productivity rather than merely redistribute rents.

Falsifiability and outcome criteria: To keep the selective framework testable, the thesis adopts outcome criteria that can validate or falsify its central claims. The framework is supported if diffusion among high-potential laggards accelerates, productivity dispersion narrows through upgrading rather than protected persistence, and reallocation strengthens.[22] Conversely, it is undermined if adoption rises only among frontier firms, dispersion widens, misallocation worsens, or support becomes persistent without measurable upgrading, which would indicate capture or ineffective delivery.

[22] Andrews et al. (2017)

2 Evolution of the Productivity Gap between the USA, EU, and China

Over the past few decades, stark differences have emerged in economic performance between the United States (US), the European Union (EU), and China. While the EU enjoyed a period of convergence and prosperity in the late 20th century, its growth has since slowed markedly relative to the US, and China has rapidly closed the gap with advanced economies. This widening prosperity gap is a source of growing concern for Europe's future. As former European Central Bank President Mario Draghi warned in 2024, Europe must act decisively on competitiveness or risk a scenario of "slow agony"[23]. A clear picture of this challenge emerges by examining the evolution of the US-EU-China productivity gap, the sectoral composition of productivity growth, and the structural "middle-technology trap" hampering Europe's progress. In this chapter, we analyse these aspects in detail, drawing on recent reports and data to understand why Europe's productivity and per capita income are lagging and how the rise of China and other emerging economies like India has altered the global productivity landscape. Productivity, the amount of output produced per unit of input, often measured per worker or per hour, is the key to long-run growth and living standards. Indeed, Paul Krugman's dictum holds true: "Productivity isn't everything, but in the long run it is almost everything". Understanding the sources of Europe's productivity slowdown is thus essential for diagnosing the competitiveness gap and formulating an effective response.

2.1. The US-EU-China Productivity Gap: Diverging Paths

2.1.1. Europe's growth slowdown and widening gap with the US

Over the last twenty years, economic growth in the EU has persistently trailed that of the US. Real GDP in the EU has expanded at a much slower pace, leading to a widening gulf in output. In 2002, the EU's total GDP (at constant prices) was only about 15% smaller than that of the US, by 2023, this gap had doubled to roughly 30%. Even adjusting for population and

[23] Draghi (2024)

differences in cost of living, a substantial prosperity gap remains. In 2023, EU GDP per capita was about 34% lower than US GDP per capita on a purchasing-power-parity basis, up from a 31% gap in 2002. In other words, the average European's standard of living (in income terms) has fallen further behind that of the average American over the past generation. Strikingly, if the EU were hypothetically considered as a single US state, it would rank among the poorest, by one estimate it "would be the third poorest state, trailed only by Idaho and Mississippi"[24]. This divergence has raised alarms because it threatens Europe's social model, slower growth in Europe translates into slower gains in incomes and living standards, making it harder to sustain the high levels of social protection and public services Europeans expect. Draghi's competitiveness report emphasizes that Europe's ability to achieve its ambitions, from social inclusion to carbon neutrality, hinges on rekindling growth, yet "growth in the EU has been slowing, driven by weakening productivity growth"[25]. Simply put, Europe's economic engine has lost momentum relative to the US.

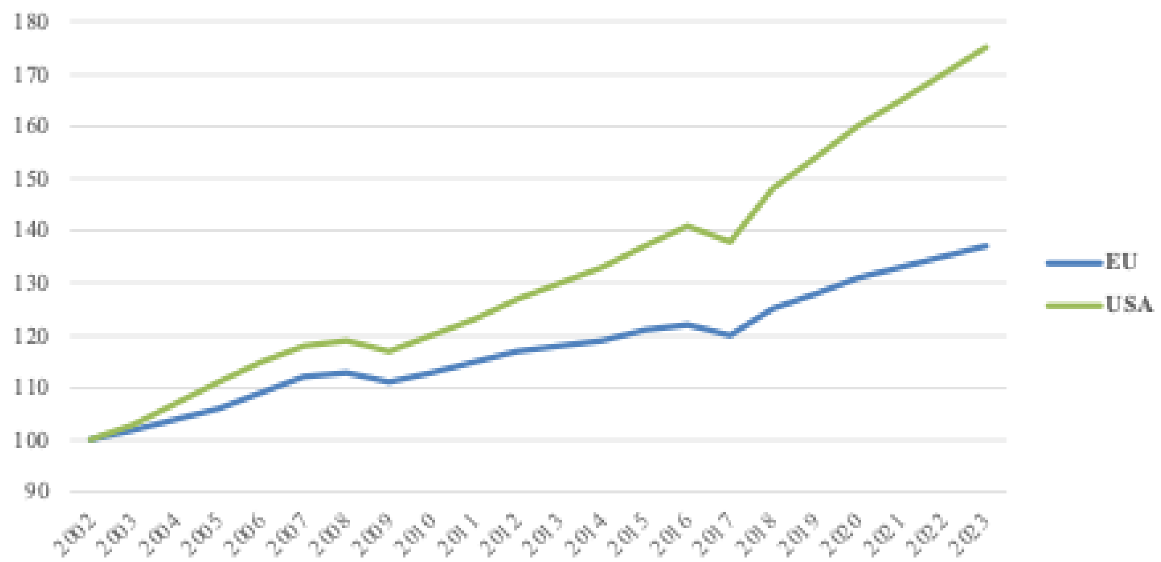

Figure 2-1 - GDP per capita (index 2002=100)

2.1.2. The central role of productivity

Analyses consistently find that the primary driver of the widening EU-US income gap is Europe's lagging productivity. Europeans do not work dramatically fewer hours than Americans overall, the gap is not chiefly because of less work or shorter holidays, as one might

[24] European Commission, "Annual Single Market and Competitiveness Report" (2024)
[25] Draghi (2024)

suspect. Instead, it is because European workers produce less output per hour on average than their US counterparts. According to Draghi's report, roughly 70% of the GDP per capita gap between the EU and US can be attributed to Europe's lower productivity levels[26]. Other factors, such as lower average working hours or demographic differences, explain the remaining 30%, but productivity is by far the dominant factor. Similarly, a recent analysis found that about half of Europe's per capita GDP shortfall is due to lower productivity, with the rest due to Europeans working fewer hours per capita over their lifetimes, reflecting societal choices like longer vacations and earlier retirement. In essence, if Europe could close the productivity gap, if European firms and workers could produce as efficiently as those in the US, the income gap would shrink dramatically. Unfortunately, the trend has been in the opposite direction: productivity growth in Europe has decelerated. Since around 2008, labour productivity in advanced economies broadly (including the EU) has grown at less than 1% per year, a sharp drop from the 2%+ annual gains seen in the early 2000s. In the EU, total factor productivity (a broad measure of efficiency gains from technology and innovation) grew a meager 0.1% per year in the decade before the pandemic, compared to approximately 0.7% pre-2008[27]. This slowdown has caused Europe to fall further behind the more dynamic US economy. Indeed, over 2000-2022 the US enjoyed faster growth in real GDP per capita, widening the transatlantic prosperity gap as a cumulative outcome of many years of small differences.

2.1.3. China's rapid catch-up (and India's contribution)

While Europe has lagged, China has experienced an extraordinary surge in productivity and output. Starting from far lower income levels, China's economy has grown roughly 6-7% per year for decades, dramatically narrowing the gap with advanced economies. Chinese labour productivity (output per worker) grew about 7.7% annually from 1997 to 2022, an astonishing pace that lifted hundreds of millions out of poverty and transformed China into the world's second-largest economy. Even India, though growing more unevenly, achieved rapid productivity gains averaging 5.6% per year over the same 25-year period. Such emerging Asian giants, along with a cohort of other fast-developing countries, have become major contributors to global productivity growth. Recent research highlights that China and India alone accounted for nearly half of the total increase in global productivity since the late 1990s[28]. In other words,

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[26] Draghi (2024)
[27] IMF, "Industry-Level Productivity Developments in Europe" (2024)
[28] World Economic Forum, "The Best Versus the Rest: The Global Productivity Slowdown, Digitalization, and Superstars. Global Competitiveness Report 2025" (2025)

about 50% of the world's productivity growth in the last quarter-century has come from those two countries, a remarkable shift in the global economic landscape. Other emerging economies in Asia, such as Bangladesh, Vietnam, and parts of Southeast Asia, have also been in the "fast lane" of convergence, posting annual productivity growth around 4-5%. As a result, the centre of gravity of productivity growth has tilted toward Asia, while many advanced economies have seen much slower improvements. For instance, countries in Central and Eastern Europe have achieved solid productivity catch-up and helped raise the EU's average, but their gains have not been enough to offset stagnation in larger Western European economies. Globally, the average productivity growth rate from 1997–2022 was about 2.3% per year, but this average masks a divergence, most advanced economies slowed to below 1% after the Global Financial Crisis, whereas emerging Asia maintained far higher rates (until very recently). The net effect is that China has moved from a minor player to a peer competitor, its GDP (in PPP terms) now rivals the EU's, and its productivity level, though still below Western levels, is climbing steadily. By contrast, Europe risks being squeezed in the middle, it is no longer improving as quickly as the US frontier, nor as rapidly as the rising Asian economies.

Figure 2-2 shows the evolution of annual labour productivity from the 2008 crisis to 2022.

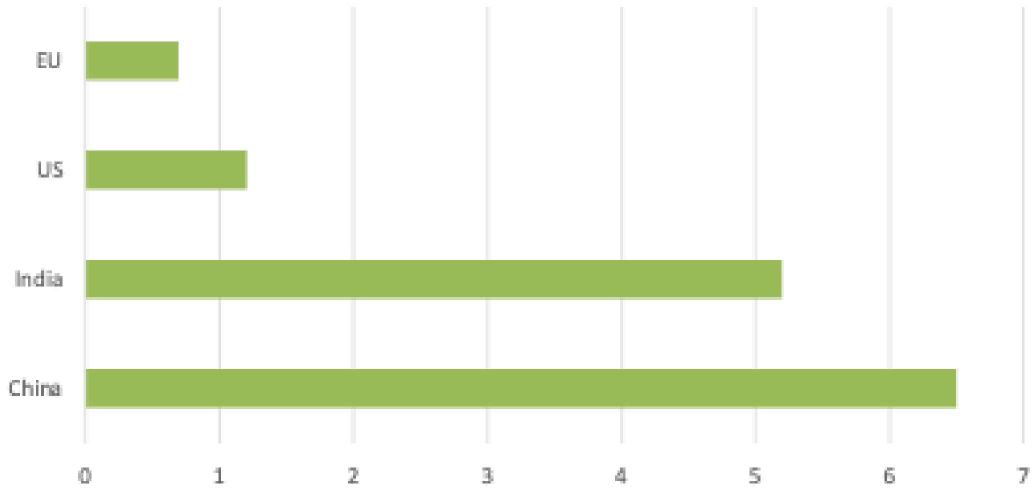

Figure 2-2 - Annual labour productivity growth 2008-2022 (%)

In summary, Europe's widening gap with the US is fundamentally a productivity gap, and it has emerged during a period when major emerging economies forged ahead. As Europe's real GDP per capita inched up only slowly, the US pulled further ahead, and China closed much of the distance from behind. This context frames Europe's competitiveness challenge, to reignite productivity growth at home in order to restore economic dynamism and keep pace in a world where others, from America's tech-driven boom to Asia's development surge, are racing forward.

2.2. Sectoral Composition of Productivity Growth: Manufacturing, Services, and Energy

A significant part of the productivity story has to do with which sectors drive growth in different economies. The US, EU, and China have distinct economic structures and have experienced differing sectoral trends in productivity. Broadly speaking, the 21st century has seen major shifts, manufacturing-led productivity booms have cooled off, the service sector's role has grown (with very different outcomes across countries), and the imperatives of energy transition have begun to influence economic performance. We discuss each in turn.

2.2.1. Manufacturing: End of the Moore's Law Era and the Offshoring Slowdown

In the early 2000s, manufacturing was a powerhouse of productivity growth. Advanced economies benefited from rapid technological progress (notably in information technology and electronics) and from globalization, which allowed efficient global supply chains. A key driver was the IT revolution, often encapsulated by Moore's Law, the observation that semiconductor performance (and thus computing power) roughly doubles every couple of years. This fuelled a wave of productivity gains in industries like electronics, computing, and communications equipment, contributing significantly to overall growth. Additionally, many Western firms increased efficiency by offshoring production to low-cost countries (often in Eastern Europe or Asia), which lowered costs and improved profitability.

However, by the 2010s these two waves had largely run their course. Evidences notes that "two waves of productivity growth in manufacturing, powered by Moore's law and offshoring, came to an end" in advanced economies after the mid-2000s[29]. The pace of improvement in computing hardware has slowed (chip miniaturization is hitting physical limits), meaning we no longer get the same productivity punch from each new generation of technology as we did in the 1990s and early 2000s. And the era of rapid globalization has given way to a more mature

[29] Fernald et al. (2025)

phase where the big gains from shifting factories to cheaper locales have already been realized. This manufacturing productivity slowdown is evident in data, manufacturing TFP growth in many advanced countries decelerated sharply after 2007, dragging down overall productivity growth. For Europe, which is home to prominent manufacturing industries (e.g., German automotive, French and Italian luxury goods, machinery, etc.), this meant the previous engine of growth lost steam. Moreover, Europe's manufacturing strength is concentrated in medium-technology industries, especially the automotive sector, which face diminishing returns. European firms excelled at incremental innovations in these mature industries (fine-tuning engines, improving mechanical design), but the global automotive paradigm is now shifting to electric vehicles and software-centric innovation, areas where Europe has lagged. Indeed, while EU companies still account for about 45% of global R&D spending in the auto industry, they are at risk of losing competitiveness as the world moves from internal combustion engines to electric drivetrains. Europe's traditional manufacturing comparative advantage is dwindling in the face of technological disruption. In contrast, the US has been dominant in high-tech manufacturing and software, by 2022, five out of the world's top 5 R&D-investing firms were American tech companies (Amazon, Alphabet, Meta, Microsoft, Apple), whereas Europe's top R&D spenders were still largely auto manufacturers[30]. This highlights how Europe's manufacturing prowess, while still significant, is tied to older tech trajectories. The slowdown of the "Moore's Law" era and the plateau of offshoring gains have left a void that Europe has struggled to fill with new high-growth industries.

2.2.2. Services: Stagnation in Europe versus Dynamic Growth in Emerging Economies

The service sector, encompassing everything from retail and transportation to finance, healthcare, and information technology, has become the largest part of modern economies. Historically, services tended to have slower productivity growth than manufacturing, partly due to the labour-intensive nature of many services and difficulties in automating them. In Europe, service-sector productivity has indeed been a notable weak spot. Since 2000, many EU countries have seen minimal productivity gains in services, especially compared to the US. Information and communication technology (ICT) services and professional services have experienced much weaker productivity growth in the EU than in the US[31]. Several factors

[30] WIPO, "Global Innovation Index 2024: R&D spending by the top 2,500 R&D spenders worldwide" (2024)
[31] European Investment Bank, "Innovation and Productivity Growth in the EU Services Sector" (2024)

explain Europe's service stagnation, fragmented markets and regulations, less intense competition, and lower adoption of digital technologies in certain service industries. The EU's single market for services remains incomplete, national regulations and language and cultural barriers hinder cross-border competition in services, resulting in less pressure to innovate and improve efficiency. Additionally, Europe was slower to embrace the large-scale, disruptive service business models that drove US productivity (for instance, the rise of e-commerce and big-box retail improved US retail productivity, whereas many European countries kept more traditional retail structures due to zoning and regulatory differences). The net effect is that Europe's overall productivity gap with the US is largely a services gap, European manufacturing productivity is closer to US levels, but in services the EU lags markedly behind. An OECD analysis finds that if Europe had matched US productivity growth in ICT and other key service industries, the EU-US gap would be significantly smaller.

By contrast, in several emerging economies, the service sector has become an unexpected engine of productivity growth. Countries like India have demonstrated that services can lead development, India built a globally competitive IT and business-process services industry, with world-class software and outsourcing firms boosting productivity and exports. Early investment in digital infrastructure and skills in the 1990s enabled India to become a global leader in IT services, defying the old notion that poor countries must industrialize before moving into services. The productivity growth in India's services has been substantial, contributing significantly to its overall economic growth. Likewise, other emerging Asian countries, such as Vietnam, have leveraged services alongside manufacturing, for example modern retail, telecommunications, and financial services, to raise productivity. Recent research notes that some emerging countries achieved high productivity growth in services, a path often downplayed in traditional development theory. In Vietnam, services like finance and telecom expanded rapidly as the country opened up, complementing its manufacturing gains. These examples show that, with the right investments (in education, urban infrastructure, digital connectivity), services can "leapfrog" in productivity even in developing contexts. In fact, the fast convergence of many emerging economies has been aided by improvements within their service sectors (e.g., the spread of mobile banking, efficient logistics, modern business services), not just manufacturing alone.

Europe's experience has been very different. In the EU, the shift of workers from manufacturing to services often meant moving into lower-productivity roles (e.g., from factory jobs into small retail or food service jobs), which can drag down overall productivity growth if the service sectors are not becoming more efficient. Analysis found that in some emerging economies, people leaving subsistence agriculture or low-end jobs moved into higher-productivity services (like modern retail or telecom), raising productivity, whereas in Europe the reallocation effect has been mixed, many workers entered relatively low-productivity service subsectors, such as hospitality or local personal services, which did not boost output per worker by much. Furthermore, Europe has not spawned service-sector giants on the scale of America's (think of Google, Amazon, or Apple, which are fundamentally service-oriented tech companies). European tech and digital services firms remain much smaller or were acquired by US rivals, reflecting a broader innovation gap. All of this has resulted in service-sector stagnation in terms of productivity in Europe. From 2010 to 2019, labour productivity in market services in the EU grew at barely above 1% per year in many countries, in some, even less, whereas the US saw much faster gains in areas like professional services, finance, and ICT services during the same period. In short, services have been Europe's Achilles heel for productivity. Unlocking higher productivity in services (through digitalization, deeper integration of the single market, and regulatory reform) is widely seen as crucial for Europe to catch up. Meanwhile, emerging economies have shown that dramatic service productivity gains are possible when technology and investment are harnessed effectively, a lesson that Europe may need to heed to reinvigorate this large portion of its economy.

2.2.3. Energy Transition and Decarbonization: High Costs and Coordination Challenges

Another sectoral, and cross-sectoral, factor affecting productivity is the energy system and the cost of decarbonisation. Energy is a critical input for the entire economy, and its price and reliability shape productivity across industries, especially in energy intensive manufacturing. In this domain, Europe faces a structural disadvantage. Relative to the United States and China, the EU has persistently higher energy costs, which compress margins and weaken cost competitiveness. Available comparisons suggest that, in recent years, European industry has often faced electricity prices roughly 2 to 3 times higher than those in the US or China.[32] his gap reflects multiple drivers. Europe has relatively limited domestic fossil fuel resources and relies heavily on imports, whereas the US benefited from a shale gas boom and China continues to draw on large scale coal based generation. In addition, climate policies, while essential for

[32] European Commission, "Energy Dimension of the Clean Industrial Deal" (2025)

sustainability, can raise effective energy costs in the short term through carbon pricing and the financing of the early phases of renewable deployment.

At the same time, Europe has adopted among the world's most ambitious decarbonisation targets, committing to net zero emissions by 2050 and substantial interim reductions. This implies sizeable adjustment costs for emissions intensive industries. Steel producers must invest in low carbon production routes, automakers must reconfigure product lines and supply chains around electrification, and utilities must accelerate the transformation of generation portfolios while maintaining system stability. Because regulatory stringency and carbon constraints remain asymmetric across major economies, the transition can create short run cost disadvantages and raise the risk of carbon leakage. The EU has introduced mitigating instruments, including border related adjustments, but the underlying policy trade off remains acute: reducing energy costs and improving energy security while accelerating emissions reductions.

Together, the trends in manufacturing, services, and energy help explain why Europe's aggregate productivity performance has disappointed. Manufacturing no longer delivers the easy gains of the past, services have not consistently offset this weakness, and the transformation of the energy system, while promising long term benefits, is costly and complex to navigate. These sectoral dynamics, however, are only part of the story. Underlying them is a deeper structural issue: the nature of Europe's innovation and industrial ecosystem and its capacity to generate, diffuse, and scale new technologies.

2.3. The European "Middle-Technology Trap": Stuck in the Middle?

Experts increasingly describe Europe as being caught in a “middle-technology trap”. This term is an analogy to the “middle-income trap” in development economics, but instead of incomes, it refers to the technological and industrial structure of Europe's economy. The idea is that Europe's industry is heavily specialized in medium-tech and mature industries (like automobiles, chemicals, machinery), and it has not transitioned successfully into the cutting-edge high-tech sectors (such as advanced digital technology, software, biotechnology, semiconductors) that are driving growth in the 21st century. As a result, Europe is missing out on the highest growth and productivity gains, which tend to come from new, disruptive technologies. In this section, we detail the evidence for this middle-tech trap and the factors contributing to it, notably Europe's innovation gap, lack of new scalable firms, and market fragmentation.

2.3.1. Slow Transition to Digital and Deep-Tech Sectors

One defining symptom of the middle-technology trap is Europe's persistent specialization in mid-tech industries with only moderate R&D intensity, while the US (and now China) have shifted more aggressively into high-tech domains. A telling data point, roughly half of all private R&D investment in the EU goes into "mid-tech" industries, especially the automotive sector, whereas in the United States a much larger share of R&D is devoted to high-tech fields like software, electronics, and pharmaceuticals. In fact, Europe's largest companies by R&D expenditure have remained largely the same over two decades, and they are mostly in traditional industries. The EU's top three corporate R&D spenders in 2022 were Volkswagen, Mercedes-Benz, and Robert Bosch, all automotive and engineering companies, just as they were (with minor variations) ten or twenty years earlier. By contrast, the top R&D spenders in the US went from being carmakers and pharma companies in the early 2000s to entirely tech companies (like Amazon, Alphabet/Google, and Meta) by the 2020s[33]. Japan shows a similar pattern to Europe (still dominated by autos and electronics), whereas China has rapidly increased R&D in high-tech manufacturing and telecoms, though it, too, started with a focus on some mid-tech areas. The implication is that Europe has not diversified into new high-tech sectors at the same pace as its competitors. Its industrial innovation is path-dependent, incrementally improving established technologies rather than leaping to new ones.

This has real consequences for growth. High-tech sectors (think of the digital economy, biotech, new materials, AI, etc.) have far outpaced traditional sectors in revenue and profit growth over the past 20 years across all major regions. Companies at the technological frontier often enjoy increasing returns and network effects that allow explosive growth and high productivity, for example a successful software platform can add millions of users without a linear increase in costs, boosting output per employee dramatically. Mid-tech industries, on the other hand, tend to see slower growth and lower profit margins once they mature. Data bears this out, in all major regions (EU, US, Japan, China), revenues and profits in high-tech industries have grown much faster than in mid-tech industries in recent decades. Notably, in the United States, by the mid-

[33] WIPO, "Global Innovation Index 2024: R&D spending by the top 2,500 R&D spenders worldwide" (2024)

2010s, high-tech sectors surpassed mid-tech sectors in total revenue, a reflection of how tech became the main engine of the US economy, whereas in the EU (and Japan and earlier-stage China) mid-tech companies still generated the largest share of revenue. Europe's failure to more strongly grow its high-tech sectors has thus meant slower overall growth. The profitability picture also highlights weaker incentives in Europe, the profit margins of high-tech firms in the US are on average about 7 percentage points higher than mid-tech firms, providing a strong incentive for US capital and talent to flow into high-tech ventures. In Europe, the profit margin gap between high-tech and mid-tech is only approximately 3 percentage points, indicating a more lukewarm reward for breaking into cutting-edge fields. This could reflect Europe's structural issues, perhaps intense competition or regulation in high-tech fields in Europe keeps returns lower, or simply that Europe's "high-tech" firms are not market-dominating giants to the same extent as America's. In any case, the economic signals in Europe have not decisively pushed the private sector towards high-tech as in the US.

Why has Europe ended up in this situation? Part of the story is that Europe historically had strengths in industries like automotive, aerospace, engineering, and chemicals, and it maintained those strengths, continuing to innovate in those fields (often in a world-leading way, e.g., German luxury automobiles or French aerospace technology). There is nothing inherently wrong with that, however, as new technology paradigms emerged (the internet, personal computing, mobile, biotech), Europe did not produce equivalent leaders in those new areas. The innovation gap with the US and Asia widened. Draghi's report bluntly states that Europe is "severely lagging behind in new technologies: only 4 of the world's top 50 tech companies are European"[34]. The continent that once led the mobile phone industry (think Nokia or Ericsson) and contributed foundational computer science saw its edge slip away to Silicon Valley and, increasingly, to East Asia. Europe today invests considerably less in research and development relative to GDP than both the US and China. According to recent analyses, Europe's business R&D spending is around 1.3% of GDP, versus 2.4% in the US and 1.9% in China[35]. This R&D gap is both a cause and consequence of the middle-tech trap, Europe's focus on mid-tech industries means a lot of R&D is channelled into moderate innovation (e.g., improving a diesel engine's efficiency) rather than radical innovation, and because its economy doesn't have as many high-tech firms, overall R&D intensity stays low. The result is seen in innovation outputs,

[34] Draghi (2024)
[35] OECD, "Main Science and Technology Indicators" (2024)

fewer European patents in key cutting-edge fields like ICT, biotech, and semiconductors, even as Europe remains strong in patents for traditional fields like automotive engineering. The EU essentially dominates in yesterday's tech (e.g., car combustion engines) but trails in tomorrow's (e.g., AI algorithms, next-gen pharmaceuticals). Without intervention, these dynamics risk leaving Europe permanently a step behind in the global technology race.

2.3.2. Scale-Up Shortage and Market Fragmentation: The Missing European Giants

A critical aspect of Europe's tech and productivity shortfall lies in its inability to generate and scale up new firms to rival the dominant American and Chinese players. The continent is not short of creativity or entrepreneurship at the start-up level, every year, many innovative European start-ups are founded, but too few of these grow into large, world-leading companies. Mario Draghi highlighted this problem starkly, in his address to the European Parliament, he noted that no EU-headquartered company with over €100 billion in market value has been founded in the last 50 years. By contrast, all six of the US companies with market valuations above €1 trillion (roughly $1.1 trillion), such as Apple, Microsoft, Google, Amazon, Facebook, and Nvidia, were created within the last half-century. This speaks to a dynamism gap, the US has continually birthed new giants in tech and other fields, whereas Europe's largest firms tend to be older, established corporations (many founded in the early-to-mid 20th century or even 19th century). Europe's economic landscape thus lacks the presence of homegrown "Big Tech" or other fast-growing firms that could drive innovation and productivity. The core problem, as Draghi put it, is that "new companies with new technologies are not rising in our economy"[36]. Europe has plenty of talented researchers and entrepreneurs with good ideas, but systemic factors impede turning those ideas into large-scale business success within Europe.

One major systemic barrier is the fragmentation of the EU single market and capital market. Unlike the United States, a single, unified market of 330 million people with one language (for business) and relatively harmonized regulations, the European Union, despite the concept of a single market, still functions in many ways as a patchwork of national markets. A start-up in Europe scaling up faces a thicket of differing rules, each country may have its own regulations on everything from labor to product standards to data privacy, its own tax regime, its own public procurement processes, etc. Expanding across Europe can be as daunting as expanding globally.

[36] Draghi (2024)

Draghi notes that innovative companies trying to scale in Europe are “hindered at every stage by the lack of a Single Market and an integrated capital market”, which effectively stops the cycle of innovation in its tracks. For instance, a fintech company that succeeds in one European country might struggle to offer the same service elsewhere due to different licensing requirements. Or consider a biotech startup, it might find that clinical trial approvals, reimbursement systems for drugs, and hospital purchasing arrangements differ vastly between Germany, Italy, and Poland, making it much harder to achieve continental scale. This fragmentation dilutes what should be Europe’s greatest advantage, the combined scale of over 440 million relatively affluent consumers.

Additionally, Europe’s financial system and venture capital ecosystem have historically been less geared toward high-risk, high-reward investment in new firms. European businesses have relied more on bank financing and less on equity markets or venture capital compared to the US. The result is scarcer risk capital for start-ups and scale-ups. Venture capitalists in the US (and increasingly China) provide not just funding but also networks and know-how to help start-ups grow rapidly. Europe has improved its VC scene in the last decade, but it still lags. Many European entrepreneurs therefore seek financing from American investors and end up relocating. Draghi pointed out a striking statistic, between 2008 and 2021, about 30% of European-founded “unicorns” (start-ups valued over USD 1 billion) moved their headquarters abroad, typically to the US[37]. This represents a significant loss of potential, these companies take their operations, talent, and future growth to jurisdictions where scaling is easier (e.g., tapping into the deep US capital markets and large homogeneous market). And that 30% figure does not even count the many young Europeans who move to the US to found companies there in the first place. It is a form of brain drain and innovation drain that deprives Europe of the very companies that might have led its high-tech growth.

Table 2-2 summarises the outcome gap behind Europe’s scale-up problem by contrasting the stock of unicorns across the EU, the US, and China and reporting the share of Europe-founded

[37] Draghi (2024)

unicorns that relocated abroad between 2008 and 2021.

Metric	EU	US	China
Active unicorns (valuation > USD 1bn)	217	850	330
Europe-founded unicorns that relocated HQ abroad (2008–2021)	~30%	n.a.	n.a.

Table 2-1 - Tech unicorns and scale-up drain (selected indicators)

Sources: Unicorn counts (active unicorns valued > USD 1bn): PitchBook (latest available year). Relocation share (Europe-founded unicorns relocating headquarters abroad, 2008–2021): Draghi (2024).

Scholarly analyses back up these observations. An IMF working paper on Europe's firm dynamics found "critical performance gaps" among both top-end firms and start-ups in Europe, leading European firms are not as dominant or productive as leading US firms, and Europe produces fewer high-growth young firms ("gazelles") than the US. The study linked these outcomes to Europe's smaller markets and limited market-based financing, as well as skill shortages and lower availability of venture capital in Europe. In other words, the very ingredients needed for scale, a big unified market, ample risk financing, fluid labour markets to attract talent, are less present in Europe. Removing remaining barriers to intra-EU trade and investment, and developing deeper capital markets, are frequently cited remedies to these issues. Another analysis by leading economists noted that Europe's innovation system is segmented and fragmented, with fragmented consumer markets, labour markets, and an obsolete industrial structure hindering the emergence of disruptive innovation. They emphasize that Europe's focus has been too much on supporting incremental innovation in existing industries, and not enough on fostering the creation of new sectors and startups. Indeed, European policies have sometimes leaned toward protecting established firms (so-called "national champions") rather than enabling challengers to unseat them, which can entrench the status quo.

The consequences of the middle-technology trap and scale-up problem are evident in Europe's productivity numbers. Frontier firms (the most productive ones) in Europe do not pull as far ahead of the pack as US frontier firms do, suggesting less "superstar" dynamism. And aggregate productivity suffers when innovative ideas are not commercialized or scaled in-region. The innovation gap translates into a productivity growth gap, Europe's slowdown in productivity coincides with the period in which it fell behind in the tech sector and did not produce equivalents to Google, Amazon, or Tencent. As Draghi observed, this innovation deficit is "at the root of Europe's slowing productivity growth relative to the US"[38]. Closing the productivity gap, therefore, will require Europe to escape the middle-tech trap by shifting more forcefully into high-tech, high-productivity activities. That means not only investing more in R&D and frontier science (Europe is already taking steps, for instance, through the European Research Council funding excellent science), but crucially also improving the ecosystem for turning research into commercial success. Europe must cultivate an environment where startups can become scale-ups and where new companies can thrive rather than being stymied by fragmentation or bought out early. This may involve difficult reforms, harmonizing regulations, creating what some call a "true single market" for digital and services, encouraging more risk-taking in financing (e.g., developing venture capital and stock markets that reward innovation), and perhaps reconsidering competition policies to allow European firms to achieve global scale in strategic sectors.

[38] Draghi (2024)

3 Socio-economic structure of the three European pillars: Germany, France & Italy

The aggregate productivity gap documented in Chapter 1 is the outcome of national trajectories that remain deeply heterogeneous despite decades of European integration. The European Union is not a unified economic space with a single growth model. It is a political construction that accommodates distinct varieties of capitalism, each shaped by specific configurations of state capacity, corporate governance, financial systems, and labour-market institutions. These national models condition how firms invest, innovate, and respond to external shocks, and they generate persistent differences in productivity levels and growth rates. To understand why Europe as a whole has struggled to close the gap with the United States and to respond to the rise of China and India, it is necessary to examine the internal diversity of European capitalism. This chapter focuses on Germany, France, and Italy, the three largest continental economies and the political and industrial core of the Union. Together, they account for approximately 60 percent of EU GDP, host the majority of Europe's large industrial firms, and embody three analytically distinct institutional logics: coordinated industrial capitalism, state-led dirigisme, and decentralised entrepreneurial networks. Understanding how these models generate or constrain productivity is essential for any realistic assessment of Europe's competitive position and for the design of effective, politically feasible industrial policy at the European level.

3.1. Why These Three Economies

Germany, France, and Italy constitute the three central pillars of Europe's productive architecture, together they account for nearly two thirds of the euro area's GDP, more than 60 percent of manufacturing value added, and a comparable share of total research and development expenditure within the European Union. Beyond their size, their importance lies in the distinct but complementary nature of their industrial and institutional systems, each embodies a different historical pathway of capitalism that has shaped how production, innovation, and state intervention interact inside the European Single Market, so that analysing these three economies provides a representative cross section of the continent's productive heterogeneity and allows the study to link micro institutional characteristics to macro level productivity outcomes.

Germany represents Europe's coordinated industrial capitalism, centred on a dense manufacturing base, a strong export orientation, and a dual system that balances large global firms with a network of specialised small and medium sized enterprises commonly referred to as the Mittelstand, France exemplifies a state engineered model of growth in which strategic coordination, large scale industrial projects, and public investment have long directed innovation and re industrialisation efforts, while Italy is characterised by a decentralised entrepreneurial economy built on regional industrial districts and highly flexible small firms that thrive in design intensive and mechanical engineering niches, together these models delineate three archetypes of European production, the corporatist industrial model in Germany, the dirigiste model in France, and the entrepreneurial artisanal model in Italy, whose coexistence within a single market produces strength, through diversification and complementarities, but also weakness, insofar as it complicates policy convergence and limits economies of scale.[39]

Empirical analyses consistently corroborate the relevance of focusing on these economies, owing to their structural weight Germany, France, and Italy are the primary contributors to the aggregate productivity dynamics of the European Union, and persistent national disparities in capital deepening, digital adoption, and skill allocation mean that developments within these three systems disproportionately shape overall European performance. At the firm-level they dominate Europe's productive structure, with Germany anchoring frontier productivity through high technology manufacturing, France concentrating research intensive and policy supported sectors, and Italy's dense network of small and medium sized firms sustaining employment while weighing on aggregate total factor productivity, together they also absorb the majority of industrial support and innovation incentives within the Union, making their internal trajectories central to any assessment of Europe's growth prospects.[40]

[39] European Commission, “Annual Single Market and Competitiveness Report” (2024)
[40] OECD, “OECD Economic Surveys, European Union and Euro Area 2025” (2025)

At the geopolitical level these economies form Europe's strategic core, simultaneously shaping and constraining the Union's competitiveness agenda, Europe's ability to scale innovation and close the productivity gap with global competitors depends crucially on policy coordination within these core industrial heartlands, which host the continent's most advanced value chains in sectors such as automotive, aerospace, machinery, and pharmaceuticals, yet also concentrate many of its structural rigidities, including fragmented capital markets, regulatory divergence, and uneven diffusion of digital technologies. Hence, despite sharing the same monetary regime and facing similar exposure to global shocks they exhibit markedly different institutional responses to technological change and industrial policy. Germany's productivity increasingly constrained by energy costs and the automotive transition, France's performance hinging on the effectiveness of its state led innovation and coordination mechanisms, and Italy's prospects depending on the capacity of its small and medium sized firms to integrate into transnational value chains. In comparative perspective their divergent trajectories encapsulate the broader dilemma of European competitiveness, namely, how to reconcile deeply rooted national economic models with the need for collective scale, coordination, and technological acceleration.

3.2. Germany: Industrial Capitalism and Corporate Ecosystem

3.2.1. Economic Geography and Industrial Clusters

Germany’s economy is characterised by a polycentric industrial geography shaped by highly specialised regional clusters. The southern states, Bavaria and Baden Württemberg, which invested €32.5 billion in research and development in 2022, the highest among German Länder, form the manufacturing heartland, specialising in automotive, precision mechanics, and high tech innovation. North Rhine Westphalia has shifted from heavy industry toward diversified clusters in chemicals, mechanical engineering, and logistics. Hamburg operates as a major port and logistics hub, while Saxony has consolidated a high tech microelectronics centre often labelled “Silicon Saxony”. Knowledge diffusion remains strongly place based: spatial interaction declines sharply with distance, with an estimated half life of around 200 km. This pattern is consistent with the predominance of tacit knowledge channels and implies that spillovers attenuate rapidly outside nearby regions.

Table 3-1 provides a stylised map of Germany's main regional specialisations and the channels through which this geography shapes productivity dynamics and shock exposure.

Region	Key Specializations	Productivity relevance / exposure channel
Bavaria and Baden-Württemberg	Automotive, Precision Mechanics, High-Tech Innovation	Dense manufacturing ecosystems, strong innovation base, high spillover potential
North Rhine-Westphalia	Chemicals, Mechanical Engineering, Logistics	Industrial restructuring legacy, energy-exposed process industries, logistics scale
Hamburg	Port & Logistics Hub	Trade-linked hub, coordination advantages, exposed to global demand and shipping cycles
Saxony	Microelectronics ("Silicon Saxony")	Concentrated high-tech cluster, strong local spillovers, scale-up/talent bottlenecks

Table 3-1 - Key industrial Cluster in Germany

Manufacturing accounts for roughly one fifth of the economy, measured at around 19 to 21% depending on the statistical definition and whether the focus is gross value added or GDP.[41] The core pillars include automotive, contributing around 3% of GDP, mechanical engineering employing about 1.3 million workers, chemicals, and electrical equipment. Aggregate research and development spending reached €121.4 billion in 2022, but the capacity to finance and absorb innovation is unevenly distributed across firm size and space.[42] This unevenness is reflected in a persistent dual structure in productivity outcomes. In the post pandemic recovery, manufacturing output per hour increased by about 7% in 2021 despite declining headcounts, yet median sized firms remain only about 65% as productive as large firms. The digital adoption gap has also widened: around 35% of small firms use advanced digital technologies compared with about 63% of large firms, and larger small and medium sized enterprises are about 2.1 times more likely to undertake digitalisation projects than micro enterprises. These gaps are reinforced by complementary constraints. Only about 15% of small firms employ ICT specialists; high speed broadband coverage in rural areas is about 37.6%, well below the EU

[41] European Commission, "2024 Country Report and Accompanying Document" (2024)
[42] Germany Trade & Invest (GTAI) (2024)

level of roughly 55.6%; and fixed adoption costs such as managerial retraining, process redesign, and compliance weigh proportionally more on smaller organisations.[43] Overall, the evidence points to a capital intensive manufacturing base concentrated in large firms and selected clusters, while peripheral regions and smaller enterprises face a higher risk of productivity stagnation amplified by distance from knowledge centres.

3.2.2. Corporate Structure: Large Firms and the Mittelstand

Germany's industrial ecosystem operates through a dual corporate structure combining global multinationals with a dense network of small and medium sized enterprises, the Mittelstand. This configuration generates complementarities in capabilities, supplier depth, and export capacity, but it also produces persistent productivity asymmetries.

Large firms such as Volkswagen, Siemens, BASF, BMW, Daimler, Bayer, and SAP function as frontier firms in the European context. They combine technological leadership with extensive global supply chains, high research intensity, and large scale export capacity. Volkswagen, for instance, invests more than €15 billion per year in research and development and produces around 10 million vehicles globally.[44] These firms set sectoral standards and anchor value chains across the single market. Their adoption of frontier technologies, especially artificial intelligence, is markedly more advanced: between about 24.5% and 34.1% of large firms have implemented AI, compared with roughly 5.8% to 19.1% of small and medium sized enterprises depending on the sector[45].

The Mittelstand constitutes around 99% of registered companies and employs more than 60% of the private sector workforce. Within this population, roughly 1,600 firms are often described as hidden champions, global leaders in narrow niche segments. They typically spend close to 6% of revenues on research and development, almost triple the intensity of comparable incumbents, hold about 1% to 10% global market share in their segments, and record average annual growth of about 8.4%, above the growth rate of major listed groups at around 4.9%.[46] Their innovative output is also distinctive, with around 31 patents per 1,000 employees, far above the rate reported for large corporations. The key structural point, however, is that this top

[43] European Commission, "In-Depth Review for Germany" (2024)
[44] Volkswagen AG (2024)
[45] Licht (2025)
[46] Rammer (2024)

tier does not represent the median firm: outside the hidden champion subset, the broader small firm base faces tighter financing, weaker internal capabilities for technology integration, and more limited strategic bandwidth to undertake large scale organisational change.

Diffusion beyond frontier firms is therefore constrained by absorptive capacity, namely the ability to recognise, assimilate, and commercialise external knowledge. Many small and medium sized enterprises lack specialised ICT staff, face persistent hiring frictions, and underinvest in digital and managerial training. Integration and compliance costs also matter: system integration, data governance, GDPR related constraints, uneven data quality, and fixed adoption costs linked to organisational redesign and managerial upskilling scale poorly for smaller firms. Survey evidence is consistent with this mechanism: in construction, for example, about 54.7% of small and medium sized enterprises consider AI irrelevant, compared with about 12.8% of large firms. Investment patterns reinforce the gap: small and medium sized enterprises allocate around 0.4% of revenues to AI investment, compared with about 0.5% for very large companies with revenues above €5 billion.[47] In this context, the Mittelstand often excels at incremental innovation in established niches, while a substantial share of smaller firms faces a risk of entrenchment in a low productivity trap as competitive pressure rises.

The implication is not that the model lacks innovative capacity, but that it concentrates it. Germany must simultaneously maintain frontier upgrading in large firms and high performing Mittelstand leaders, while lowering the effective fixed costs of diffusion for the broader tail. Otherwise, the dual structure risks hardening: hidden champions and multinationals continue to advance, while a wide set of peripheral small and medium sized enterprises stagnate under cost pressures, lengthy approval processes reported as a barrier by around 70% of firms, and persistent labour shortages.[48]

3.2.3. Institutions, Public Private Coordination, and Finance

Germany’s institutional environment relies less on deregulation than on coordination through structured complexity and rule-based corporatism. Firms are embedded in a dense system of intermediary organisations and codified participation mechanisms that shape training, governance, and conflict resolution. All firms must register with the local Chambers of

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[47] Licht (2025)

[48] European Commission, “In-Depth Review for Germany” (2024)

Commerce and Industry, which support training oversight, dispute resolution, and institutional representation. Labour participation is formalised through works councils and, in firms with more than 2,000 employees, codetermination on supervisory boards. In productivity terms, these arrangements can strengthen alignment between workers and management, encourage internal knowledge sharing, and support continuous incremental innovation. The same consensus seeking model may, however, slow decision making and reduce responsiveness when rapid strategic pivots are required.[49]

The dual vocational training system is central to industrial skill formation and to the Mittelstand's capacity to sustain specialised production. Around 1.2 million apprentices are trained annually, with more than one million hosted by small and medium sized enterprises, representing over 90% of apprentices, up from about 84% in 2010. Training combines workplace instruction, which accounts for roughly three quarters of the content, with classroom education coordinated by the federal institute responsible for vocational education and training standards. Developed jointly by firms, industry associations, and public authorities, the model aligns curricula with labour market needs and supplies technicians and specialists across 326 recognised occupations. Yet participation is increasingly strained: the share of small and medium sized enterprises offering apprenticeships declined from around 12% in the 2010 to 2018 period to about 9.1% by 2024, reflecting the post energy crisis adjustment, demographic ageing, and a stronger youth preference for tertiary education.[50] To partly offset these pressures, inter company training centres provide shared facilities, digital equipment, and pilot programmes that expand small firm training capacity, while recent skilled immigration reforms aim to ease recruitment of vocational track workers from abroad. The net effect is a system that allows small firms to access high quality skills without directly competing with large firms for university graduates, but where a narrowing training base increases the risk of future skill bottlenecks.

Financial coordination is an additional pillar of the model and is particularly relevant for diffusion and investment among small and medium sized enterprises. Germany maintains a three tier banking architecture that combines private banks, cooperative banks, and public savings banks with associated regional institutions. The cooperative segment, organised around roughly 670 member institutions, serves around 30 million customers and accounts for about

[49] European Commission, "In-Depth Review for Germany" (2024)
[50] Bundesinstitut für Berufsbildung (BIBB), "Vocational Training Statistics 2023" (2024)

18% of domestic lending, with relationship based lending supported by strong local embeddedness, as a majority of members are also customers. This structure tends to stabilise small firm credit access and can sustain modest loan growth even in periods of weak macroeconomic momentum. Alongside commercial and cooperative finance, the national development bank plays a central role by providing investment and innovation loans, including for decarbonisation and the energy transition.[51]

Recent funding plans targeted roughly €90 to €95 billion, including around €10 to €13 billion for green projects such as energy efficient buildings, renewable infrastructure, and clean transport, with projected annual emissions reductions of around 620,000 tonnes.[52] Dedicated facilities have also channelled more than €100 million into venture capital funds to support innovative small and medium sized enterprises in transition related technologies. This institutional ecosystem supports problem solving through coordinated institutions and long term financing mechanisms that mobilise capital without relying primarily on rapid deregulation. At the same time, policy design remains uneven. Recent international assessments of scale up finance point to a strong emphasis on innovation instruments, around 73% of the policy mix, with comparatively limited attention to investment and human capital, around 12.6%, suggesting a potential imbalance relative to the broader requirements of the green and digital transitions. Measures to address these gaps, including additional low interest loans totalling €11.7 billion, expanded equity support for small and medium sized enterprises, and efforts to simplify permitting, have moved in the right direction but remain incomplete.[53]

3.2.4. Productivity and Innovation Outcomes

Despite its institutional strengths, Germany has experienced a marked productivity slowdown shaped by structural change and a set of binding constraints. Labour productivity growth averaged about 0.4% per year between 2015 and 2023, below the OECD average, while total factor productivity growth has been close to zero since 2017.[54] A significant component reflects composition effects: part of the aggregate deceleration is explained by the shift of activity from manufacturing toward services where productivity growth is weak, particularly in business services where employment expanded while labour productivity declined for several years. This

[51] OECD, “Financing SME Growth in Germany” (2024)
[52] KfW Group, “KfW Development Bank Annual Report 2023” (2024)
[53] European Commission, “2024 Country Report and Accompanying Document” (2024)
[54] OECD, “Special Chapter on Strengthening Productivity and the Single Market” (2025)

rebalancing matters because Germany's aggregate performance remains unusually dependent on manufacturing as a carrier of capital deepening, export capacity, and diffusion of process innovation.

The manufacturing base itself has become more productive but less weighty. While manufacturing maintained a stable share of gross value added of around 22% from 1995 to 2017, it declined to about 20% by 2023 and to around 17.8% by 2024.[55] This occurred despite strong productivity gains in the previous decade, with roughly 30% growth in the 2010 to 2020 period, indicating that output per worker increased while employment and the sector's aggregate weight contracted. In this setting, productivity improvements are increasingly concentrated in the most capital intensive segments and in frontier firms, while the employment shift toward lower productivity services drags on the aggregate.

Disruptive pressures on the industrial core are now intersecting with this structural reallocation. The electric vehicle transition illustrates the scale of adjustment. German manufacturers and suppliers have estimated that around 186,000 automotive jobs could be lost over the next decade, with roughly 46,000 already lost by 2024.[56] Volkswagen has announced plans for more than 35,000 redundancies by 2030 out of about 295,000 domestic workers, and suppliers such as Bosch, ZF, Audi and other tier one firms have communicated combined job cuts exceeding 30,000. The transition is compounded by demand volatility: electric vehicle registrations in Germany fell by around 27% in 2024, leaving parts of the supplier base with overcapacity and limiting near term job creation in electric powertrain production. The adjustment is also strategic rather than purely cyclical, as production footprints and sourcing strategies are gradually shifting toward lower cost locations and to more localised procurement in overseas markets, reflecting both Chinese competitive pressure and longer run supply chain reorganisation.

Energy costs remain a central constraint on manufacturing competitiveness and investment planning. Industrial electricity prices were around €0.19 per kWh in 2024, roughly 2.4 times the United States level of about €0.08 per kWh. This differential compresses margins in energy intensive segments and raises the hurdle rate for investment, particularly for capital intensive

[55] European Commission, “In-Depth Review for Germany” (2024)
[56] Fraunhofer ISI, “Automotive Transformation Study” (2024)

upgrading and decarbonisation projects. The shock dynamics and the associated policy response are examined in detail in Chapter 5.

Innovation performance at the frontier also shows signs of weakness relative to global benchmarks. Over the past two decades, productivity in United States technology firms increased by about 40%, while European equivalents stagnated. Germany also exhibits a scale up deficit: only around one in ten start ups grows into a large firm, compared with roughly one in four in the United States. Digital technology adoption remains uneven. Survey based measures indicate that close to 40% of German firms report some use of artificial intelligence, but estimates vary between about 12% and 27% depending on methodology and are concentrated among large firms. Manufacturing and ICT lead, while commerce, healthcare, and social work lag. Cloud adoption remains limited, with about 47% of firms using cloud services, and only around 30% of small and medium sized enterprises assessed as data ready compared with about 77% of large firms. Crucially, the same complementary bottlenecks described earlier, skills constraints, uneven connectivity, and high fixed organisational costs, imply that adoption is not only a technology choice but also a reorganisation problem that is harder to solve in smaller firms. [57]

Firms' expansion intentions are consistent with subdued diffusion and investment momentum. Only about 14% of German companies prioritise investment in new products or processes, below the European Union average, while capacity expansion plans are more common among United States firms than among German firms. At the same time, labour supply constraints are tightening. The workforce is projected to contract significantly by 2040, and skills mismatches are acute: around nine out of ten firms report hiring difficulties for required qualifications, with a large majority describing this as a major obstacle.[58] Rapid occupational restructuring, with manufacturing roles declining while service sector and higher skill roles expand, is progressing faster than the education and training system can fully absorb.

Taken together, weak frontier dynamism, limited diffusion into the long tail, energy and transition costs, and labour constraints point toward a prolonged period of subdued productivity growth and lower potential output unless adjustment accelerates. The binding nature of the constraints matters: progress in one dimension, for example digital adoption, may be dampened

[57] Licht (2025)
[58] Müller (2024)

by bottlenecks in skills or energy costs, implying that policy and firm strategy need to operate across multiple margins simultaneously.[59]

Table 3-2 condenses the main aggregate indicators that summarise Germany's recent productivity performance and the key cost and transition constraints discussed in this section.

Indicator	Value
Labor Productivity Growth (2015-2024)	0.4% per year (avg.)
Average TFP Growth (post-2017)	~0.0%
Manufacturing Share of GDP (2024)	17.8%
Illustrative projected EV-related job losses	186,000
Industrial Electricity Price (2024)	€0.19/kWh (US: €0.08/kWh)

Table 3-2 - Key productivity indicators for Germany

These aggregates are consistent with a dual structure in which frontier firms remain strong while diffusion into the long tail is slower.

3.3. France: The State as Economic Architect

3.3.1. Centralized Economic Geography and the Role of Paris

France exhibits a markedly centralised economic geography, dominated by the Paris region (Île-de-France), which accounts for roughly 30-31% of national GDP while hosting about one-fifth of the population. Île-de-France concentrates high value-added activities, corporate headquarters, skilled labour, and research capacity; in 2015, 29 out of 31 French Fortune Global 500 firms were headquartered there. These agglomeration forces support frontier performance through dense firm networks, leading universities, and R&D intensity, making Paris the country's main productivity engine.

Outside the capital, France hosts smaller but relevant clusters: Auvergne-Rhône-Alpes (Lyon) in high-tech manufacturing and engineering, Occitanie (Toulouse) in aerospace/defence, and industrial bases in Hauts-de-France and Provence-Alpes-Côte d'Azur. However, none

[59] OECD, "R&D Spending Growth Slows in OECD" (2025)

approaches Île-de-France's weight. The resulting macrocephalic structure sustains strong frontier TFP yet weakens aggregate growth via persistent regional divergence: since 2000, Île-de-France has continued to pull ahead, growing around 0.5 percentage points per year faster in GDP per capita than the least prosperous regions.[60]

The underlying diffusion constraint is quantifiable. R&D capital is hyperconcentrated across employment areas: about 88% of local R&D capital stock lies in the top 10% of areas, and Paris plus a small set of satellite poles account for roughly 70% of national R&D employment. Knowledge externalities are correspondingly local: the elasticity of firm TFP to local R&D spillovers is ≈ 0.03 (whole economy), falls to ≈ 0.015 within 100 km, and approaches zero beyond ~200 km; in manufacturing it can reach ≈ 0.09 but remains confined to dense agglomerations. Cross-industry spillovers are negligible (≈ 0.01-0.02), limiting transmission from specialised hubs to unrelated peripheral activities. This produces self-reinforcing sorting: high-productivity firms and high-skill workers concentrate where spillovers are accessible, while peripheries face low learning opportunities; consistent with this, the correlation between individual fixed effects (unobserved skill/efficiency) and density is ≈ 0.44. Overall, France's geography delivers high local frontier TFP but structurally weak national diffusion and persistent regional fragmentation.[61]

3.3.2. Public Interventionism: Industrial Policy, Grands Projets, and National Champions

France exemplifies a *dirigiste* model of capitalism, in which the state acts as an economic architect shaping industrial development. Since the post-war period, governments have pursued grands projets and cultivated national champions in strategic sectors. Public coordination and investment have steered modernisation, from the TGV network and the nuclear programme to Airbus and the Ariane launcher, reflecting the premise that concentrating resources on high-impact technologies can accelerate upgrading and secure strategic autonomy.[62]

A central instrument is the state's ownership and shareholder influence in key firms. France remains distinctive among large advanced economies in maintaining significant public equity stakes across energy, transport, defence, and core infrastructure, using these firms as vehicles

[60] INSEE, “Comptes régionaux 2023” (2024)
[61] European Commission, “In-Depth Review France 2024” (2024)
[62] European Commission, “In-Depth Review France 2024” (2024)

of industrial strategy. This architecture helped produce globally competitive multinationals, especially in aerospace, defence, energy, luxury goods, and telecommunications, operating at or near the technological frontier.

From a productivity standpoint, the model has delivered clear but uneven benefits. Targeted public investment and coordination have supported high TFP in selected sectors by channelling physical and intangible capital into advanced technologies, strengthening engineering capabilities, and building infrastructure that lowers transaction costs and facilitates agglomeration, pushing the frontier outward in areas such as aerospace, nuclear, and transport equipment.[63]

The trade-offs, however, are material. Preferential support for large incumbents can distort resource allocation and weaken competitive pressures, slowing entry and creative destruction; prolonged backing of weak firms generates misallocation and weighs on aggregate TFP. Many champions are also highly internationalised, so a large share of employment and growth occurs abroad, reducing domestic spillovers. Despite sustained industrial activism, France experienced pronounced deindustrialisation: manufacturing employment roughly halved since 1980 and industry's share of GDP fell sharply, indicating that high-tech enclaves were preserved without preventing broader competitiveness erosion.[64]

Overall, France's dirigiste tradition yields strong static outcomes in targeted frontier sectors but weaker aggregate dynamics. The main channels operate through uneven diffusion (reinforced by the highly local nature of spillovers documented above), a firm-size and sectoral bifurcation in innovation effort, and slower reallocation under selective support. Around two-thirds of French business R&D is carried out by firms with more than 250 employees (consistent with policy instruments such as the Crédit d'Impôt Recherche) while SMEs, especially outside major clusters, face weaker absorption and limited access to spillovers.[65] Estimates suggest misallocation linked to selective support and sheltered sectors may account for 1-2 percentage points of forgone potential TFP growth. Taken together, these channels produce high frontier productivity with weak diffusion and limited reallocation, helping explain why innovation pockets coexist with subdued aggregate TFP growth.

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[63] INSEE, “Recherche et développement en France: Données 2023” (2024)
[64] OECD, “Economic Surveys: France 2024” (2024)
[65] Banque de France, “Productivity Trends in France: Structural Factors” (2024)

Table 3-3 summarises the core institutional features of the French dirigiste model, highlighting the centrality of state-led ‘Grands Projets’, the role of national champions, and the concentration of business R&D in large firms.

Feature	Description
Grands Projets	TGV, Nuclear Program, Airbus, Ariane Launcher
National Champions	State-owned or influenced firms in strategic sectors (energy, transport, defence)
Deindustrialization	Manufacturing employment halved since 1980
R&D Concentration	~66% of BER&D conducted by firms with >250 employees

Table 3-3 - The French Dirigiste model: key features

These traits underpin a model that can mobilise resources for large-scale strategic projects, but they also help explain why innovation and productivity gains may remain concentrated rather than diffusing broadly across the firm population.

3.3.3. Bureaucratic Proactivity, Implementation Frictions, and the Reindustrialisation “Productivity Paradox”

Building on France's dirigiste tradition, the Macron-era agenda has pursued reindustrialisation through an activist administrative apparatus and programme-based financing. France 2030 (initially €54bn) had committed €38bn by end-2024 across roughly 7,500 projects, with SMEs and mid-caps representing 55% of beneficiaries; Bpifrance complements this with a €35bn reindustrialisation plan for 2024-2028.[66] This centralised allocation can raise productivity by relaxing financing constraints for modernisation and intangible investment and by coordinating risk-sharing in frontier technologies provided implementation capacity and complementary inputs hold.

Yet productivity has responded less than the scale of financing would suggest, reflecting a reindustrialisation "productivity paradox" in which activity and employment improve faster than measured efficiency. Two forces underpin the post-Covid slowdown. Temporary drivers include labour hoarding and adjustment frictions under tight labour markets: since end-2019 total hours worked rose by about 5.6% while labour productivity remained below its pre-Covid trend. Banque de France estimates place labour productivity around 8.5% below trend

[66] Gouvernement français, “France 2030: Bilan d'exécution fin 2024” (2024)

by mid-2023, partly reflecting these transitory factors and short-run composition effects in hours.[67] Structural drivers are more binding for medium-term TFP: the productivity shortfall also reflects durable composition shifts toward lower-productivity segments and worker cohorts, including the expansion of apprenticeships (≈1.2 pp of the gap) and a workforce composition effect linked to a higher share of lower-skilled labour (≈1.4 pp). These mechanisms mechanically depress measured productivity when labour inputs expand faster than output and reallocation toward high-productivity activities is incomplete.

Translation of capital deployment into TFP is further constrained by institutional implementation frictions. A first bottleneck is administrative throughput: industrial permitting still takes around 17 months in practice (versus about 9 months in Germany), delaying capacity deployment and lowering effective returns. Reforms target this channel: the 2023 Industrie verte law aimed to cut timelines (≈17 to ≈9 months) via parallel processing and a "project of major national interest" status (PINM/PIINM), reinforced by the June 2025 simplification bill.[68] The binding constraint remains execution capacity, sustained coordination and staffing, so procedural acceleration may outpace reductions in effective lead times.

Human capital is the second binding constraint, slowing reindustrialisation through three channels: demographic pressure (retirements reducing experienced technicians/engineers), STEM pipeline constraints (shortages/mismatches in technical and ICT profiles), and VET/technician formation limits that weaken firms' absorption capacity and slow diffusion across supplier networks. Programme funding can therefore generate many projects while execution and productivity gains become bottlenecked by staffing, training throughput, and shop-floor capabilities.[69]

Macroeconomic conditions mainly interact with these constraints: higher interest rates can delay private co-investment, while fiscal limits and EU state-aid ceilings constrain prolonged subsidy-led acceleration. Recent indicators nevertheless show mobilisation: Business France reports 1,688 foreign investment decisions in 2024 (37,747 jobs expected to be created/maintained), with manufacturing ranking first (28% of decisions) and 32% of decisions and jobs linked to France 2030.[70] The policy challenge is to convert mobilisation into sustained

[67] Devulder et al. (2024)
[68] Ministère de l'Économie, “Loi Industrie verte: Réforme des autorisations d'exploitation industrielle” (2023)
[69] Pôle emploi, “Dares, Besoins en main-d'œuvre 2025: Focus sur les métiers industriels” (2024)
[70] Business France, “Rapport sur les décisions d'investissement international 2024” (2025)

TFP growth by tightening the implementation chain, permitting speed, land readiness, and especially human-capital formation, so capital deepening and frontier projects diffuse into broad-based efficiency gains.

3.3.4. High-Tech Frontier vs. Diffusion to SMEs: A Dual-Productivity Structure

A final mechanism linking the preceding sections is France's firm-level dualism: frontier strength (concentrated in Paris, large incumbents, and targeted high-tech enclaves) coexists with a persistent SME "long tail," limiting aggregate TFP. Cross-country evidence suggests firms with more than 250 employees produce roughly twice as much output per hour as small firms (10-19 employees). France's size structure amplifies this gap: large enterprises account for 59.3% of total turnover (EU: 49.6%), while SMEs account for only 10.2% (EU: 12.6%), indicating a weak middle segment and concentration of high-productivity activity in incumbents.[71]

This dual structure is reinforced by institutional barriers that slow diffusion and scaling.

First, competitive exposure is limited. SMEs generate about 44% of value added but only 16% of exports, so fewer firms benefit from "learning-by-exporting" (standards, customer pressure, supply-chain integration) that typically accelerates upgrading.[72]

Second, adoption is constrained by capability gaps and low absorptive capacity, not financing alone. Turning technology into efficiency gains requires complementary intangibles, managerial practices, digital skills, process redesign, and compliance/cybersecurity, that raise fixed costs relative to firm size.

Third, these fixed costs are reflected in the digital divide. Only 35% of small firms (10-49 employees) use advanced digital technologies versus 63% of large firms, and basic digital intensity among French SMEs (≈52%) is below the EU average (≈57.7%). Because digitalisation is intangible-intensive and returns rise with scale, subscale firms rationally delay adoption; the spatial concentration of specialised labour and service providers further raises costs for provincial SMEs.[73]

[71] INSEE, "Structure des entreprises en France 2023" (2024)
[72] European Commission, "In-Depth Review France 2024" (2024)
[73] European Commission, "Digital Decade Country Report 2024: France" (2024)

Fourth, size-contingent regulation discourages growth. The 50-employee threshold triggers additional representation and profit-sharing obligations; exploiting this discontinuity, empirical work interprets the effect as equivalent to a 2-3% tax on labour, with welfare costs around 3.4% of GDP. Clustering below the threshold reduces the number of firms reaching the scale needed to amortise adoption costs and invest systematically in skills and managerial upgrading.[74]

Fifth, constraints in equity-like financing and growth capital limit intangible-intensive transitions, biasing SMEs toward incremental tangible upgrades rather than risky organisational change.

Together with spatially localised spillovers, selective support for incumbents, and administrative/skill constraints discussed above, these frictions help explain why France sustains world-class productivity at the frontier yet achieves weak diffusion and scaling, keeping economy-wide TFP growth subdued.[75]

Table 3-4 summarises France's recent aggregate productivity performance and the key structural constraints discussed in this section, combining labour productivity, TFP dynamics, the manufacturing weight of the economy, and transition-related adjustment pressures.

Indicator	**Value**
Labor Productivity Growth (2015-2024)	0.4% per year (avg.)
Average TFP Growth (post-2017)	-0.1%
Manufacturing Share of GDP (2024)	9.4%
Illustrative projected EV-related job losses	~30,000
Industrial Electricity Price (2024)	€0.14/kWh (US: €0.08/kWh)

Table 3-4 - Key productivity indicators for France

Together, these indicators are consistent with a model in which innovation capacity is strong in selected large firms and strategic projects, while aggregate productivity remains constrained by weak diffusion and persistent cost pressures.

[74] Garicano et al. (2014)
[75] INSEE, "Structure des entreprises en France 2023" (2024)

3.4. Italy: Entrepreneurial Creativity and the SME Fabric

3.4.1. Socio-Industrial Geography: Industrial Districts and the North-South Divide

Italy's productive landscape remains anchored in Marshallian industrial districts in the Centre and North (textiles in Tuscany, machine tools in Emilia Romagna, furniture in Veneto). These systems historically converted dense supplier ecosystems and specialised skills into incremental upgrading. In the digital era, however, productivity gains increasingly require complementary intangible investments (data, software, process integration, managerial and organisational capital) that are easier to assemble in large urban areas with broader knowledge pools, advanced services, and diversified talent. The relative productivity premium of districts has therefore weakened, and the gap between district-oriented SMEs and firms linked to metropolitan ecosystems has widened, with signs of thinning supply chains and fewer active firms in some once world class clusters.

Regional disparities compound the diffusion problem. The Centre and North host most districts and medium sized firms, while the South remains more exposed to low productivity activities. A Southern worker produces roughly 30% less output than a worker in the Centre and North, and dispersion across regions is wide: Lombardy is about +22% above the national average in labour productivity, while Calabria is around -20% below, a spread of roughly 42 percentage points. Southern GDP per worker remains around 55% of Northern levels over 2000–2020. Institutional and capability gaps reinforce this persistence and feed directly into TFP via higher uncertainty and compliance costs and lower returns to intangibles. Labour market frictions add to the drag: female participation is around 66% in the North but below 45% in the South, undeclared employment is about 15.6% in the South versus 8.9% in the North, and knowledge intensive activities account for around 3% of employment in the South versus about 6% in the North.[76]

The outcome is a dual economy: high productivity export clusters and better connected ecosystems in the North, and broader low productivity equilibria in the South where diffusion is slower and intangible investment is harder to execute. This spatial structure limits the transmission of frontier practices and dampens Italy's overall TFP level.

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[76] ISTAT, "Rapporto Annuale 2024: Disparità territoriali" (2024)

3.4.2. Absent Coordination: Weak Bureaucratic and Industrial Policy Framework

Italy has historically lacked a strong system of bureaucratic and industrial coordination that reduces adoption frictions and aligns incentives around upgrading. As the role of the state in production and long-term planning weakened after the 1980s, coordination increasingly depended on fragmented administration and uneven local capacity. The result is a higher fixed cost of doing complex things: organising investment projects, contracting with confidence, scaling operations, and navigating permits and compliance. These frictions lower capital deepening and, more importantly, slow the accumulation of intangibles that raise TFP.

Administrative performance and legal enforcement are a core channel. Contract enforcement remains slow, with a typical commercial dispute requiring around 1,120 days to resolve. When enforcement is costly and uncertain, firms shorten planning horizons and discount the returns to long lived intangible investments such as software integration, organisational redesign, data capabilities, and workforce training. Diffusion therefore weakens because the complementary investments needed to absorb frontier practices become harder to justify for the median SME.

Innovation support and skills constraints reinforce the same mechanism. Italy's overall R&D intensity is about 1.33% of GDP, of which business R&D accounts for around 0.9% of GDP. Only 32% of firms undertook R&D or broader intangible investment initiatives over 2021 to 2024, and only 33.5% plan similar investments over 2025 to 2026. Public R&D spending is around 0.5% of GDP and R&D tax relief is about 0.07% of GDP, leaving many SMEs with limited external de-risking capacity.[77] On the human capital side, only about 16% of workers have advanced ICT skills, while around 69% of firms report difficulty recruiting technical personnel. Apprenticeships involve roughly 350,000 participants per year, yet coverage and quality remain uneven, and the estimated shortfall is roughly 280,000 specialised technicians in manufacturing. The annual cost of mismatch is around €44 billion, about 2.5% of GDP.[78]

Collective action problems then compound the picture. Only about 25% of small firms make systematic use of public business support services, and digital support, innovation hubs, and export facilitation remain uneven across territory. The aggregate implication is a persistent gap between frontier potential and broad based performance: diffusion slows, intangible

[77] ISTAT, "Rapporto Annuale 2024: Innovazione e R&D" (2024)
[78] INAPP, "Besoins en main-d'œuvre qualificata 2025: Costo mismatch" (2024)

accumulation remains constrained, and TFP growth is held back by the long tail of firms upgrading gradually and unevenly.[79]

3.4.3. Collective Direction through Decentralized Entrepreneurship: Family Firms, Districts, Networks, and Export Niches

Italy's economy is fundamentally shaped by decentralised entrepreneurship rather than large scale corporate hierarchies or tightly integrated national coordination. The country comprises around 4.3 million SMEs, and micro firms with fewer than 10 workers represent about 95% of all firms. Ownership and control are similarly decentralised: roughly 85–90% of companies are family owned, often with strategic and operational decisions concentrated within the founding family.[80] This social structure matters for productivity because it shapes incentives and capabilities. It can support speed of decision making and long-term commitment, yet it often limits managerial professionalisation and the internal capacity to invest in complex intangible projects.

Taken together, Italy's productive structure is characterised by a very dense SME base and a persistent scale gap relative to frontier firms. To anchor this claim, Table 3-5 summarises a small set of comparative indicators on firm size, productivity differentials, innovation intensity, and export participation.

Metric	**Italy**	**EU Average**
Share of Firms <50 employees	95%	93%
SME Productivity vs. Large Firms	~40% less productive	20-30% less productive
R&D Intensity (most SMEs)	<1%	2-3%
Share of Exporting SMEs	25%	40%

Table 3-5 - SME Dominance in Italy: A comparative view

These stylised facts clarify why Italy's constraint is not simply sectoral composition, but a capability and organisational problem linked to firm scale. The following sections trace how

[79] Banca d'Italia, "Questioni di Economia e Finanza" (2024)
[80] ISTAT, "Struttura delle imprese italiane 2023" (2024)

districts and networks partially substitute for hierarchy, while leaving diffusion and intangible accumulation structurally uneven.

In this setting, collective direction emerges through networks rather than through a central planner. District linkages, subcontracting relationships, and consortia partially substitute for scale by enabling flexible specialisation and local diffusion of know how. When these networks connect to international demand, they can generate strong performance. SMEs account for about 53% of total exports, and Italy's SME exports exceed €260 billion annually.[81] Export activity, however, is concentrated: roughly 9,000 medium large exporting companies generate about 75% of manufacturing exports, indicating that a relatively small subset operates close to the frontier while the broader base participates more episodically or indirectly. The mechanism is a selection and capability channel: exposure to demanding foreign markets rewards quality, reliability, and continuous upgrading, pushing better equipped firms toward higher productivity and stronger intangible accumulation.

The same decentralised structure also creates a ceiling for broad based upgrading. Family control and small scale can discourage external capital, professional management, and the organisational redesign needed to adopt digital technologies. Evidence indicates that firms run by family CEOs show about 5–10% lower productivity than those run by external professional CEOs, consistent with weaker managerial practices and slower diffusion of modern routines.[82] Innovation therefore tends to be incremental and design intensive rather than formal and research intensive, which preserves niche competitiveness but limits the speed at which frontier technologies are absorbed across the long tail.

3.4.4. Productivity and Innovation Limits in Fragmented Ecosystems

Italy’s fragmented productive structure translates into persistent constraints on productivity through scale ceilings, diffusion frictions, weak reallocation, and macro level composition effects. With only 0.1% of firms above 250 employees, roughly 5,000 companies, many sectors are populated by sub scale units that struggle to sustain the fixed costs of advanced machinery, formal R&D, and specialised talent.[83] Within the same sector, productivity in micro and small firms is typically 30–40% lower than in medium and large firms, indicating that fragmentation

[81] Banca d’Italia, “Relazione annuale 2023: Esportazione delle PMI” (2024)
[82] Cucculelli & Le Breton-Miller (2024)
[83] Eurostat, “SME Performance Review - Italy” (2025)

is not merely a composition effect but a capability and organisation gap that weighs on aggregate total factor productivity. The scale ceiling becomes more binding in the current technology regime because productivity gains depend on bundles of complementary investments. Digital transformation is not only a purchase of hardware or software, it is a joint investment in data systems, process integration, cybersecurity, managerial routines, and training. At small scale, these costs are lumpy and front loaded, and the payoffs depend on organisational redesign that is hard to execute without professional management layers. This is one reason why the "missing middle" matters for Italy's total factor productivity, when firms remain small even after long survival, they underinvest in organisational capital and in the intangible complements that make new technologies productive.[84]

Diffusion frictions follow from the same structure and can be observed in adoption indicators. Only about 60% of SMEs reach at least a basic level of digital intensity, and cloud adoption among small firms is around 30%.These gaps are reinforced by complementary bottlenecks, only about 15% of small firms employ ICT specialists, and around 37.6% of rural areas lack high-speed fibre optic coverage, limiting data intensive applications.[85] The mechanism is cumulative, low organisational and digital capital reduces the productivity gains from adoption, which lowers incentives to invest further, prolonging the productivity distance between frontier firms and the long tail. Recent aggregate dynamics are consistent with this interpretation. In 2024, value added in market sectors increased by about 0.4% while hours worked rose by about 2.3%, implying a decline in labour productivity of about 1.9%. Over the same year, total factor productivity fell by about 1.2%, indicating that the short-run weakness was not only a capital deepening story but also an efficiency story. Capital input still grew by about 0.5%, and within capital, ICT and non-ICT intangible components expanded more strongly than total capital, suggesting that intangible accumulation is occurring but is not yet translating into broad-based efficiency gains.[86] One plausible channel is that complementary capabilities and organisational redesign lag behind investment, especially in smaller firms, delaying the TFP payoff.

Table 3-6 summarises Italy's recent aggregate productivity performance and the main structural constraints discussed in this section, combining labour productivity, TFP dynamics, the

[84] OECD, "Economic Survey: Italy" (2024)
[85] European Commission, "Digital Economy and Society Index (DESI) – Italy" (2024)
[86] Banca d'Italia, "Bollettino Economico" (2025)

manufacturing weight of the economy, transition-related adjustment pressures, and the industrial energy cost gap.

Indicator	Value
Labor Productivity Growth (2015-2024)	0.3% per year (avg.)
Average TFP Growth (post-2017)	+0.1% to +0.2%
Manufacturing Share of GDP (2024)	14.6%
Illustrative projected EV-related job losses	77,000
Industrial Electricity Price (2024)	€0.23/kWh (US: €0.08/kWh)

Table 3-6 - Key productivity indicators for Italy

The remainder of the section unpacks the mechanisms behind these aggregates, focusing on reallocation frictions and the constraints on intangible deepening and diffusion.

Resource reallocation remains another binding constraint. Many low productivity firms stay active for long periods, in part because insolvency and restructuring are slow and because credit can remain available even when performance is weak. Among businesses operating for more than 25 years, the average firm size remains below 10 employees, consistent with limited scaling over the life cycle.[87] The share of capital tied up in zombie firms rose to roughly 19% by 2013 compared with roughly 7% before 2007, congesting markets and limiting the expansion of more productive entrants.[88] Estimates suggest that manufacturing total factor productivity would be roughly 18% higher if allocative efficiency had remained at its 1995 level, highlighting how misallocation can offset the gains generated by frontier exporters.[89]

Innovation outcomes reflect these ecosystem constraints. Business R&D intensity remains around 0.9% of GDP, indicating that formal innovation is concentrated in a narrower set of firms, while the broader base upgrades through slower, incremental pathways. Investment also appears uneven within intangibles, ICT investment has recently grown only modestly, consistent with a pattern where some firms invest but diffusion and complementarity gaps prevent rapid aggregate payoff. The result is a durable two-tier configuration, pockets of high

[87] ISTAT, “Struttura delle imprese italiane 2023” (2024)
[88] OECD, “Economic Survey: Italy” (2024)
[89] European Commission, “Annual Single Market and Competitiveness Report” (2024)

capability firms close to the frontier and a wide base of small firms facing scale limits, low diffusion speed, and weak reallocation, which together dampen Italy's aggregate total factor productivity performance.

3.5. Transatlantic Relations and Industrial Alignment

3.5.1. Comparative trade and technological dependencies with the United States

Following Trump's return to office, transatlantic economic relations between the United States and Europe's three largest continental economies have become simultaneously deeper and more politically contingent. The relationship remains anchored in dense goods and services trade, cross investment, and highly integrated production networks, yet it is increasingly shaped by policy instruments that treat trade, technology, and industrial location as strategic variables. From a productivity perspective, this matters because the transatlantic channel affects European total factor productivity through market access and scale, the cost and availability of key inputs, investment location decisions, and the diffusion of general purpose technologies. A useful organising concept is industrial alignment, understood as the joint outcome of three measurable exposures: the extent to which exports to the United States are concentrated in politically sensitive sectors, the degree to which those exports and associated supply chains are vulnerable to US policy actions such as tariffs, export controls, procurement discrimination, and subsidy induced investment diversion, and the reliance on US based technology stacks and standards that condition digital transformation. Applying this lens reveals distinct national patterns consistent with each country's socio economic model and clarifies why the same US policy shock can generate asymmetric productivity effects across Germany, France, and Italy.

Italy's trade dependence is increasingly structured around differentiated manufacturing and brand premium categories that match US demand in high income segments. A large share of Italian manufacturing is organised around districts and small and medium sized firms that compete via product differentiation, customisation, and quality rather than pure scale. These micro structures translate into export baskets dominated by precision machinery and equipment, high value intermediate goods, premium consumer products, and design intensive categories. The causal link is that flexible production networks and reputational assets raise non price competitiveness, enabling stable market access and margins even when price competitiveness fluctuates. The counterpart is a dispersed exposure, because many exporters are smaller and more sensitive to sudden increases in border costs, compliance burdens, or exchange rate shifts. Germany's dependence is more concentrated in politically salient sectors, notably automotive, alongside capital goods and chemicals including pharmaceuticals. Its coordinated industrial architecture converts scale and complex supply chains into export volumes, but also makes market access a binding condition for capacity utilisation and for financing innovation. France's profile is more diversified in exposure but strategically sensitive in composition, reflecting a state shaped model and the presence of national champions in aerospace, defence related industries, pharmaceuticals, and high value consumer goods including luxury. In this configuration, vulnerability is less about aggregate export shares and more about the political visibility of iconic sectors and the role of procurement and standards in shaping competitive outcomes.

Technology dependence is the most structural dimension common to all three economies. Digital transformation in European firms and public administrations is deeply conditioned by US provided cloud infrastructure, enterprise software, cybersecurity services, and platform ecosystems. ICT functions as a general purpose input, so productivity gains depend on complementary organisational change, data governance, and integration across business processes. Reliance on external providers can raise short run efficiency, but it can also create lock in, increase compliance costs, and shift bargaining power over standards and interoperability. In a policy environment where security requirements, procurement rules, and export control logics increasingly cover digital services and dual use technologies, digital dependence becomes a channel through which geopolitical and regulatory shifts can transmit into firm-level efficiency, investment incentives, and ultimately export performance.

3.5.2. Germany and France detachment: pharmaceutical and automotive divergence

The Germany-France comparison shows that transatlantic alignment is sector specific and that socio economic structures generate different exposure profiles, creating scope for detachment or divergence. In automotive, Germany is tightly tied to the US market, while France is largely detached.[90] German producers have historically relied on US demand for premium vehicles and on transatlantic value chains that combine exports with local production networks, whereas French brands have limited direct presence in the United States. This asymmetry means that

[90] Eurostat, "EU Trade by Partner and Sector Database" (2025)

tariffs, local content requirements, and electric-vehicle incentive design disproportionately affect Germany. The causal transmission runs through reduced effective demand as border costs rise, strategic relocation of assembly and component production to the United States to preserve market access, and fragmentation of supplier networks that raises fixed costs and reduces scale efficiencies. For Germany, these mechanisms can depress productivity by lowering capacity utilisation at home, diverting investment away from domestic upgrading, and weakening the learning dynamics reinforced by large market reach.

France's relative detachment from US automotive exposure changes its bargaining position and its domestic adjustment constraints. Because the sector is not directly dependent on US market access, the short-run output channel is weaker and political room for a tougher stance is greater. France's main automotive concern is instead indirect and forward looking: subsidy and standard regimes that pull investment toward the United States, especially in batteries and electric mobility, potentially eroding Europe's future industrial base.[91] This links to a broader French preference for autonomy in strategic sectors, where policy seeks to shape industrial location and capability rather than simply preserve export volumes.

In pharmaceuticals, the divergence is more nuanced and partially inverted. Germany's pharmaceutical linkages reflect strong commercial integration through multinational production and trade, which can reduce perceived strategic vulnerability because German firms are embedded in transatlantic innovation networks.[92] France's exposure is often framed through an innovation and sovereignty lens, reflecting concerns about dependency on external R&D and critical supply chains.[93] The implication is that Germany tends to prioritise negotiated stability to protect an export- and scale-based productivity model, while France more readily justifies autonomy-oriented measures in sectors where control, standards, and public procurement shape long-run capability.

3.5.3. Italy's alignment: precision mechanics, design, and niche quality exports

Italy's transatlantic alignment is anchored in specialisation patterns that are complementary to US demand and relatively difficult to substitute quickly. District based industrial organisation supports variety, responsiveness, and incremental upgrading, while the made in Italy brand

[91] European Battery Alliance, "Investment Flows and Transatlantic Shifts in Battery Manufacturing" (2024)
[92] Statistisches Bundesamt, "Außenhandel und Industrieproduktion 2024" (2025)
[93] French Ministry for the Economy, "Rapport sur la souveraineté industrielle et pharmaceutique" (2024)

provides pricing power in premium segments. These features sustain exports in precision mechanics, specialised machinery for industrial processes, high value components, and design intensive consumer categories.[94] The causal link is that non price competitiveness and niche positioning allow Italian firms to benefit from the scale of the US market without relying on mass production in direct competition with US incumbents. This can be productivity enhancing because stable access to a large market supports scale at the firm level, learning effects, and the financing of process innovation, even within a landscape of medium sized enterprises.[95]

At the same time, Italy's alignment implies a distinctive vulnerability profile. Because exporting firms are numerous and often smaller, broad tariff actions or sudden changes in regulatory standards can compress margins across the distribution, reducing investment capacity and slowing upgrading.[96] Moreover, the same firms that excel in mechanical and product excellence frequently rely on US digital inputs for cloud, enterprise software, and cybersecurity. If policy changes raise the cost or uncertainty of these inputs, the impact can propagate from digital adoption to operational efficiency and then to export performance.[97] Italy is therefore aligned in demand and specialisation, but exposed to both trade shocks and technology dependence shocks that can undermine productivity through higher input costs, reduced scale, and slower diffusion of organisational and digital innovations.

3.5.4. Implications for European strategic autonomy and policy coordination

Taken together, these patterns imply that Europe's strategic autonomy challenge is not simply external but also internal. Germany's priority is export stability and scale, France's is control over strategic capabilities and standards, and Italy's is the resilience of a dispersed exporting base and the protection of niche competitiveness. This heterogeneity complicates coordinated responses to US tariffs, procurement discrimination, export controls, and subsidy induced investment diversion, yet it also points to a coherent EU level agenda.[98] First, the Union needs instruments that preserve access and bargaining power without fragmenting the Single Market, including a more operational approach to procurement reciprocity and targeted trade defence tools that can deter discriminatory measures.[99] Second, it must reduce technology related

[94] Eurostat," EU Trade by Partner and Sector Database" (2025)
[95] OECD, "Economic Survey: Italy" (2024)
[96] European Commission, "EU–US Trade and Technology Council: Economic Security Briefing" (2024)
[97] European Commission, "Digital Economy and Society Index (DESI) – Italy" (2024)
[98] European Council, "Conclusions on the EU's Economic Security Strategy" (2024)
[99] European Commission, "EU–US Trade and Technology Council: Economic Security Briefing" (2024)

asymmetries by accelerating capacity building in digital infrastructure and key enabling technologies that underpin productivity growth, notably cloud, cybersecurity, and semiconductors, while ensuring interoperability and portability to limit lock in. Third, policy coordination should explicitly link industrial policy to productivity channels, prioritising measures that sustain scale and learning in exposed sectors, protect investment in intangible capabilities, and prevent subsidy driven relocation from hollowing out Europe's upgrading capacity. The overarching implication is that transatlantic integration remains a source of scale and innovation, but in a more politicised environment it can quickly become a channel of asymmetric vulnerability. Europe's productivity agenda therefore depends not only on domestic reforms and investment, but also on reducing structural dependencies while maintaining the benefits of an open and rules based transatlantic economic space.[100]

To close the comparative analysis, Table 3-7 condenses the defining strengths, structural weaknesses, and productivity constraints of the German, French, and Italian socio-economic models into a single stylised framework.

Feature	**Germany: Coordinated Industrial Capitalism**	**France: State-Led Dirigisme**	**Italy: Decentralized Entrepreneurialism**
Core Strength	Export-oriented manufacturing, Mittelstand	Strategic sector champions, infrastructure	Niche specialization, flexibility
Core Weakness	Slow reallocation, dependence on mature sectors	Missing middle, regional inequality	Firm size limitations, low R&D
Productivity Constraint	Slow diffusion to SME tail, energy costs	Weak spillovers outside Paris, misallocation	Scale-up barriers, low investment absorptive capacity for intangible investment

Table 3-7 - Comparative summary of national models: Germany, France, Italy

This comparison clarifies that Europe's productivity challenge is not uniform: the binding constraint differs across national models, implying that any selective industrial policy must be designed to operate across heterogeneous institutional and firm structures.

[100] European Commission, "Digital Economy and Society Index (DESI)" (2024)

4 The Emerging Economies: Technological Ascent of China and India

4.1. China: Industrial Policy, Technological Self-Sufficiency, and Overcapacity

The debate on European competitiveness increasingly depends on how two large non-European political economies translate state capacity into productivity gains and technological upgrading. China and India are not simply fast-growing markets. They represent distinct institutional logics through which governments shape incentives, coordinate investment and build capabilities. China has pursued a scale-intensive, supply-side model in which industrial policy, guided finance and administrative targets accelerate manufacturing upgrading, but also generate recurrent imbalances, including overcapacity and debt overhangs. India's ascent is anchored in a different configuration, a state-built digital backbone that lowers transaction costs across services and formal firms, combined with selective manufacturing policy that leverages domestic demand and global supply-chain reallocation. For Europe, the analytical question is not whether either model is normatively desirable. It is how these state-led trajectories change relative prices, technological frontiers and competitive constraints, and what realistic policy responses remain compatible with Europe's institutional setting.

4.1.1. Evolution of industrial strategy and strategic sectors

China's growth model has evolved from export-led catch-up to a more explicit techno-industrial state strategy, increasingly framed in terms of resilience and self-reliance. In the earlier phase, the state's primary comparative advantage was the orchestration of market access, infrastructure build-out and integration into global value chains. The productivity mechanism was largely classical, rapid capital deepening, scale economies, technology diffusion through foreign-invested firms and intense competition in tradable manufacturing. The current phase adds a stronger emphasis on moving into higher value-added segments and reducing dependence on external technology, especially where geopolitical risk is salient.

This shift is visible in the policy architecture that ties long-horizon planning to sectoral prioritisation. Five-year plans provide the macro frame, while flagship initiatives specify technology domains and capacity targets. "Made in China 2025" articulated a broad agenda of upgrading in advanced manufacturing, including high-end numerical control machinery, robotics, aerospace equipment, advanced rail, energy equipment, new-energy vehicles, biomedicine and high-performance medical devices. Later, the "dual circulation" strategy repositioned domestic demand and domestic innovation as the core engine of growth. The idea is that internal circulation should provide scale for firms, support learning and diffusion, and reduce dependence on external demand and imported technology. External circulation remains relevant for exports, capital inflows, and access to critical inputs, but it becomes more selective and increasingly shaped by resilience concerns, technology controls, and standard setting.

The implication is that industrial policy is tasked with delivering productivity gains and strategic autonomy at the same time. This helps explain the prioritisation of sectors where supply chain security and upgrading overlap, notably semiconductors and advanced manufacturing equipment, batteries and electric vehicles, renewables supply chains, telecom and AI, and critical materials.

Table 4-1 summarises the main strategic domains prioritised in China’s industrial policy, providing a stylised map of the sectors through which state-led upgrading and technological autonomy are pursued.

Category	**Examples**
Advanced Manufacturing	CNC machinery, Robotics, Advanced rail
Green Technology	New-energy vehicles, Batteries, Renewables supply chains
Core Technologies	Semiconductors, AI, Telecom equipment
Strategic Materials	Critical minerals, High-performance materials

Table 4-1 - Key strategic sectors in China's industrial policy

This sectoral prioritization provides the organizing logic for the following discussion, which traces how China has combined targeted support, scale mobilization, and export discipline to accelerate capability building in these domains.

The state's strategic approach is not limited to identifying sectors. It also shapes market structure through the rules of entry, financing and public procurement. Industrial upgrading in China has been supported by a dense ecosystem of local and central instruments that lower the cost of scaling and accelerate learning.

4.1.2. The techno-industrial state: subsidies, control, and scaling

China's techno-industrial state relies on a relatively coherent set of instruments that link strategic priorities to firm behaviour. One channel is broad state aid, including fiscal incentives, direct subsidies, and preferential access to land, utilities, or energy pricing. A second channel is guided finance, where policy banks, state-owned commercial banks, and government-guided funds translate industrial priorities into credit allocation and investment pipelines. A third channel is administrative coordination, especially through the role of local governments in meeting national targets, attracting projects, and building industrial clusters.

The political economy mechanism is consistent across sectors. Central authorities set priorities and quantitative signals that shape expectations about future demand, financing, and regulatory support. Local governments then compete for investment, employment, and output, often reinforcing the same strategic sectors, sometimes beyond what final demand can absorb. This centre--periphery dynamic is a key reason why China can generate scale quickly, but it also creates a structural tendency toward duplication and capacity races.

In advanced manufacturing, China's advantage is therefore not only cost-based. It is the speed at which firms scale and move down learning curves. Large domestic markets for electrification, renewables deployment, and digital services provide demand-side pull, which supports large production runs and faster feedback. On the supply side, concentrated investment, vertical integration, and dense supplier ecosystems facilitate learning-by-doing. Repeated production cycles reduce defects, shorten throughput times, and standardise processes across firms and suppliers. Clusters and coordinated finance lower the fixed costs and risks of expanding capacity, enabling firms to iterate products rapidly and to enter global markets with competitive pricing.

At the same time, policy support does not translate mechanically into productivity improvements. Firm-level evidence indicates that targeted programmes can raise subsidy receipts and innovation signalling without immediately increasing measured productivity. Branstetter and Li, analysing listed firms affected by "Made in China 2025", find that "more innovation promotion subsidies seem to flow" to targeted firms, but "little statistical evidence of productivity improvement" in the period they study[101]. Finance and capital allocation sit at the core of this ambiguity. Because China's banking system has long operated as a policy lever, credit guidance can accelerate scaling in targeted sectors by easing financing constraints and sustaining investment. Yet when domestic demand weakens and firms and local governments prioritise deleveraging, continued credit-driven expansion can keep low-return projects alive and widen the gap between installed capacity and effective demand, thereby increasing misallocation. The macro context of 2024-2025 illustrates this tension. The IMF and World Bank both emphasise continuing constraints linked to the property sector, local government finances, and subdued domestic demand, which influence the returns to investment and the sustainability of leverage.

Local government financing vehicles illustrate how state capacity can simultaneously enable investment and create balance-sheet vulnerabilities. Many infrastructure and industrial projects are promoted at the local level, but they are often funded through entities that sit outside the core municipal budget and are backed, implicitly or explicitly, by local public balance sheets. When local revenue models weaken, especially those reliant on land sales and property-linked activity, these vehicles tend to search for alternative funding channels to keep investment programmes running, including borrowing structures that are less transparent than standard budget financing.[102]

BIS research helps clarify why this matters for capital allocation. It notes that non-bank channels can interact with credit guidance, observing that shadow banking can allow banks to "avoid the credit policies and bank lending guidance" from the centre.[103] In practice, this means that investment can remain high even when the centre seeks to tighten or reorient credit, because financing can be rerouted through off-balance-sheet or non-bank structures. The implication is not that policy is ineffective, but that layered incentives and multiple financing channels can

[101] Branstetter & Li (2024)
[102] Shih & Elkobi (2023)
[103] BIS, "China's Shadow Banking: Bank's Shadow and Traditional Shadow Banking" (2019)

sustain investment volumes that are hard to justify on efficiency grounds. When growth and employment targets remain binding, projects with low expected returns can still be financed and rolled over, which weakens balance sheets over time and lowers the long-run marginal product of capital.

Human capital and innovation capacity partly offset these risks. China's innovation system has expanded rapidly, with sustained increases in R&D spending and a rising role of business-performed R&D. Figure 4-1 illustrates OECD report indicating that R&D expenditure growth in China continued to outpace that of the EU and the United States in 2023, and that business-performed R&D now accounts for a share comparable to the United States and higher than the EU average.[104] In parallel, World Bank data shows China's R&D intensity at levels consistent with an innovation-driven economy rather than a low-cost assembler.[105]

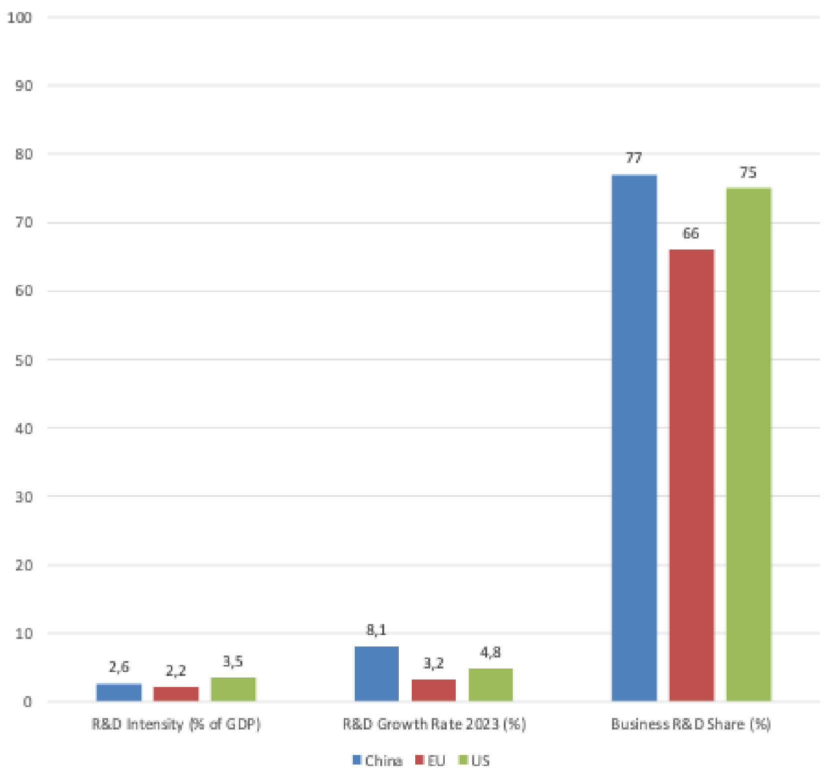

Figure 4-1 - R&D Effort and Innovation Scale: China in Comparative Perspective

[104] OECD (2025a, 2025b), "R&D Spending Growth Slows in OECD, Surges in China, and related OECD science, technology and innovation indicators for China, EU and United States" (2025)
[105] World Bank, "Research and Development Expenditure (% of GDP)" (2025)

Finally, governance and regulation increasingly shape the innovation frontier. The Chinese state has tightened control over data and platform governance, which can support security objectives and domestic standard setting. However, it can also increase policy uncertainty for private investors, especially in digital and frontier sectors.

4.1.3. Overproduction and its global distortive effects

Overcapacity is best treated as an economic imbalance rather than a political label. The key point is that the gap is not only cyclical. It can be institutional, reflecting incentives that keep investment and output high even when profitability is weak.[106] Because capacity, utilisation, and demand are not measured uniformly across sectors and countries, overcapacity is typically assessed indirectly. Analysts therefore rely on observable proxies, including utilisation rates, inventory accumulation, export surges, producer-price dynamics, and the frequency of trade remedy actions.

In heavy industry, OECD evidence provides a clear benchmark. The OECD Steel Outlook documents that "Chinese steel exports have more than doubled since 2020", reaching "a record-high 118 million metric tonnes (mmt) in 2024", while imports fell sharply (OECD, 2025c).[107] The report connects excess capacity and subsidisation to changing trade flows and a greater use of trade remedies, which is consistent with the view that when domestic absorption is insufficient, external markets become the adjustment margin.

In clean-energy manufacturing, the mechanism is similar, but the global context differs. Capacity expansion can support climate transitions by lowering costs, yet it can also run ahead of near-term deployment. The IEA highlights that solar manufacturing capacity is set to rise far beyond annual installations, signalling the scale of potential imbalances between supply and near-term demand.[108] The IEA also documents China's dominant share in global PV manufacturing capacity, reinforcing how concentrated scale can translate into price-setting power and competitive pressure on foreign producers.[109] In electric vehicles and batteries, overcapacity debates are often conflated with competitiveness. The analytically relevant issue is the interaction between policy-driven supply expansion and a weaker domestic demand

[106] Guo et al. (2022)
[107] OECD (2025c), “Surging Excess Capacity Threatens Steel Market Stability, Employment and Decarbonisation Plans, and OECD Steel Outlook 2025” (2025)
[108] IEA, “Renewables 2024: Analysis and forecast to 2029” (2024)
[109] IEA, “Energy Technology Perspectives 2024: Special Report on Clean Energy Manufacturing” (2025)

environment, which can push firms toward more aggressive export strategies to maintain utilisation. For Europe, the exposure is immediate in segments where European industry is simultaneously investing in decarbonisation and facing higher energy and compliance costs. When global prices fall because supply expands faster than demand elsewhere, European firms may benefit as downstream users, but margins in upstream manufacturing compress, potentially weakening incentives and financing conditions for European scale-up in clean-tech value chains.

The external effects of overcapacity operate through three channels. First, global price deflation in tradable manufactures reduces profitability for higher-cost producers, forcing consolidation or exit. Second, trade frictions rise, with greater use of anti-dumping, countervailing duties and industrial policy responses. Third, investment expectations shift, as firms revise beliefs about future margins in contested sectors. These effects are not evenly distributed. They are strongest in industries with high fixed costs, modular production and steep learning curves, such as steel, chemicals, solar modules, batteries and some consumer electronics.[110]

China's domestic constraints feed the mechanism. The World Bank notes subdued domestic demand and easing manufacturing investment growth in 2025, with industrial profits constrained (World Bank, 2025).[111] When domestic absorption weakens, sustaining employment and utilization becomes politically salient, especially for local governments. This can prolong capacity beyond market-clearing levels.

Overcapacity also has internal costs. When capacity races are financed through leverage and implicit guarantees, the marginal product of capital can fall, reinforcing debt vulnerabilities. The IMF emphasises the need for reforms to local government finances and broader balance-sheet repair to sustain medium-term growth.[112]

Finally, technological decoupling interacts with overcapacity in non-obvious ways. Export controls and restricted access to frontier semiconductors raise the value of domestic substitution efforts and can intensify state support, potentially increasing investment even when demand is uncertain. This can deepen imbalances in some segments while accelerating capability building

[110] Guo et al. (2022)
[111] World Bank, “Unlocking Domestic Demand Key to Reviving Growth Momentum in China” (2025)
[112] IMF, “China’s Real Estate Sector: Managing the Medium-Term Slowdown” (2024)

in others. For Europe, this implies that competitive pressure may intensify in mid-range technologies even if frontier access constraints remain.

4.2. India: Digitalization and the Service-Led Manufacturing Model

4.2.1. ICT and AI as growth levers

India's recent growth trajectory is shaped by a different institutional engine. Rather than building momentum primarily through large-scale manufacturing deepening, India has leveraged services, ICT, and digital platforms to reduce transaction costs, widen market access, and expand formal economic activity. The centrepiece is Digital Public Infrastructure, a state-enabled stack that combines digital identity, payments, and interoperable data exchange layers on which private firms can build. The main productivity channel is therefore less about subsidising capacity and more about creating common rails that improve market functioning, competition, and inclusion.[113]

The IMF's analysis of India's digital journey is explicit about the systemic role of DPI. It argues that India's foundational DPI "has been harnessed to foster innovation and competition" and to "expand markets" while improving the efficiency of public spending.[114] This framing is important because it treats digitalisation as a dimension of state capacity rather than a simple wave of private adoption. The state sets standards, governance, and interoperability, while private actors compete in services, fintech, e-commerce, and software built on top of the rails.

Payments provide a measurable output. Official data show a rapid increase in digital transactions over the last decade, consistent with the view that interoperable payment rails have reduced costs for small firms and households and expanded formal financial interaction.[115] The macro implication is that a larger share of transactions becomes legible to the tax system and to formal credit markets, which can gradually improve capital allocation by reducing information frictions and widening access to finance.

[113] Maheshwari (2023)
[114] Alonso et al. (2023)
[115] Government of India, "Press Information Bureau, Official communications on growth of digital payments and UPI transaction volumes" (2023)

The World Bank's DPI framework clarifies why institutional design matters. DPI is not only a set of applications. It is infrastructure that affects competition through open access and standardised interfaces, which can lower entry barriers and support innovation by smaller firms and new entrants.[116] This shifts the locus of policy from firm-level support to ecosystem-level conditions, where productivity gains depend on diffusion across sectors rather than on a narrow set of champions.

AI enters as a complement rather than the initial driver. India's AI and data ecosystem benefits from scale in digital services, large pools of software talent, and an expanding base of digital transactions. The binding constraint is less the availability of use cases and more the unevenness of connectivity, data quality, and skills across the broader workforce and across regions. This is where the state's role in education and skilling becomes central to whether digital productivity gains diffuse beyond the high-performing enclaves of IT and modern services.[117]

4.2.2. Make in India, PLI schemes, and domestic demand-driven industrialization

India's manufacturing push has become more explicit in the last decade, but it remains structurally different from China's. The objective is not to replicate a purely export-led manufacturing model at any cost, but to combine domestic demand, infrastructure investment, and targeted incentives to attract supply chains and raise manufacturing capability. The "Make in India" initiative signalled the political priority of manufacturing and investment facilitation. The more operational instrument has been the Production Linked Incentive schemes, which provide time-bound incentives tied to incremental output in selected sectors. Official documentation frames PLI as a tool to expand domestic manufacturing in strategic industries, attract investment, and integrate into global value chains while building scale in specific segments[118].

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[116] World Bank, "Digital Public Infrastructure and Development: A World Bank Primer. March 2025" (2025)
[117] Raghunath (2026)
[118] Shih & Elkobi (2023)

Table 4-2 summarises the core design logic of India’s PLI schemes, highlighting their performance-linked, time-bound structure and the sectoral domains they target.

Feature	Description
Objective	Boost domestic manufacturing, attract investment, integrate into global value chains
Mechanism	Time-bound fiscal incentives tied to incremental output
Key Sectors	Electronics (smartphones), Pharmaceuticals, Auto Components, Solar PV modules

Table 4-2 - India's Production Linked Incentive (PLI) scheme: Key features

This design illustrates how India has tried to combine targeted upgrading with scale mobilisation, an approach that differs in both intent and execution from the Chinese model discussed above.

The institutional logic is a hybrid of industrial policy and market competition. Incentives are linked to performance, which reduces the risk of permanent subsidies. However, the targeting remains selective, raising classic concerns about picking winners and about the administrative capacity required to monitor compliance. Unlike China's deep reliance on directed credit, India's approach is more fiscal and rule-based, though state-level facilitation, land, power, and permitting still play important roles.

India's growth is also supported by public infrastructure investment, which can crowd in private investment and reduce logistics costs. OECD projections emphasise that growth is led by fixed investment, notably in manufacturing, amid rapid increases in public infrastructure spending.[119] The macro-economic channel is that improving transport, power, and logistics raises the returns to manufacturing investment, making targeted incentives more effective.

[119] OECD, “OECD Economic Outlook” (2024)

Domestic demand is a critical stabiliser. A large internal market can support scale even when external demand is volatile. This reduces dependence on export markets compared to China's earlier phase, but it also means that manufacturing upgrading is constrained by the distribution of purchasing power, the speed of urbanisation, and firms' ability to meet the quality and standards required for advanced manufacturing exports.

The governance structure is another differentiator. India's federal system implies that implementation capacity varies across states. Competition among states to attract investment can accelerate reforms and infrastructure provision, but it can also produce fragmentation, uneven enforcement, and coordination challenges. Reforms such as GST can mitigate fragmentation by reducing internal trade barriers and simplifying indirect taxation, though the net effect depends on enforcement, compliance costs, and the quality of the digital systems supporting tax administration.

4.2.3. Upgrading in manufacturing and materials quality

India's upgrading is most visible where global value chains allow modular entry. Electronics assembly and smartphone production illustrate this pattern, as firms can locate assembly, testing, and final integration domestically before deeper localisation of components and supplier tiers becomes feasible. Pharmaceuticals and automotive components are other areas where India has established capabilities and can move upward through stricter regulatory compliance, quality standards, and process innovation. Chemicals and materials are more uneven, because upgrading requires higher capital intensity, stronger safety regimes, and consistent input quality across complex production processes.

The central productivity constraint is supply-chain depth. Assembly can scale relatively quickly, but moving into higher value-added stages requires reliable suppliers, intermediate technical skills, metrology and testing capacity, credible standards infrastructure, and predictable regulation. State capacity affects productivity through these less visible channels, including the quality of certification systems, standards enforcement, vocational education, and coordination between training institutions and industry demand.

Human capital is a structural asymmetry. India has globally competitive pools of software engineers and high-skill service workers, but a thinner base of mid-level technicians and production engineers that modern manufacturing needs to raise yields, reliability, and consistency. The result is a dual structure typical of many emerging economies. Frontier firms integrate into global supply chains, while a large informal or low-productivity segment persists. Skilling initiatives can narrow this gap, but outcomes depend on implementation quality and on labour-market absorption, especially for younger cohorts entering the workforce.

Institutional sources also emphasise that DPI can support manufacturing upgrading indirectly. The IMF Article IV for India frames digital public infrastructure as providing "the necessary building blocks for interacting in the digital economy", namely identity, payments, and data (IMF, 2025)[120]. In practice, this can reinforce formalisation, reduce compliance costs, and improve access to credit for smaller firms. Yet it does not automatically resolve the physical and organisational bottlenecks inside factories, including process control, supplier quality, and logistics reliability.[121]

4.3. Comparative Outlook

4.3.1. China vs India: industrial vs digital model

A channel-based comparison clarifies why China and India pose different competitive challenges.

On industrial policy, China's model is supply-side intensive, prioritising capacity build-out, vertical integration and national champions in strategic technologies. The state leverages planning, procurement, standards and finance to accelerate scale and learning. India's model is more platform-oriented in digital infrastructure and more selective in manufacturing, using performance-linked fiscal incentives and investment facilitation to attract targeted supply chains, while relying more on domestic demand and private competition.... On finance and capital allocation, China's advantage has been the ability to mobilise large volumes of credit and investment quickly, but this creates persistent risks of misallocation when incentives favour investment quantity over returns. The IMF's focus on local government finances and medium-term debt dynamics reflects these constraints (IMF, 2024).[122] India's capital allocation is constrained by different frictions, including infrastructure gaps, heterogeneous state capacity

[120] IMF, "India: 2024 Article IV Consultation-Press Release" (2025)
[121] Raghunath (2026)
[122] IMF, "China's Real Estate Sector: Managing the Medium-Term Slowdown" (2024)

and credit-market imperfections, but the digital backbone can improve allocative efficiency by increasing formality and reducing information costs over time.[123]

On human capital, China's manufacturing upgrading has been supported by large-scale STEM expansion and industrial learning, reinforced by clustering and supplier ecosystems. India has a world-class services talent base but a shallower middle-skill manufacturing layer. This tends to produce a services-led productivity frontier with uneven diffusion.

On governance, China's centralised capacity supports rapid coordination and implementation, but can also create systemic risks when targets propagate through local incentives and when policy correction is delayed. India's federalism supports experimentation and competition among states, but it can increase transaction costs and generate unevenness. These governance features are not peripheral. They shape how quickly policy objectives translate into firm behaviour and how quickly failures are corrected.

On openness and global integration, both countries remain deeply embedded in global markets, but with different strategic orientations. China's self-reliance agenda and external technology controls have increased the salience of standards and supply-chain security. India's strategy is more aligned with attracting supply-chain shifts and leveraging diaspora and services trade, while navigating its own data governance choices.

4.3.2. Implications for European competitiveness: price, scale, and tech

For Europe, the immediate competitive pressure from China is concentrated in tradable manufacturing where scale and policy-supported capacity can compress global prices. Overcapacity is the mechanism that translates domestic imbalances into external shocks. Steel illustrates this clearly, with record Chinese exports and shifting trade flows that challenge market-oriented economies, including the EU (OECD, 2025c)[124]. Clean-tech manufacturing raises the stakes because Europe's industrial strategy is simultaneously trying to expand domestic production for strategic and climate reasons. When global supply expands faster than

[123] Alonso et al. (2023)
[124] OECD (2025c), "Surging Excess Capacity Threatens Steel Market Stability, Employment and Decarbonisation Plans, and OECD Steel Outlook 2025" (2025)

demand, margins fall, and European scale-up becomes harder unless policy instruments compensate or the single market provides sufficient scale.

The technology channel is broader than prices. It includes standards, ecosystems and speed of innovation diffusion. China's large domestic deployment in EVs and renewables supports rapid iteration and cost reduction, and its innovation system has expanded in scale with strong R&D momentum relative to Europe.[125] This does not guarantee frontier leadership in every domain, but it can create competitive dominance in manufacturing-intensive technologies where learning curves are steep.[126]

India's competitive pressure is different. It is strongest in digitally delivered services, software and business process capabilities, and in segments of manufacturing where modular entry is feasible. The DPI model can gradually reduce the productivity gap in formal services and enable new firm formation and competition. The IMF frames India's DPI as fostering "innovation and competition" and expanding markets.[127] For Europe, this matters in at least two ways. First, it intensifies competition for digital talent and for services exports. Second, it offers a template for how public digital rails can support private-sector dynamism without large-scale directed credit.

[125] OECD (2025a, 2025b), "R&D Spending Growth Slows in OECD, Surges in China, and related OECD science, technology and innovation indicators for China, EU and United States" (2025)
[126] Guo et al. (2022)
[127] Alonso et al. (2023)

Feature	China: Supply-Side Intensive Model	India: Platform-Oriented and Selective Model
Industrial Policy Focus	Capacity build-out, vertical integration, national champions	Digital Public Infrastructure (DPI), performance-linked incentives (PLI)
Finance & Capital Allocation	State-guided credit, high leverage, risk of misallocation	Fiscal incentives, public infrastructure investment, market-based finance
Human Capital	STEM expansion, deep manufacturing skills	World-class services talent, mid-skill manufacturing gap
Governance	Centralized coordination, rapid implementation, systemic risk	Federal experimentation, state-level competition, coordination challenges
Key Productivity Channel	Scale, learning curves, overcapacity, price deflation	DPI-led transaction cost reduction, formalization, domestic demand

Table 4-3 - Comparative summary: China vs. India

Taken together, these contrasting upgrading channels define the external competitive environment facing Europe. Chapter 5 turns to how this environment interacted with Europe's internal frictions during the 2019–2025 shock sequence, shaping sectoral reconfiguration and firm-level outcomes.

5 Recent Developments in European Business and Industry (2019-2025)

Between 2019 and 2025, European industry faced a compressed sequence of shocks that altered operating conditions and accelerated structural transitions. This chapter examines how firms and sectors responded, focusing on sectoral reconfiguration (digitalisation, energy, manufacturing, and supply chains) and on firm-level heterogeneity in adoption, investment, and productivity outcomes.

5.1. Overview of Sectoral Transformation in Europe

In this chapter, "sectoral transformation" refers to changes in the composition of economic activity, the configuration of value chains, and the technological intensity of industries, together with the evolution of critical inputs and complementary investments such as infrastructure, skills, and R&D that underpin production. Sections 5.1.1 to 5.1.5 document how the 2019–2025 period altered sectoral conditions and firm operating environments, tracing the interaction between ongoing transitions, notably digitalisation and decarbonisation, and the strategic re-prioritisation of resilience and de-risking. The section aims to establish the main sectoral channels through which adjustment occurred, providing the foundation for the firm-level analysis of heterogeneous adoption, investment, and productivity outcomes in Section 5.2.

5.1.1. Shock Sequence 2019-2025 and the Shift in the Operating Regime

The transformation was propelled by a rapid-fire sequence of exogenous global shocks that fundamentally altered European industrial operations.[128] Each shock introduced distinct pressures that exposed structural vulnerabilities and forced adaptations in business models, supply chain architecture, and strategic resilience calculations.

[128] Draghi (2024)

COVID-19 Pandemic (2019-2020) and Forced Digital Acceleration

The COVID-19 pandemic abruptly disrupted both supply and demand globally, causing severe disarray in European supply chains through lockdowns and transport stoppages. Simultaneously, firms underwent rapid experimentation with remote work, e-commerce, and digital workflows. This was nonlinear change: not gradual technology adoption but sudden forced experimentation that compelled traditional sectors to digitalize or collapse. Retailers with no online presence pivoted to e-commerce; companies with no telecommuting infrastructure shifted entirely remote.

Across advanced economies, the share of workers using computers with internet access rose by an average of 6 percentage points within two years, with lagging countries experiencing fastest catch-up.[129] By 2021, pandemic pressures eased but left operational legacies: firms had embedded digital tools, remote collaboration infrastructure, and e-commerce capabilities that persisted. However, the economy faced new bottlenecks as pent-up demand collided with supply constraints.

2021 Supply Chain Crisis: Semiconductor Shortage and Logistical Breakdown

As pandemic pressures eased, 2021 brought sharp economic rebound accompanied by unexpected production constraints. The euro area recovery was affected by increasing global supply chain disruptions, with real GDP growth driven by services while manufacturing lagged due to shortages of intermediate inputs.[130] Pandemic-induced foundry closures in Asia, electronics boom colliding with supply stoppages, and underestimated demand from automotive, IoT, and consumer electronics sectors triggered the semiconductor shortage. This component shortage directly weakened Europe's automotive sector.

The disruption cascaded across multiple dimensions. Global demand surge for goods accelerated as households shifted spending from services to goods, combined with firm IT investment needs. Simultaneously, lockdowns in Asia-Pacific semiconductor hubs including Malaysia, Singapore, Thailand, and Vietnam disrupted chipmaking capacity. Container logistics networks collapsed as pandemic disruptions left containers stranded in Western ports;

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[129] Jaumotte et al. (2023).
[130] European Central Bank, “Sources of supply chain disruptions and their impact on euro area manufacturing” (2021)

when Asian exports rebounded, cargo capacity became catastrophically scarce. Average port turnaround times in major European harbours increased over 25% above pre-pandemic levels by mid-2021, with German ports +42% and French ports +25%.[4] Container shipping costs quintupled in 2021 relative to pre-pandemic levels.

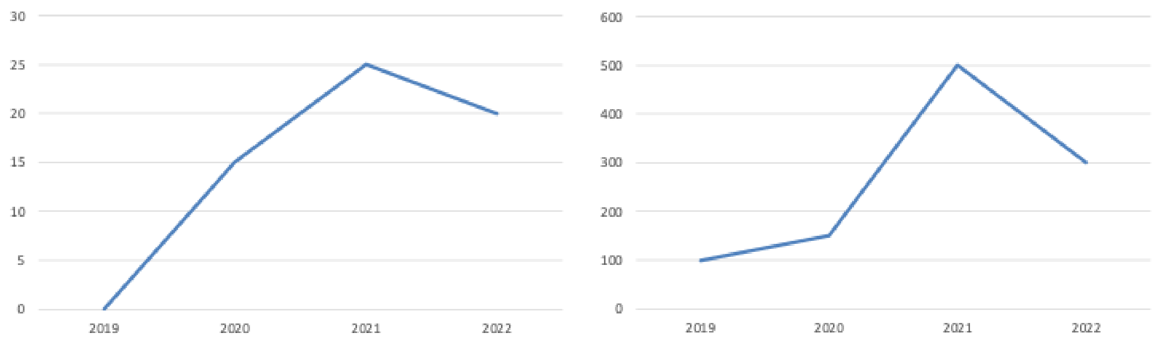

Figure 5-1 Port turnaround time (% increase) & Container shipping cost (index 2019=100)

The ECB's structural vector autoregression model estimated that supply bottlenecks reduced euro area industrial production by approximately 2.6% cumulatively between October 2020 and September 2021. Given that manufacturing represents roughly 20% of euro area value added, real GDP growth in 2021 would have been 0.5 percentage points higher without these supply constraints.[4] Rather than normal demand-driven patterns, 2021 saw both longer delivery times and declining inventories simultaneously, indicating supply bottlenecks prevented adequate demand response. European manufacturers from automotive to machinery faced forced slowdowns and temporary halts. These observations revealed that just-in-time supply chain architectures had created fragility when subjected to tail risks.[131]

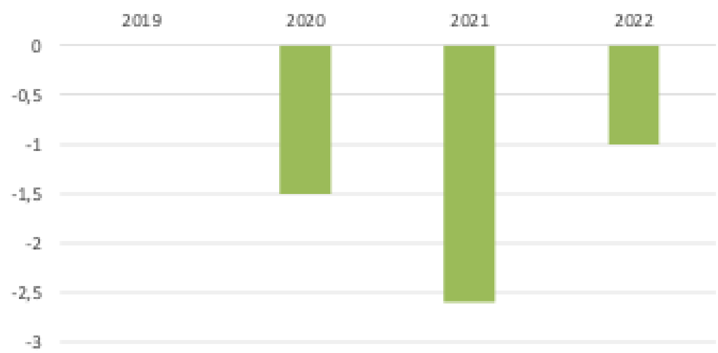

Figure 5-2 – Eu industrial production loss (% cumulative)

[131] IMF, "Europe's Productivity Weakness: Firm-Level Roots and Remedies" (2025)

2022 Energy Crisis: Geopolitical Shock and Cost Competitiveness

Russia's February 2022 invasion of Ukraine delivered a fundamentally different shock: direct energy supply and price shock threatening both cost-competitiveness and security of supply. Europe entered 2022 with pre-existing handicaps: European companies paid electricity prices 2-3 times higher than US or Chinese competitors, with natural gas prices already elevated, reflecting energy import dependence and EU ETS mechanisms.[132]

Italian wholesale natural gas prices rose from approximately €30/MWh in early 2021 to €300/MWh in August 2022, a 10-fold increase. Electricity prices followed proportionally since gas-fired plants set marginal pricing. Government subsidies partially offset increases at retail level (retail electricity +47%, natural gas +29%), but competitiveness deteriorated sharply.[133] Manufacturing sectors where energy represents 20-40% of total costs, including chemicals, steel, fertilizers, glass, paper, and ammonia, immediately curtailed production. Fertilizer plants across Western Europe idled; ammonia producers announced 50%+ output cuts. BASF announced in early 2023 the closure of one ammonia production line and 2,600 job cuts, citing energy escalation.

Germany experienced sharper initial price spikes but more substantial industrial response. Italian wholesale prices rose to €300/MWh in August 2022, but German industry faced six-fold price increases, with prices reaching €227 to €339/MWh during peak disruption. German industrial firms initiated gas demand reduction as early as September 2021 (4% decline) and sustained reductions up to 27% by October 2022, substantially exceeding Italian elasticity responses.[134] This aggressive response reflected both higher price exposure and technological capabilities for substitution. However, this came at cost: energy-intensive industries' output fell sharply, declining over 15% by end-2023 compared to 2021, far exceeding Italian or Spanish contractions.[135] German government intervention through a €200 billion protective shield partially offset costs but required substantial fiscal support, particularly through price cap

[132] European Commission, “EU industrial strategy framework documents and REPowerEU” (2024)
[133] Alpino et al. (2024)
[134] Ruhnau et al. (2023)
[135] Archanskaia et al. (2024)

mechanisms for industrial consumers at 7 cents per kWh on 70% of 2021-level consumption starting January 2023.[136]

Spain showed moderate exposure relative to Germany and Italy. Electricity prices peaked at €167.5/MWh in 2022, well below Italy's €287/MWh, but still burdensome.[137] Gas consumption fell by 3.7%, and manufacturing output declined modestly by 5–10% before stabilizing in 2023[138], outperforming German industrial contraction. Spain's resilience stemmed from a diversified energy mix and timely intervention. The Iberian Peninsula cap mechanism, introduced mid-2022, decoupled electricity prices from natural gas.[139] IMF and Bank of Spain assessments credited this policy with muting wholesale-to-retail price transmission and enhancing competitiveness through accelerated renewable generation—56% of electricity in 2024, contributing to a 40% price cut versus baseline projections. By 2023, electricity prices in Spain normalized at €53.3/MWh[140].

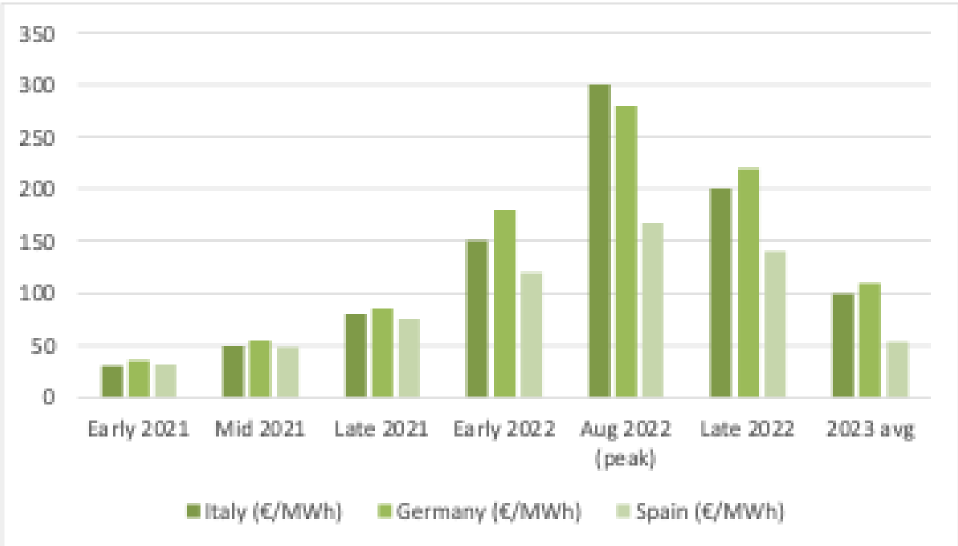

Figure 5-3 - Energy price comparison in Italy, Spain, and Germany from 2021 to 2024

[136] German Government (2022)
[137] European Commission, "Report on Energy Prices and Costs in Europe" (2024)
[138] Archanskaia et al. (2024).
[139] Amaglobeli et al. (2024)
[140] IMF, "Europe's Productivity Weakness, Firm-Level Roots and Remedies" (2022).

Empirical evidence suggests that this intervention helped Spanish firms sustain profitability and production. Unlike firms in Italy with more rigid energy demands, Spanish manufacturing displayed adaptability, reflected in a production rebound by 2023.[141]

Manufacturing output in metals, chemicals, glass, and paper sectors declined from 2021 to 2022, contrasting with overall manufacturing growth and indicating production shutdowns concentrated in energy-intensive branches. Upon fixed-price contract expiration, Italian firms reduced natural gas demand by 34% on average, with heterogeneity: gas-intensive firms cut only 8% , while non-essential-gas users cut 41%.[142] Electricity demand showed zero elasticity on average; firms maintained output despite higher costs. The dominant adjustment mechanism was profit margin compression rather than production cuts.

The 2022 shock crystallized Europe's strategic dilemma: Europe's key economic dependencies were turning into geopolitical vulnerabilities, with Europe the most exposed major economy due to openness and reliance on handful of foreign suppliers. This extended beyond energy to critical commodities and intermediates, activating policy discussions on strategic autonomy.[143]

2023-2025: Unstable Normalization and Regime Shift

By 2023-2025, acute crises subsided but left fundamentally altered operating environment. Post-pandemic inflation triggered aggressive interest rate increases through 2022-2023, raising cost of capital. This stress-tested investment projects; only strategically robust investments proceeded. The European Commission deployed the EU Chips Act (€43 billion commitment to semiconductor capacity), the Green Deal Industrial Plan, and critical raw materials strategies.[144]

Trade flows in 2023-2025 showed regionalization rather than decoupling. European LNG imports replaced Russian pipeline gas; firms shifted sourcing from Asia to proximate locations including Eastern Europe and Mediterranean manufacturing. Inventory baselines remained elevated as buffer stocks replaced minimal just-in-time inventory, reflecting firms' internalization of supply chain risk.

[141] Fontagne, Martin & Orefice (2025).
[142] Alpino et al. (2024)
[143] European Commission, "EU Industrial Strategy and Strategic Autonomy" (2024)
[144] European Commission, "European Chips Act and Green Deal Industrial Plan" (2024)

Paradigm Shift: From "Lean" to "Robust"

Across this shock sequence, European firms internalized fundamental strategic reorientation from cost minimization to resilience optimization. The five-year period exposed hidden costs of hyper-optimized efficiency: minimal inventories and concentrated sourcing enabled low cost structures during stable periods but proved catastrophically fragile when tail risks materialized.[13]

The new operating regime prioritizes redundancy and optionality. Firms increasingly maintain alternative suppliers, including local ones, for critical inputs, hold elevated buffer inventory levels, and invest in supply chain flexibility despite short-term cost penalties. A machinery producer might retain Eastern European supplier despite slightly higher costs, trading efficiency for reliability. A utility company signs long-term contracts with allied nations rather than relying on spot markets. This shift represents fundamental reorientation in how firms understand competitive advantage under uncertainty.[145]

Policymakers became inclined toward industrial policies ensuring capacity for essential goods remains accessible through domestic or allied production rather than relying on pure global market allocation.[146] The principle synthesized in late 2024 was that independence comes at cost, but that cost is price of security and resilience. Europe's openness and import dependencies meant strategic repositioning was essential to avoid becoming less prosperous, less secure and less free.[147]

Crucially, this regime shift created conditions whereby digitalization became not merely productivity lever but instrument of operational resilience. Firms forced to digitalize during COVID-19 discovered that remote operations, supply chain visibility systems with IoT sensors and real-time data, and automated coordination mechanisms provided buffers against physical disruptions.[148] Digital tools enabled rapid supplier switching, dynamic inventory management, and distributed production coordination. The pandemic-induced digital shift thus proved to have dual benefits: immediate operational necessity and long-term resilience enhancement.

[145] OECD, “The Best Versus the Rest: The Global Productivity Slowdown, Digitalization, and Superstars” (2025)
[146] European Commission, “Strategic Autonomy and Industrial Capacity Planning” (2025)
[147] European Commission, “EU industrial strategy framework documents and REPowerEU” (2024)
[148] Eurofound, “SME Digitalisation in the EU: Trends, Policies and Impacts” (2025)

5.1.2. Digitalization and ICT Integration as a General-Purpose Technology

Digitalization functioned as a general-purpose technology (GPT) bundle during 2019-2025, requiring complementary innovation throughout firms rather than operating as standalone investment. The ecosystem encompassed hard infrastructure like cloud computing, sensors, and data centers alongside cybersecurity frameworks and crucially organizational and human capital changes needed to exploit digital tools. A firm adopting cloud services must simultaneously redesign processes, retrain workers, and hire data-savvy managers. Firms combining ICT adoption with high managerial quality and worker skills achieved substantially stronger performance gains than technology-alone adopters.[149]

Digitalization improved productivity through multiple channels. Within-firm efficiency gains emerged as automation streamlined internal processes, reducing errors and accelerating tasks. Manufacturing sensor-equipped machines with AI-based quality control detected defects in real time, minimizing waste. Firms adopting digital workflow tools during pandemic periods found certain processes became 20-30% faster than legacy paper-based methods. However, productivity gains depended on managerial execution; European firms sometimes lagged US peers in extracting ICT returns, often attributed to differences in management practices and complementary investments.

Digital platforms and data analytics enabled firms to match supply with demand more efficiently. E-commerce and digital marketing allowed even small European producers to reach global customers at low cost. In manufacturing supply chains, digital tracking systems enhanced transparency about inventory and customer orders, permitting dynamic adjustment. Companies like DHL and Maersk adopted AI-based systems for shipment consolidation and routing optimization, reducing delivery times and logistics costs. Predictive analytics in inventory management helped firms avoid bullwhip effects, operating with leaner inventories without stockout risks.[150] Digital platforms improved labor market matching and B2B capacity allocation, though Europe's scale remained below US or China due to market fragmentation.[151]

European firms leveraged digital technologies to enhance product quality and variety without excessive cost penalties. Advanced manufacturing techniques including 3D printing and modular production enabled greater product customization. Italian automotive parts

[149] Draghi (2024)
[150] European Central Bank, "Sources of supply chain disruptions and their impact on euro area manufacturing" (2021)
[151] European Commission, “Digital Single Market and Strategic Autonomy” (2024)

manufacturers used CAD/CAM software and connected tools to produce specialized components tailored to client specifications. Digital design simulations (digital twins) drastically shortened development cycles.[152] Data-driven insights improved quality: products with IoT connectivity provided real-world performance data enabling design refinement and failure pre-emption. In pharmaceuticals, AI-based drug discovery and automated labs accelerated R&D.[153] These capabilities allowed European firms to differentiate through innovation rather than cost competition, crucial given high labour costs.

Supply chain resilience and working-capital management improved through ICT integration. Real-time visibility over upstream and downstream inventories allowed tighter control of supply-demand balancing. Firms adopting centralized digital "control tower" platforms consolidated information across supply chains, often using AI to predict disruptions like port delays or supplier failures, enabling proactive mitigation.[154] Digital contracts and electronic procurement facilitated multi-sourcing without incurring efficiency losses, since digital tools managed multi-relationship complexity. Companies with data-driven supply chain management and high supply chain visibility responded faster to 2020-21 disruptions, maintaining output and market share when competitors faltered.[155] This operational resilience provided productivity advantages across the cycle.

Despite wide-ranging benefits, a persistent "potential-performance gap" existed in European digitalization adoption. Despite wide-ranging benefits, a persistent ‘potential-performance gap’ existed in European digitalisation adoption, reflecting uneven diffusion and structural bottlenecks that limited scale and returns. Additionally, infrastructure and skill disparities persisted: northern and western Europe enjoyed high-speed internet and advanced cloud adoption, while some southern and eastern member states lagged. Surveys showed firms in Romania and Bulgaria engaged in big data analysis or e-commerce at much lower rates than Netherlands or Finland. The EU's 2022 Digital Economy and Society Index showed only 55% of EU SMEs met basic digital intensity (using four of twelve identified technologies), falling below 40% in least digital countries.[156]

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[152] Brynjolfsson et al. (2018)
[153] Tambe et al. (2019)
[154] European Commission, “Industry 4.0 and Supply Chain Digitalization” (2025)
[155] Lucalli et al. (2022)
[156] ECIPE, “Unlocking the Power of Digital Technology for Europe's Competitiveness” (2025)

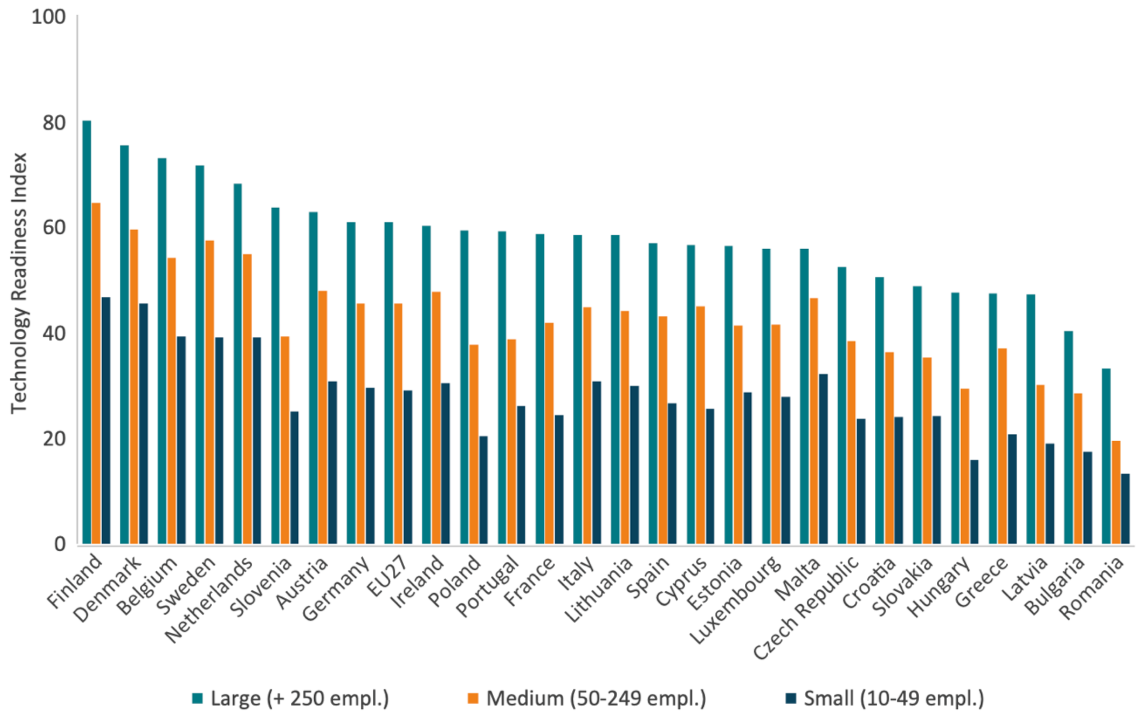

Figure 5-4 - Ranking of ECIPE Technology Readiness Index by firm size

Source EICPE

Skills shortages constituted another brake on digitalization. European companies reported difficulty hiring sufficient IT specialists and digital talent, with the problem acute in certain countries and rural areas. Without adequate human capital, available digital tools remained under-utilized. Inconsistent standards and lack of interoperability across Europe meant truly continental scale of digital platforms remained aspirational compared to US or China's unified markets.[157] European policymakers addressed these through Digital Single Market strategies, cross-border data flow regulations, and Recovery and Resilience Facility investments in digital skills, though these represented medium-term solutions.[158]

Some economists labelled this the "European productivity paradox": high-quality technologies exist, but structural factors prevent broad efficient adoption.[159] This reflects that complementary investments in training, organizational capital, and data infrastructure require sustained firm-level commitment often constrained by financing and skills availability in less advanced regions. The gap between potential and realized productivity from digitalization widened as US

[157] European Commission, “Digital Single Market and Strategic Autonomy” (2024)
[158] European Commission, “Recovery and Resilience Facility: Digital Skills Investment” (2024)
[159] Van Ark (2016)

firms scaled data-driven organizational technologies at faster pace; studies suggested Europe could achieve additional 3.2% GDP over a decade by matching US adoption rates.[160]

Digitalization intersected critically with energy and supply chain dimensions of transformation. As industries relied increasingly on data centres, electrified processes, and cloud connectivity, performance hinged on reliable electricity and communications infrastructure. Data centres consumed significant energy; electrified manufacturing (electric arc furnaces in steel, heat pumps in food processing) shifted burdens to power grids. Thus as European firms digitized and electrified, they increased exposure to energy constraints discussed subsequently. Europe's ability to provide affordable sustainable power and resilient networks directly affected how far digital technologies could drive growth. Digital transformation, energy security, and supply-chain configuration became tightly interlinked. Digital strategies now incorporated energy considerations, such as locating data farms in regions with cheap renewable power, while supply-chain strategies depended on digital visibility.

5.1.3. Telecom and Digital Infrastructure as Productive Capital

Over 2019-2025, digital and telecommunication infrastructure was reclassified from supporting services to critical productive inputs. Manufacturing research indicates that 5G-enabled factories achieve productivity gains of 20–30% overall, including 50% improvements in assembly time, 20% gains in asset lifecycle, and 90% increases in defect detection.[161] Yet adoption remains uneven across Europe. European cloud infrastructure penetration reached 45.2% of businesses by 2023, compared to 77.6% for large enterprises, 59% for medium enterprises, and only 41.7% for small businesses. The 2023-2025 growth is illustrated in the image below.

[160] Bruegel (2020)
[161] Wang et al. (2021)

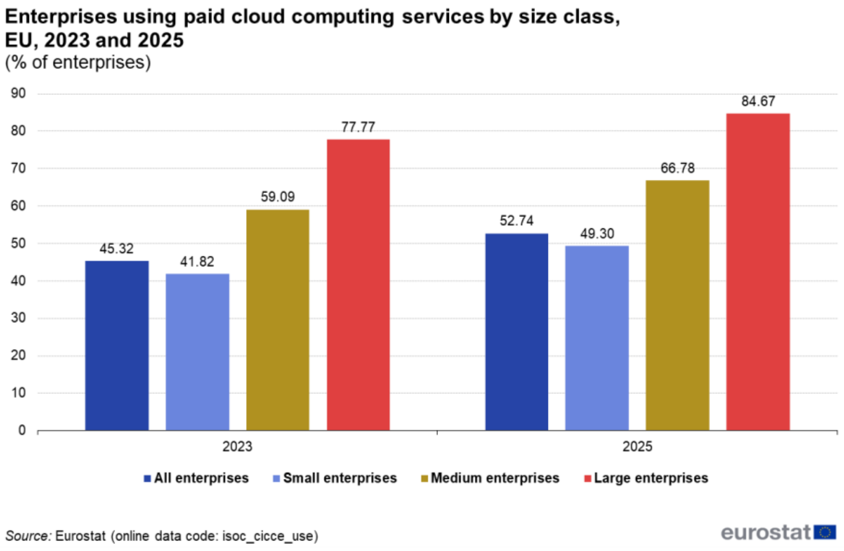

Figure 5-5 - Cloud adoption rate (%)
Source Eurostat

Among businesses using cloud, 75.3% purchase sophisticated services (databases, computing platforms for development), while 10.4% buy intermediate-level services and 12.9% rely only on basic cloud services. Geographic disparities are acute: Finland (78.3%), Sweden (71.6%), and Denmark (69.5%) report cloud adoption above 70%, while Greece (23.6%), Romania (18.4%), and Bulgaria (17.5%) remain below 25%.[162]

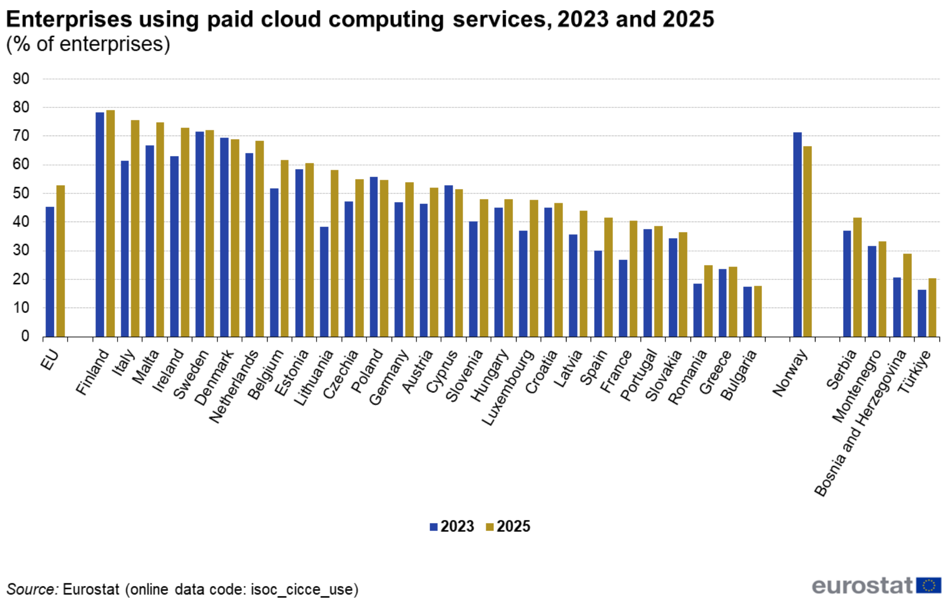

Figure 5-6 - Cloud adoption rate by country
Source Eurostat

[162] Eurostat, "Cloud adoption by member state" (2025)

European access to high-performance computing capacity for artificial intelligence development lags peers materially. The EuroHPC Joint Undertaking operates five petascale supercomputers (10^{15} calculations/second capability) and three pre-exascale systems (10^{17} calculations/second target) with nine additional AI-optimized supercomputers under procurement, which will triple current EuroHPC AI computing capacity by 2026–2027.[163] However, aggregate global capacity comparisons reveal structural imbalance: as of mid-2025, detailed data on Europe's share of global AI-ready supercomputing capacity remain limited in official sources, though EuroHPC commissioning data and international benchmarking studies (outside this analysis) suggest material gaps relative to US and Chinese capacity. By contrast, 5G network deployment has advanced notably: as of 2024, 5G subscriptions accounted for 37% of all mobile broadband subscriptions across the OECD, with Europe participating in this trend.[164] By end-2024, 5G Standalone services (full independent 5G network operation without legacy 4G dependency) had been launched by 18 European operators, indicating technical maturation of the infrastructure layer.[165] Five-generation mobile deployment is projected to contribute materially to European GDP and employment, though quantifying this effect depends on sectoral diffusion rates that vary substantially by member state and industry.

Labour productivity growth in Europe remains the core justification for treating digital infrastructure as productive capital. Between 2019 and 2024, European Union labour productivity growth weakened relative to the United States. The OECD reports that in sectoral analysis, weak productivity growth in information and communications technology (ICT) and professional services, sectors that most heavily depend on digital infrastructure deployment, explains much of Europe's aggregate underperformance relative to peers. European firms remain too small, regulated, and fragmented to fully exploit digital technologies compared to US counterparts, according to OECD institutional assessments.[166] Artificial intelligence adoption offers theoretical productivity gains of 0.2 to 0.8 percentage points per year according to IMF high-adoption scenarios, while OECD analyses of G-7 countries suggest gains up to 1.3 percentage points annually under full deployment.[167] Yet Europe's actual AI contribution to GDP growth over 2020–2025 has been estimated significantly lower than these potentials,

[163] European Commission, "Horizon Europe Strategic Plan 2025–2027, Priority Area on Advanced Manufacturing and Key Digital Technologies" (2025)
[164] OECD, "Fibre and 5G drive OECD digital transformation" (2024)
[165] European Commission, "EuroHPC Joint Undertaking mission and AI Factories" (2024–2025)
[166] OECD, "Competition in the Provision of Cloud Computing Services" (2025)
[167] IMF, " Artificial Intelligence and Productivity in Europe" (2025)

reflecting limited enterprise adoption, insufficient skills, and constrained access to computing infrastructure. The persistent productivity gap between Europe and the United States, measured as slower growth in output per worker in comparable sectors, is not technological determinism but reflects policy choices around investment, market structure, and regulatory framework design.

Three structural constraints systematically impede European realisation of digital infrastructure's productivity potential. First, Europe's telecom markets remain highly fragmented, preventing infrastructure operators from achieving scale economies necessary for next-generation investment. The European Union contains 41 mobile operating groups (defined as operators with over 500,000 customers), compared to 5 in the USA, 4 in China and Japan, and 3 in South Korea. This fragmentation results in per-capita telecom capital expenditure roughly half that of the United States in the mid-2020s. Operators cannot justify massive fibre or 5G SA rollout investments at national scale; divergent spectrum auction timelines and regulatory regimes across member states further fragment procurement and deployment strategies. The incomplete integration of Europe's digital markets creates systemic bottleneck effects: preventing operators from capturing economies of scale, diluting return-on-investment on capital projects, and slowing diffusion of cutting-edge telecom infrastructure. European Commission targets for the Digital Decade programme (gigabit broadband for all households by 2030) remain significantly unmet in many member states due to this underlying fragmentation and underinvestment.[168]

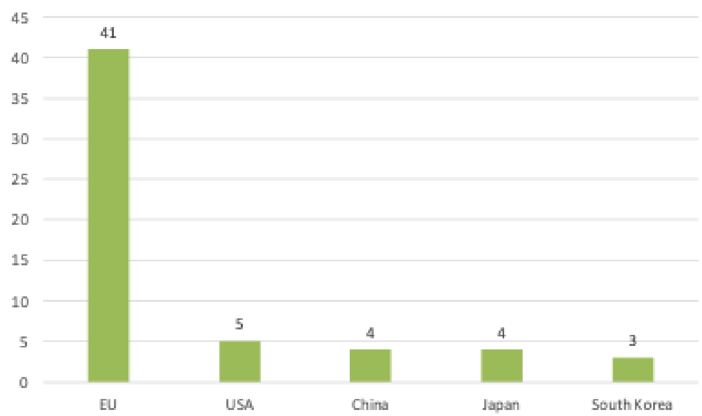

Figure 5-7 - Number of mobile operating groups

[168] European Commission, "Telecom sector analysis" (2025)

Second, the digital infrastructure sector exhibits pathological tension between capital intensity and dispersed financial returns. Network operators and data-centre providers require very high capital expenditures (fibre-laying, 5G base station deployment, energy-efficient data centres) but struggle to capture proportionate revenue growth. Intense competition and regulatory pressure constrain pricing power; furthermore, much of the value created by advanced networks is extracted by over-the-top (OTT) digital services rather than by infrastructure operators. European telecom firms invested heavily in 5G deployment during 2020–2023, yet anticipated revenue streams from 5G applications (internet-of-things connectivity, premium enterprise services) frequently failed to materialise or offset capital costs, partly because global technology giants captured majority end-user revenues from networks that European operators financed. In cloud computing, this dynamic is more acute. European cloud provider market share remains constrained: Eurostat and OECD data on cloud adoption show that 45.2% of EU businesses use cloud services, yet market share data from government and research sources indicate that non-European providers (US-based) command the majority of revenue concentration, limiting indigenous European platform ecosystem development.[169] European Commission assessments note that most monetisation of Europe's digital transition flows outside the region, representing both direct revenue loss and forfeited opportunity to develop indigenous capabilities in platform management, applied AI systems, and security-critical infrastructure.[170] The capital-intensity and pricing-power constraint creates a vicious cycle: underinvestment today undermines productivity gains tomorrow, yet raising prices or consolidating firms faces political barriers and competition law constraints that prevent resolution.

Third, Europe faces acute strategic dependency on non-European technology stacks. The European Commission's Draghi report (2024) documents that Europe imports over 80% of its digital technology, making it the most dependent major economy on external suppliers.[171] This dependency spans semiconductors (Europe's share of global production fell below 10% as of 2023), servers, operating systems, enterprise software, and cloud platform ecosystems. For European enterprises, reliance on a handful of non-EU providers leads to vendor lock-in (high switching costs), extraterritorial regulatory exposure, and loss of agency over standards, data

[169] Eurostat, Cloud adoption by member state & European Commission, “Telecom sector analysis” (2025)
[170] European Commission, “Majority of EU digital transition monetisation flows to non-European providers” (2024)
[171] Draghi (2024)

governance, and pricing. The 2021 global semiconductor shortage, during which European car manufacturers halted production for lack of advanced chips, starkly illustrated that technological capacity translates directly to industrial resilience.[172] The EU responded with the European Chips Act (2023), mobilising €43 billion to increase domestic semiconductor production capacity, targeting 20% of global market share by 2030. The GAIA-X initiative attempts to develop interoperable European cloud standards and reduce lock-in to US platforms. However, these efforts require multi-year execution, leaving interim European reliance on external digital stacks.

Cybersecurity has become integral to digital infrastructure's function as productive capital. Cyberattacks generated significant economic costs in 2020–2025: a European Commission-cited analysis estimates €307 billion in cyberattack costs across Germany, France, Italy, and Spain during this period, with approximately 49% of firms in these economies experiencing at least one attack. Yet penetration of cyber-insurance remains low (22–29% in major EU economies), indicating underestimation of risk and inadequate defensive investment. As firms digitalise operations and interlink with suppliers via cloud platforms, network vulnerabilities translate directly into factory stoppages, supply chain disruptions, and intellectual property theft. Consequently, enterprises increasingly treat cybersecurity spending (network segmentation, encryption, employee training, incident response) as non-discretionary operating cost essential for maintaining productivity. Strong cybersecurity has become a prerequisite for collaboration: firms with robust security protocols find it easier to participate in data-sharing partnerships or industry platforms. In advanced manufacturing and defence, cybersecurity and operational resilience are now part of firms' competitive value propositions. Digital infrastructure that is not secure cannot serve as reliable productive capital; hence security investments have become integral to Europe's telecom and cloud infrastructure.

Policy responses to these constraints have been multi-faceted. The European Commission introduced Digital Decade targets (gigabit broadband for all households by 2030, quantum communication networks, 5G Standalone standardisation) and regulatory measures (NIS2 Directive for critical entities).[173] The EU set a target that 75% of European businesses should use cloud-edge technologies for their activities by 2030; under current deployment trends, penetration is expected to reach approximately 64% by 2030, suggesting a sustained

[172] European Commission, "2021 semiconductor shortage halted European car production" (2021)
[173] European Commission, "NIS2 Directive for critical entities" (2025)

implementation gap.[174] The EuroHPC Joint Undertaking expanded its mandate in 2024 to include development of AI Factories and Gigafactories: large-scale facilities offering massive computing power hosted in energy-efficient data centres to support development, training, and deployment of large foundation AI models.[175] The Clean Industrial Deal (2025) mobilises more than €100 billion for digital infrastructure and clean manufacturing, though budget constraints and competing priorities limit immediate execution. However, structural gaps persist: energy-cost competitiveness, skills supply shortages, and cross-border value-chain integration remain underdeveloped. The tension remains unresolved: European firms cannot fully leverage digital infrastructure to boost productivity without access to world-class, secure, scalable, domestically viable platforms, yet developing such platforms requires massive coordinated capital investment and acceptance of short-term margin pressure to build scale and market power.

To anchor this argument in a small set of comparable indicators, Table 5-1 summarises Europe's 5G deployment maturity and the order of magnitude of factory-level productivity gains reported in 5G-enabled manufacturing.

Indicator	Value
Deployment and readiness (EU-level)	
5G subscriptions (% of mobile broadband, OECD 2024)	37%
5G Standalone operators in Europe (end-2024)	18
Productivity gains in 5G-enabled factories	20-30% overall
Illustrative factory-level outcomes	
Assembly time improvement	50%
Asset lifecycle improvement	20%
Defect detection improvement	90%

Table 5 -1- 5G Deployment & Productivity Gains

[174] OECD, "The Adoption of Artificial Intelligence in Firms" (2025)
[175] European Commission, "EuroHPC Joint Undertaking mission and AI Factories" (2024)

5.1.4. Energy Transition and Post-2022 Resilience

The EU's post-2022 energy investment strategy combines immediate crisis response with a structural shift toward an electrified, low-carbon energy system intended to sustain industrial competitiveness under higher and more volatile fossil fuel costs. This strategy rests on four main pillars: the European Green Deal, the Recovery and Resilience Facility (RRF), InvestEU, and the Innovation Fund. REPowerEU, worth approximately €300 billion, was appended to accelerate diversification away from Russian fossil fuels and to expedite renewable deployment and efficiency improvements.[176]

The 2022–2023 shock made short-term energy security the priority. The transition shifts the focus to building clean generation, grids, and related manufacturing capacity fast enough to stabilise costs and sustain industrial activity.

Between 2020 and 2023, green investment increased to approximately €498 billion per year across energy, buildings, transport and clean technology manufacturing, equal to about 2.9 percent of EU GDP, yet still below the roughly €842 billion per year, or 4.9 percent of GDP, estimated as necessary until 2030 to meet Green Deal and Net Zero Industry Act objectives. The resulting climate investment gap of around €344 billion, equivalent to 2 percent of GDP, is concentrated in underinvestment in wind power, building renovation, and grids, with building energy renovation about 34 percent of the level consistent with 2030 targets. Clean technology manufacturing investment remained modest at about €13.9 billion in 2023, dominated by batteries, and is projected to decline in 2024 for solar and batteries, signalling an early risk of stalled scale-up in technologies that underpin long-term competitiveness.[177]

This investment push is occurring against a backdrop in which the environmental goods and services sector has already become a measurable component of EU output and employment. Table 5-2 shows Eurostat estimates on gross value added and employement generated by environmental goods and services[178]. Growth has been driven by renewable energy production, energy efficiency activities, and waste management.[179] These dynamics support an industrial interpretation of the transition: green domains are already expanding faster than the rest of the

[176] European Commission, "REPowerEU Plan" (2022)
[177] I4CE, "The State of Europe's Climate Investment 2025 edition" (2025)
[178] European Environment Agency, "Gross value added of the EU's environmental goods and services sector" (2025)
[179] Eurostat, "Environmental economy - statistics on employment and growth" (2025)

economy, but productivity and export performance must keep pace with subsidised capacity expansion to avoid locking resources into low-performing segments.

Indicator	2010	2022	Growth
GVA (% of GDP)	2.1%	3.3%	+57%
Employment (million FTE)	~4.0	6.7	+69%
Employment (% of total)	~2.8%	3.1%	+9.7%

Table 5-2 - EU environmental economy: gross value added and employment (2010–2022)

Against this structural context, EU and national authorities mobilised several hundred billion euros for energy-related measures between 2022 and 2025. The RRF made available approximately €648 billion (2022 prices), with a minimum of 37 percent of each national plan earmarked for climate-related spending, implying roughly €240 billion or more directly targeted at green and energy transition objectives.[180] The REPowerEU top-up contributed approximately €20 billion in fresh grants plus reallocation of unspent loans, bringing the total REPowerEU package to around €300 billion.[181] Member states additionally notified approximately €672 billion in national state-aid measures to support firms facing high energy prices and to accelerate decarbonisation investments, including Germany's Carbon Contracts for Difference and large French and Dutch schemes for industrial electrification and hydrogen.[182] The Innovation Fund, financed by EU Emissions Trading System revenues, contributed roughly €12 billion to over 200 projects targeting first-of-a-kind low-carbon technologies in energy-intensive industries, renewable energy, energy storage, and hydrogen.[183]

These commitments translated into a fairly stable set of investment priorities shaped by post-2022 bottlenecks: renewables, grid infrastructure, battery production, and green hydrogen. Within RRF and REPowerEU allocations, member states dedicated large shares to accelerating solar and wind deployment, with particular emphasis on rooftop solar and large-scale onshore and offshore projects.[184] Battery production and supply-chain localisation received dedicated support under both RRF and the Green Deal Industrial Plan, complemented by national schemes

[180] European Commission, “Recovery and Resilience Facility (RRF) size and climate earmarking” (2024)
[181] European Commission, “REPowerEU top-up and financing design” (2024)
[182] European Commission, “EU State Aid framework reporting and monitoring” (n.d.)
[183] European Commission, “Innovation Fund overview” (2023)
[184] European Commission, “REPowerEU Plan” (2022)

in Germany, France, Spain, and Eastern Europe. Green hydrogen featured prominently through the European Hydrogen Bank and Innovation Fund auctions. Disbursement remained uneven: larger economies with stronger administrative capacity and ambitious plans, such as Germany, France, Spain, and Poland, secured sizeable RRF envelopes, while countries such as Spain and Portugal benefited disproportionately in renewables and hydrogen due to resource endowments.[185]

At mid-term, implementation performance and system constraints condition whether these financial commitments translate into deployable capacity. The effectiveness of the investment wave proved mixed. The EU-27 reduced Russian pipeline gas imports in 2022-2023 while avoiding widespread industrial shutdown, partly through demand reduction and partly through accelerated renewable deployment and LNG infrastructure supported by EU and national funds. However, by October 2025 only approximately 40 percent of RRF milestones and targets had been assessed as achieved, implying execution risk ahead of the August 2026 deadline.[186] Regulatory bottlenecks and permitting delays remained central obstacles despite the revised Renewable Energy Directive's entry into force in late 2023.[187] The same logic extends to networks: Europe faced 1,700 gigawatts of renewable projects stuck in grid connection queues, and distribution system operators received 450,000 connection requests in 2024, up 133 percent from 2021, far exceeding current processing capacity. Grid infrastructure age compounded constraints, with 40 percent of transmission assets exceeding 40 years. In 2024, €7.2 billion in renewable generation was curtailed across seven European countries due to transmission constraints, indicating that the binding margin is often connection and reinforcement capacity rather than project intent.[188]

The industrial implications of these constraints are mediated by input prices. European energy-intensive industries (EIIs) comprising steel, aluminium, chemicals, glass, ceramics, and refining employed 18 million people and contributed approximately €3.2 trillion in value added as of 2021, yet confronted structural competitiveness collapse post-2022. Table 5-3 benchmarks the 2024 level of industrial electricity prices across Europe, the United States, and China. Looking forward, available projections suggest that European electricity prices will remain structurally

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[185] European Commission, "The net-zero manufacturing industry landscape across the EU" (2025)
[186] European Parliament, "Briefings on RRF implementation progress" (2025)
[187] European Commission, "Competitiveness report highlights EU potential in clean energy transition" (2023)
[188] Beyond Fossil Fuels et al., "Grid connection queues and curtailment estimates" (2025)

above those of key competitors, staying around twice US levels by 2030 and with the gap expected to persist through 2050. The 2022 shock also widened the gas differential, with European gas prices remaining approximately twice US levels through 2024-2025.[189]

Region	Electricity (€/kWh)	US levels
Europe	€0.199	2,65x
China	€0.082	1,09x
USA	€0.075	Baseline

Table 5-3 - Industrial energy price differentials

These differentials translated into visible capacity contractions in the most electricity- and gas-intensive segments. Primary aluminium is the clearest case: European capacity declined sharply over the last decade and a substantial share of remaining capacity was curtailed during the 2022 price spike, with part of it not returning despite wholesale price normalisation. In ammonia and basic chemicals, curtailments during the 2022 price spike were followed by only partial restart, and parts of the value chain began to reorient toward lower-cost jurisdictions. In steel, higher energy costs tightened margins on commodity output, while decarbonisation investment proceeded selectively where support and infrastructure conditions reduced execution risk.

This cost environment shifts energy from an operational expense to a location constraint, influencing which activities can remain viable domestically and which tend toward relocation, downsizing, or product-mix adjustment.[190]

Internationally, Europe's strategy is large in scale but differs in incentive structure from the United States and China. The US Inflation Reduction Act relies on uncapped tax credits for deployment and manufacturing, with headline estimates around $370 billion but potentially larger outlays, creating clear price signals for batteries, hydrogen, carbon capture, and renewables.[191] The EU's Green Deal Industrial Plan instead combines multiple funding instruments (RRF, InvestEU, Innovation Fund, cohesion funds) and regulatory initiatives (Net-Zero Industry Act, Critical Raw Materials Act), aiming for at least 40 percent domestic manufacturing of eight strategic net-zero technologies by 2030. China continues to leverage

[189] Draghi (2024)
[190] Draghi (2024)
[191] European Parliament, "Recovery and Resilience Dialogue with the European Commission" (2026)

directed credit and state-backed investment to reinforce established global positions in solar PV, batteries, and critical raw material processing. In practice, Europe's challenge is not only financial scale but also predictability and speed of permitting, procurement, and connection processes.[192]

Within this macro and execution context, clean technology domains can be assessed as industrial segments with different competitive logics. Official competitiveness reports show that Europe's clean energy technologies remain system-competitive in deployment, but face acute pressure on manufacturing where value chains are mature and dominated by Chinese producers. The European Commission's progress reports indicate that in 2022 the roll-out rate of wind and solar increased around 50 percent compared to 2021, and that by 2024 renewables generated about 48 percent of EU electricity, up from 41 percent in 2022 At the same time, China holds highly concentrated manufacturing capacity across key solar PV supply-chain steps and dominates global solar cell output and capacity In 2024 the EU ranked second after China in newly installed solar capacity, yet domestic PV manufacturers struggled to compete, while EU firms retained stronger positions in wind equipment and heat pumps.[193] Dahlström (2023) argues that the EU's relative strength in the clean energy arms race is concentrated in innovation and upstream segments of strategic net-zero technologies, with Germany acting as the main innovation hub, yet these advantages are only imperfectly converted into large-scale production capacity.[194]

Macro evidence on innovation is broadly supportive but emphasises conditionality. The European Commission's eco-innovation index increased by 27.5 percent between 2014 and 2024, driven largely by a 62 percent improvement in resource efficiency outcomes such as greenhouse gas productivity.[195] Empirical work finds that technological innovation and renewable energy consumption are significant determinants of green growth, with stronger effects when policies are stable enough to support long-term R&D and capital formation. Other studies show heterogeneous effects across member states, with green patents associated with lower ecological footprints where regulatory frameworks provide clearer price signals and stable support. The implication for an industrial taxonomy is that green sectors display above-

[192] Draghi (2024)
[193] European Commission, "Competitiveness report highlights EU potential in clean energy transition" (2023)
[194] Dahlström (2023)
[195] European Environment Agency (EEA), "Eco-innovation index in Europe" (2024)

average productivity only when regulatory and financial conditions allow innovation to translate into scalable deployment, and when investment discipline prevents the persistence of subsidy-dependent, low-productivity capacities.[196]

Firm-level investment surveys point in the same direction: climate investment is increasingly mainstream but sensitive to uncertainty and financing conditions that matter disproportionately for capital-intensive clean technologies. The European Investment Bank reports that the share of European firms investing in climate action rose by 10 percentage points between 2021 and 2023 to 53 percent, with strong increases in Central and Eastern Europe and among SMEs. Around 88 percent of EU firms have adopted at least one mitigation measure, and energy-intensive manufacturers show stronger investment appetite than other firms.[197] However, tighter credit conditions and uncertainty are already dampening readiness to invest in complex projects with long payback periods, including industrial process transformation and large-scale renewable generation, risking delays precisely in the capital deepening that would raise sectoral TFP.[198]

A sectoral view highlights where competitive advantages are plausible and where structural disadvantages are difficult to overturn.

Renewables and grids sit in a central enabling position: investment in renewables and electricity grids grew by about 17% in 2023, yet wind investment still covered only about 29% of the annual level required for 2030 targets and grid investment fell short by roughly €19 billion. The EU remains a global leader in offshore wind deployment and European firms are at the technological frontier in turbine design and grid integration, but domestic manufacturers face margin compression and rising non-European competition; integrated wind and grid-equipment producers with export capacity and robust order books are plausible "winners", while high-cost component segments reliant on repeated rescue packages risk becoming fiscally intensive.

Solar photovoltaics illustrates the limits of broad re-shoring under extreme upstream concentration: the EU can meet deployment objectives while remaining exposed on manufacturing given China's dominance in upstream production. Horizon Europe invested about €320 million in solar PV R&I between 2021 and 2024, pointing to a more credible niche

[196] Cervantes (2023)
[197] European Investment Bank (EIB), "EIB Investment Report chapter evidence" (2021)
[198] European Investment Bank (EIB), "EIB Climate Investment Report 2022–2023" (2023)

in specialised equipment and high-efficiency modules for industrial and building applications than in commodity-scale mass production.[199]

Batteries and EV supply chains combine deep demand with execution risk. European battery demand is expected to exceed 1 TWh per year by 2030; EVs accounted for 13.6% of new passenger car registrations in 2024 and public charging points reached about 934,000 by early 2025.[200] On this basis, large integrated gigafactories with scale, learning effects and embedded R&D are plausible winners, whereas smaller high-cost plants without secure contracts tend toward subsidy-dependent capacity.[201]

Hydrogen and electrolysers remain high-potential but high-uncertainty. For green hydrogen-based ammonia to be competitive, wholesale electricity prices would need to fall below about €40/MWh, a condition not met across most EU regions given average industrial power prices around €0.199/kWh in 2024. EU strategies identify hydrogen as a cornerstone for decarbonising steel, chemicals and segments of heavy transport, and EU-level auctions have concentrated early winners in lower-cost renewable regions. Peer-reviewed work finds the cost of green hydrogen remains above fossil-based hydrogen in most European locations, though declines are possible under scenarios combining cheap renewables, high load factors and learning in electrolyser manufacturing.[202] EU instruments (including auctions, carbon contracts for difference and Innovation Fund calls) can credibly support clusters that combine low renewable costs, dense industrial demand and logistics access, while isolated projects in structurally high-price regions risk long-term subsidy dependence.[203]

Buildings and heat pumps show that mature technologies can still be strategic if demand is stabilised. EU heat pump production increased by about 30% in 2023 to more than €5 billion and the value chain employed around 416,000 people in 2022, but renovation and heat-pump demand slowed in 2023 and is expected to decline further in 2024.[204] Export-oriented manufacturers and system integrators with strong R&D and labour productivity remain

[199] I4CE, "The State of Europe's Climate Investment 2025 edition" (2025)
[200] Link et al. (2025)
[201] I4CE, "The State of Europe's Climate Investment 2025 edition" (2025)
[202] Ueckerdt et al. (2024)
[203] Draghi (2024)
[204] European Commission, "Heat Pumps in the European Union" (2024)

plausible winners, while fossil-locked lines and fragmented installation networks that resist upskilling are better treated as managed transition rather than protected capacity.[205]

National support instruments attempt to close cost gaps and de-risk investment, but they also shape single-market conditions. Germany's Carbon Contracts for Difference were approved with multi-billion euro funding envelopes, subsidising operational cost gaps while requiring repayments once low-carbon production becomes cheaper. France and Spain have likewise mobilised multi-billion euro schemes for industrial decarbonisation and renewable hydrogen, while the Netherlands' SDE++ operates technology-neutral auctions based on cost per tonne CO2 avoided. By early 2023, European governments had approved €672 billion in state aid, while EU ETS state-aid guidelines provide substantial scope for compensation for higher electricity costs in selected sectors. The proliferation of uncoordinated national programs raises fragmentation risks, with fiscal capacity generating asymmetric advantages between well-funded member states and fiscally constrained economies.[206]

At an aggregate level, the green economy's faster growth in value added and employment suggests that clean activities are becoming structurally important, even if total factor productivity effects remain heterogeneous across technologies and countries. Country statistics indicate meaningful heterogeneity across member states, but a consistent pattern of expansion in renewables, energy-efficient construction and circular-economy activities.[207] Empirical research links green patenting and energy R&D to improved environmental performance and, under supportive policy conditions, to higher green growth, while noting that aggregate productivity gains depend on spillovers, innovation systems and labour market adjustments.[208]

From an industrial policy perspective, the core trade-off is between accelerating decarbonisation and avoiding the entrenchment of structurally uncompetitive production capacities. The Net Zero Industry Act and related instruments seek to raise domestic production of strategic clean technologies by 2030, but investment evidence suggests that current levels remain below what targets imply, and manufacturing dynamics in solar and batteries already show underutilisation and closures under competitive pressure. Academic analysis stresses that

[205] I4CE, "The State of Europe's Climate Investment 2025 edition" (2025)
[206] European Commission, "EU State Aid framework reporting and monitoring" (2023)
[207] European Environment Agency (EEA), "Employment in the EU's environmental goods and services sector" (2025)
[208] Cervantes (2023)

Europe's comparative advantage is often strongest in innovation and upstream segments, while attempts to recreate entire value chains in every technology may dilute scarce fiscal and political capital.[209] A selective sectoral taxonomy can therefore prioritise segments where Europe combines innovation leadership, scale potential, strong linkages to domestic demand and export prospects, and the feasibility of overcoming infrastructure and cost constraints, while withholding open-ended support from segments that remain structurally high-cost and low-productivity.[210]

Finally, the regional dimension is integral to a politically sustainable taxonomy. Clean technology facilities are spread across the EU, with Germany hosting the largest number of plants, Poland and Hungary leading in battery manufacturing capacities, Sweden specialising in advanced batteries and green steel, and Spain emerging as a hub for solar, renewables and potential hydrogen exports. Environmental goods and services also show cross-country divergence in value added and employment shares, reflecting different starting points and institutional capacities. These patterns imply that selective industrial policy will generate geographic winners and losers. The policy challenge is to align technology-specific support with cohesion and transition instruments so that the taxonomy does not map mechanically onto a core-periphery divide, but instead leverages comparative advantages in renewable resources, industrial capabilities and human capital to broaden the geography of green reindustrialisation.[211]

5.1.5. Advanced Manufacturing and Automation

Advanced manufacturing in Europe in the 2020s is characterised by a striking productivity paradox. During 2015-2024, aggregate total factor productivity in the European Union grew at only around 0.5 percent per year, with almost half of member states recording negative TFP growth despite significant investment in machinery, ICT, and intangible assets. At the same time, the European Union emerged as one of the most robotised regions in the world in aggregate terms, with around 219 industrial robots per 10,000 manufacturing employees in 2023 and several member states, including Germany, Sweden, Denmark, and Slovenia, in the global top tier of robot density.[212] This combination of high measured automation and weak

[209] Dahlström (2023)
[210] I4CE, "The State of Europe's Climate Investment 2025 edition" (2025)
[211] European Commission, "The net-zero manufacturing industry landscape across the EU" (2025)
[212] IFR, Global Robot Density in Factories Doubled in Seven Years (2025)

productivity growth is not simply a statistical curiosity, it poses a central challenge for European industrial policy, which seeks to use advanced manufacturing as a lever to restore competitiveness, reduce dependence on external suppliers, and accelerate the green and digital transitions under tight fiscal and state aid constraints. The guiding question for this subsection is therefore why, in Europe, high adoption of robotics and other advanced manufacturing technologies has not translated into commensurate gains in aggregate productivity, and how this gap should inform a selective sectoral taxonomy that distinguishes between dynamic winners and structurally weak or quasi-zombie activities.

From the perspective of physical capital, European manufacturing appears to have embraced automation on a scale that should be sufficient to generate sizeable efficiency gains. Within Europe, automotive, machinery, and electronics account for the bulk of robot installations, and several national manufacturing systems, including those of Germany, Austria, Slovenia, and the Benelux economies, report robot densities in key segments that are comparable to, or exceeding, those of Japan and the United States.[213] Yet industry-level productivity data show that the sectors hosting the densest deployments of robots and automation equipment, such as metal fabrication, general machinery, and chemicals, have posted TFP growth in the order of 0.2 to 0.8 percent per year during the 2010s and early 2020s, markedly below high-innovation activities such as pharmaceuticals and selected food and beverage niches.[214] The implication is that the mere presence of advanced machinery is insufficient to drive structural performance improvements and that the diffusion, integration, and effective use of these technologies across heterogeneous firms and regions is the binding constraint.

A first explanation for the paradox lies in the pronounced heterogeneity of adoption across firms and plants within the same sectors. Plant-level evidence for German manufacturing illustrates this pattern with unusual clarity. Despite Germany's position among the most robotised economies in terms of average density, survey data show that robot use is strongly concentrated in a relatively small share of large exporting plants with more than 250 employees, a high share of skilled labour, and exposure to international competition, while around 70 percent of manufacturing plants operate without any robots at all.[215] In other words, high national robot density coexists with a long tail of small and medium sized producers that remain entirely

[213] IFR, "Global Robot Density in Factories Doubled in Seven Years" (2025)
[214] IMF, "Industry-Level Productivity Developments in Europe: Chasing the Dream "(2024)
[215] Deng et al. (2020)

manual or only partially automated, particularly in supplier tiers, traditional metalworking, plastics, textiles, and localised food processing. Firm-level studies for Italy reinforce this picture of positive selection in automation adoption, over the period from the late 1990s to the mid 2010s, robot-adopting firms expanded employment by more than 50 percent, whereas non-adopting firms in the same industries experienced declines in employment exceeding 20 percent and gradually lost market share. The observed macro outcome is a reallocation of output and employment towards a relatively small group of frontier firms that combine automation with innovation and export orientation, while a large group of laggards stagnates or contracts. Aggregate TFP growth remains modest because gains at the frontier are partially offset by weak or negative productivity in the long tail, especially where resources are not fully reallocated away from structurally uncompetitive producers.[216]

This intra-sectoral divergence has important implications for a sectoral taxonomy. It suggests that even within nominally the same industry, such as automotive components or fabricated metals, there coexist segments that operate at or near the global technological frontier and segments that survive through protected local demand, low wages, or political support but contribute little to dynamic efficiency.[217] The former group, often located in regions with strong industrial ecosystems such as southern Germany, western Poland, parts of the Czech Republic, and Sweden, tends to invest in advanced automation, digital twins, and predictive maintenance as part of broader strategies of quality upgrading and platform integration. The latter group, more prevalent in structurally weaker regions of Southern and Eastern Europe, faces higher financing costs, weaker skill bases, and more fragmented supply chains, and therefore deploys limited automation in isolated production steps without full organisational integration. From an industrial policy perspective, a taxonomy that treats these segments identically would be misleading. Frontier sub-sectors that already demonstrate high productivity and export dynamism warrant continued support in order to diffuse advanced manufacturing practices further into their supply chains, whereas chronically underperforming segments with low innovation intensity may be candidates for managed contraction, particularly where automation investments fail to raise productivity above minimum competitive thresholds.[218]

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[216] Banca d'Italia, "Robots and Employment: Evidence from Italy" (2020)
[217] IMF, "Europe's Productivity Weakness: Firm-Level Roots and Remedies" (2025)
[218] European Commission, "Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery" (2021)

A second, closely related, driver of the productivity paradox is the structural disadvantage of small and medium sized enterprises in adopting, financing, and effectively using advanced manufacturing technologies. Advanced manufacturing technologies, including robotics, industrial internet of things, and AI-based quality control, require a minimum capability base in data management, cybersecurity, and process digitalisation. In environments where SMEs still rely on paper-based workflows or fragmented legacy software, the introduction of isolated robots or sensors often yields limited, localised efficiency gains without transforming overall TFP. The result is a dual economy in which large firms and a minority of digitally advanced SMEs capture most of the benefits of automation, while the majority of smaller firms remain locked in low productivity trajectories that drag down aggregate performance.[219]

Financial constraints reinforce these capability gaps. As discussed earlier, cloud computing purchase in the EU is uneven. Sophisticated services, such as databases, computing platforms, and advanced analytics, are, among cloud users, disproportionately purchase by large firms, whereas SMEs tend to confine themselves to basic storage or email solutions.[220] Advanced manufacturing systems that rely on real time data collection, edge and cloud computing, and integration with enterprise resource planning software therefore remain disproportionately accessible to larger firms. Financing advanced robotics installations, digital twins, and predictive maintenance also typically requires significant upfront capital, long payback periods, and the ability to absorb implementation risks, characteristics that favour well capitalised multinationals over liquidity constrained SMEs. The consequence is that, in many European manufacturing sectors, the technological frontier is pushed outward by a limited number of global or regional champions, while the median firm either abstains from automation or adopts partial solutions that do not generate substantial TFP gains.[221]

A third set of explanations relates to skills, organisational complexity, and the time profile of returns to complementary intangible investments. Recent industry-level productivity work for Europe emphasises that higher TFP growth is associated not only with physical ICT and machinery capital, but also with investments in research and development, human capital, and organisational innovation, particularly in countries and sectors that operate close to the global

[219] OECD, “Economic Surveys: European Union and Euro Area 2025” (2025)
[220] Eurostat, “How digitalised have the EU’s enterprises become?” (2024)
[221] IMF, “Industry-Level Productivity Developments in Europe: Chasing the Dream” (2024)

technological frontier.[222] Empirical analyses of firm-level productivity weakness in Europe confirm that lagging firms are characterised by deficits in management quality, workforce skills, and adoption of modern business practices, rather than by an absence of physical capital alone. Advanced manufacturing technologies magnify these complementarities. Realising the full potential of robotics, digital twins, and AI-based quality control usually requires re-engineering production lines, redesigning product architectures, changing maintenance regimes, and empowering workers to interpret and act on data. These changes entail substantial organisational disruption, learning costs, and the need for continuous up-skilling of technicians, engineers, and managers. In practice, many European firms deploy isolated automation solutions without undertaking deeper process redesign, either because of risk aversion, labour relations constraints, or lack of managerial capabilities, which leads to capital deepening without corresponding TFP growth.

Skills shortages constitute a particularly binding constraint in several member states. Surveys and vacancy data reveal persistent unfilled demand for mechatronics technicians, data analysts, software engineers, and production managers with experience in Industry 4.0 environments, especially in Germany, the Netherlands, Sweden, and parts of Central and Eastern Europe.[223] Firms that are able to attract and retain such profiles, often large multinationals or high-growth scale-ups, can reorganise production around integrated digital platforms, collaborative robots, and predictive maintenance systems, yielding step changes in quality and throughput. In aerospace and high-end automotive manufacturing, leading European producers have implemented digital twins across design and production so that thousands of engineers, suppliers, and partners can collaborate on virtual prototypes and simulate production layouts before physical implementation, which reduces the cost and risk of reconfiguration and supports continuous improvement. In several advanced plants, predictive maintenance has lowered machine failure rates and unplanned downtime compared with traditional scheduled maintenance, and, in electronics and automotive painting lines, artificial intelligence systems already perform quality inspection at a scale and precision unattainable by human inspectors, sharply cutting defect rates and downstream repairs.[224] Such integrated deployments, exemplified by highly digitalised plants in German automotive and electronics and by major aerospace assembly sites in France and Spain, are however the exception rather than the norm.

[222] OECD, “Compendium of Productivity Indicators 2025” (2025)
[223] Cedefop, “Skills for Industry 4.0: Training the Workforce of the Future” (2020)
[224] European Commission, “Horizon Europe Strategic Plan 2021–2024” (2021)

A large share of European SMEs lack both the specialised personnel and the organisational structures needed to interpret sensor data, maintain complex cyber-physical systems, and translate insights into process innovation, which helps explain why automation yields large firm-level productivity gains in a few cases but only modest improvements in the median firm.

A fourth explanation for weak aggregate productivity outcomes lies in the fragmentation of industrial data and the incomplete integration of digital systems across the value chain. Many European manufacturers operate a patchwork of proprietary machine control systems, legacy enterprise resource planning software, and vendor specific data formats that impede the creation of unified data lakes required for advanced analytics and machine learning.[225] Data generated by sensors on the shop floor often remain siloed in on-premise systems or are accessible only to equipment suppliers, who use them to sell maintenance contracts, rather than being fully integrated into firms' own production planning and product development processes. Concerns about cybersecurity, trade secrets, and intellectual property further discourage data sharing, both along supply chains and across firms participating in industrial data ecosystems. In response, European standardisation bodies and public-private initiatives, including sectoral data spaces and automotive data platforms, have begun to develop common architectures and reference standards for secure industrial data exchange, while European standardisation organisations such as CEN, CENELEC, and ETSI have intensified work on interoperability and industrial data management.[226] Nonetheless, progress remains uneven and many SMEs opt for simpler, stand-alone solutions that do not interoperate with wider data ecosystems. As a result, a significant fraction of installed automation capital operates below its potential, functioning as sophisticated mechanical equipment rather than as nodes in fully integrated cyber-physical production systems that could generate stronger dynamic TFP effects.[227]

The interaction between firm-level heterogeneity, SME constraints, skills, and data fragmentation is further shaped by Europe's sectoral specialisation pattern. Empirical analyses of sectoral TFP in Europe point to a "mid-tech" profile, in which a large share of value added is generated by medium technology industries such as machinery, transport equipment, and basic chemicals, while the weight of high-R&D, high-TFP sectors such as information and

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[225] OECD, "Industry Concentration in Europe: Trends and Policy Implications" (2024)
[226] European Commission, "Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery" (2021)
[227] Eurostat, "Productivity trends using key national accounts indicators" (2025)

communication technologies, advanced pharmaceuticals, and certain business services remains comparatively modest.[228] Within manufacturing, this specialisation amplifies the importance of process innovation, incremental product upgrading, and supply chain coordination, all of which rely heavily on the effective use of advanced manufacturing technologies. Where these complementarities are realised, as in segments of automotive, aerospace, and capital goods production in Germany, France, Spain, and Sweden, Europe remains globally competitive despite relatively high energy and labour costs.[229] Where they are not, as in parts of fabricated metals or low value-added plastics and food processing in some Southern and Eastern member states, high automation can coexist with stagnant or falling TFP if investment is channelled into replacing labour without accompanying innovation or market expansion.[230] For a sectoral taxonomy, this implies that mid-tech sectors cannot be treated homogeneously. Sub-segments that participate in global value chains and invest strongly in R&D, digitalisation, and skills have the potential to function as winners and deserve targeted support, whereas domestically oriented, low-innovation sub-segments displaying persistent TFP underperformance should be managed as declining activities with active redeployment policies for labour and capital.[231]

International comparison reinforces this interpretation of Europe's productivity paradox. East Asian leaders such as the Republic of Korea and, increasingly, China combine high robot density with industrial policies that strongly promote complementary investments in R&D, skills, and diffusion across supplier networks. Korea's manufacturing structure is dominated by large business groups with close links to national innovation systems, heavy investment in vocational training, and strong integration between electronics, automotive, and machinery, which facilitates system-wide deployment of advanced automation. China has rapidly raised its robot density to levels comparable with advanced European economies, while directing substantial public subsidies and regulatory support towards semiconductor equipment, power electronics, and AI applications in manufacturing, resulting in high patenting intensity and dense innovation networks in advanced manufacturing fields These countries also tolerate more rapid exit of non-competitive firms and more aggressive consolidation in sectors identified as strategic, which accelerates the reallocation of resources towards frontier producers. By contrast, Europe combines high automation in a subset of large firms with stricter competition

[228] Midelfart (2025)
[229] OECD, "Compendium of Productivity Indicators 2025" (2025)
[230] IMF, "Industry-Level Productivity Developments in Europe: Chasing the Dream" (2024)
[231] European Commission, "Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery" (2021)

and state aid rules, more fragmented capital markets, and heterogeneous labour market institutions, which can slow both the scaling of high-productivity firms and the contraction of structurally weak ones. The outcome is that similar levels of physical automation yield larger aggregate productivity effects in East Asia than in Europe because the former context provides stronger complementary investments and more decisive reallocation mechanisms.

At the same time, Europe has launched a series of policy initiatives intended to narrow these gaps and translate advanced manufacturing adoption into broader productivity gains. At EU level, Horizon Europe's "Made in Europe" partnership and related industrial alliances co-finance pilot lines, testbeds, and demonstration projects for advanced manufacturing, bringing together large firms, SMEs, and research organisations to validate Industry 4.0 solutions under realistic conditions and to diffuse best practices across regions. The European Commission estimates that full manufacturing digitalisation could add on the order of one hundred billion euros annually to the value of European industry, primarily through improved resource efficiency, reduced downtime, and shorter time-to-market, which provides a macroeconomic rationale for sustained support to such initiatives. At the same time, the Digital Decade strategy sets explicit targets for SME digital intensity and connectivity, while cohesion policy funds are increasingly used to finance regional innovation ecosystems, competence centres, and training programmes focused on advanced manufacturing and automation. However, these measures are still relatively general in scope. From the perspective of a selective industrial policy taxonomy, their effectiveness will depend on the extent to which they are targeted towards sectors and regions with demonstrated potential to convert automation into TFP growth, rather than being distributed uniformly across all activities.[232]

The evidence reviewed in this subsection suggests a number of concrete implications for such a taxonomy. First, sectors and sub-sectors where advanced manufacturing is already associated with strong TFP and export performance, such as segments of transport equipment, machinery for renewable energy, and high value-added chemicals and pharmaceuticals, should be classified as strategic winners. In these cases, policy should focus on reinforcing positive externalities through support for supplier upgrading, skills development, and cross-border industrial data spaces, rather than on subsidising further robot purchases per se.[233] Second,

[232] European Commission, "Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery" (2021)
[233] Midelfart (2025)

sectors where automation adoption is concentrated in a small set of frontier firms, while the long tail of SMEs remains technologically and organisationally laggard, such as traditional metalworking, basic plastics, and parts of food processing, call for policies that combine diffusion support and capability building with stricter exit mechanisms for firms that fail to reach minimum productivity thresholds despite support. This implies that subsidising automation hardware in isolation is unlikely to be efficient, more granular instruments that condition support on complementary investments in skills, digital infrastructure, and integration into data ecosystems are required. Third, low-innovation, domestically oriented sectors that display persistent negative or near-zero TFP growth even in the presence of automation, and that face strong import competition from lower cost producers outside the European Union, should be candidates for managed decline, with public resources redirected towards worker retraining and regional diversification rather than capital subsidies.

Finally, the paradox of high automation and low productivity in European manufacturing underscores the need to complement macro and sectoral analyses with firm-level perspectives. Aggregate indicators such as robot density or average TFP conceal the underlying distribution of firms, technologies, and business models. The next section of the thesis, which examines micro-data on firm performance, innovation, and internationalisation, is therefore essential to validate and refine the taxonomy proposed here. It will document more precisely how frontier firms in selected sectors translate advanced manufacturing into productivity gains, how far behind laggard firms remain, and which combinations of technology, skills, and organisational change are associated with successful transition paths. This micro-evidence will, in turn, inform the design of selective industrial policy instruments that can tilt resource allocation away from structurally unproductive, quasi-zombie activities and towards sectors and firms that are capable of leveraging advanced manufacturing to strengthen Europe's long-term competitiveness in an increasingly contested global environment.[234]

5.1.6. Reshoring, Nearshoring, Friendshoring and Supply-Chain Adaptation

European companies and policymakers have increasingly pursued strategies to reconfigure supply chains for greater reliability and control in response to the shocks experienced since 2019. European companies and policymakers have increasingly pursued supply-chain reconfiguration for greater reliability and control in response to the shocks experienced since

[234] IMF, "Europe's Productivity Weakness: Firm-Level Roots and Remedies" (2025)

2019. In what follows, reshoring, nearshoring, and friendshoring are used as shorthand for a common shift away from single-source, cost-minimising configurations towards diversified and geopolitically safer sourcing patterns.

Geopolitical fragmentation and weaponization of trade have made friendshoring an attractive strategy despite its costs. The pandemic exposed Europe's over-reliance on single-country sourcing, exemplified by initial scrambles for medical supplies concentrated in China; subsequent Western sanctions on Russia following its 2022 invasion of Ukraine demonstrated how rapidly geopolitical events can sever major trade flows, including Russian gas accounting for 40 percent of Europe's supply prior to 2022.[235] US-China tensions over semiconductor technology introduced new uncertainties: export controls on advanced chips mean European companies suddenly face restrictions on both sourcing critical high-tech components from Asia and selling to China, pushing firms to ask whether their supplier's country could become politically inaccessible.[236] The European Union's 2021 identification of strategic dependencies for rare earths, active pharmaceutical ingredients, batteries, and cloud computing services revealed that many critical inputs came overwhelmingly from China or other single sources, with rare earth elements showing 100 percent EU import dependency. The policy response centred on mitigating dependencies via stockpiling, partnerships with aligned countries, and boosting domestic capacity. Companies have begun redesigning procurement with geopolitical considerations: a European electronics firm previously sourcing primarily from China might diversify to Southeast Asian partners (Vietnam, Malaysia) while considering Europe's own emerging electronics manufacturing for a portion of supply, with defence and tech industries explicitly redirecting supply chains toward NATO and EU allies. The EU is pursuing partnerships with countries like Canada, Australia, and Chile to secure critical minerals (lithium, cobalt) rather than relying overwhelmingly on Chinese processing, which dominates rare earths and battery metal refinement[237]. According to a 2023 survey, a majority of executives worldwide expect accelerated friendshoring by 2025, and Europe follows this trajectory.[238]

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[235] Draghi (2024)
[236] Nobletz et al. (2024)
[237] European Parliament, "Securing Europe's supply of critical raw materials" (2023)
[238] World Bank, "Global supply chain survey on friendshoring expectations" (2023)

Logistics costs and lead-time pressures have made nearshoring economically compelling. The 2021-2022 supply chain chaos, featuring sky-high container shipping rates, months-long port delays, and shipping disruptions, forced companies to reckon with the fragility of extended just-in-time chains: the cost of shipping a container from Asia to Europe spiked tenfold at one point, erasing labour cost savings from Asian production for many goods, while lengthy lead times proved inflexible when demand swung.[239] As a result, regionalization of supply chains became economically rational: producing closer to consumer markets cuts transit time and inventory pipeline, reducing variability and operational risk. Empirical analysis of European reshoring between 2016 and 2024 reveals a strong intra-European trend with production often relocated from Eastern Europe to Western Europe, with China the dominant host country for previous offshoring decisions now being reversed; large firms dominate this pattern, yet SMEs have begun increasing reshoring activity.[240] Within Europe, Poland emerged as a critical nearshoring hub: Polish transport companies accounted for 20 percent of EU freight transport in 2023, leading the European market, with Polish carriers executing nearly two-thirds of all cabotage transport performed by non-domestic EU carriers in Germany (Europe's largest transport market) and achieving 18 percent market share in cross-trade operations within the EU. Nearshoring activity in Poland accelerated, with logistics projects increasing 12 percent in 2023 as companies relocated production closer to Western European markets, benefiting from Poland's central location, well-developed transport infrastructure, and lower labour costs than Western Europe.[241] Fashion retailers heavily dependent on Asian factories with three-month lead times have expanded sourcing in Turkey, Morocco, and within Europe for fast-fashion items to respond to trends in weeks rather than miss entire seasons. Automakers burned by Asian semiconductor delays are pushing for new chip plants in Europe via the EU Chips Act or facilitating closer foreign investments (Intel and TSMC building in Germany). European logistics real estate demand reached record levels in 2021-2022 as companies sought to position goods closer to customers and hold greater buffer stock, reflecting a new appreciation for proximity and shorter supply chains with fewer breakable links.[242]

Compliance and ESG standards have aligned with resilience pressures to encourage regional supply chain configurations. The EU's proposed Corporate Sustainability Due Diligence

[239] Draghi (2024)
[240] Ahlqvist (2025)
[241] Poland Trade Ministry / Eurostat, "Poland - Europe's logistics leader" (2025)
[242] Draghi (2024)

Directive will obligate large companies to audit supply chains for human rights and environmental violations, a substantially easier task when suppliers are geographically nearby or within jurisdictions with similar standards.[243] When suppliers operate several tiers down and across continents, monitoring working conditions and environmental practices becomes genuinely difficult, raising legal and reputational risks; after forced labour revelations in Asian supply chains, some European textile and apparel brands shifted sourcing to countries with stronger labour protections or brought production back in-house within Europe to ensure compliance. The carbon footprint of long-distance shipping is increasingly scrutinized by consumers and regulators, with shorter supply chains reducing transport-embedded emissions; some companies now include carbon calculations in procurement decisions as part of ESG commitments. Organizational simplicity and reduced intellectual property leakage favour local supply chains: simpler, more local sourcing is easier to coordinate and less prone to IP risks, particularly important in high-tech sectors.[244] European policymakers encourage these shifts indirectly by raising standards, essentially making noncompliant imports less viable and nudging production toward locations where compliance can be ensured; companies getting ahead of this curve can create competitive advantages through transparent, sustainable supply chains.

Subsidy competition and investment diversion have created a new political economy of supply chain location decisions. The US Inflation Reduction Act and CHIPS Act deployed massive subsidies for American production; China maintains long-standing subsidy regimes and is escalating support in EV batteries and solar panels; India's Production-Linked Incentives, Mexico, and others offer incentives to capture manufacturing relocating from China. This global subsidy race creates investment diversion risk for Europe: if a European battery maker can secure billions in US subsidies with easier regulatory processes, why build in Europe? Several battery and auto companies announced pauses or reviews of European projects while evaluating US incentive packages, forcing Europe to respond with its own programs or risk losing new industrial capacity.[245] The EU's response, the Green Deal Industrial Plan and Temporary Crisis Framework, allows expanded state aid for green technologies and attempts to pool EU funds for critical projects, yet the reality remains fragmentary: European companies build in the US to serve American markets (leveraging IRA incentives) and build in Europe

[243] European Union (2023-2025). "Corporate Sustainability Due Diligence Directive."
[244] Draghi, M. (2024). "The Future of European Competitiveness."
[245] Draghi, M. (2024). "The Future of European Competitiveness."

only with equivalent EU aid, otherwise capacity migrates elsewhere.[246] This dynamic produces geographic duplication: instead of one giant factory serving global markets, parallel nodes emerge in each major region (Americas, Europe, East Asia) serving those regions, increasing global costs through lost economies of scale while increasing resilience to regional shocks and trade restrictions.[247] Semiconductor manufacturing exemplifies this pattern: the US is building new fabs via its CHIPS Act, Europe via its Chips Act, while Taiwan's TSMC continues expanding there, creating multi-node rather than single-location structures, each node less efficient in isolation but more resilient to geopolitical disruption.

The combined outcome represents not a full reversal of globalization but a recomposition into more regional and risk-conscious forms. Eurostat data on enterprise responses to supply chain disruptions shows marked sectoral differentiation: high-tech and automotive sectors adopted nearshoring strategies substantially more than logistics and lower-value sectors, with 28 percent of large enterprises in high-tech implementing nearshoring compared to 13 percent in service-oriented Poland and Bulgaria. Trade data and corporate plans indicate global trade volumes recovered post-pandemic, yet their composition shifted: regional trade agreements increased, intra-European sourcing for European firms expanded, and critical sectors tilted toward home or allied production.[248] Rather than reversing globalization, firms reconcile global market-seeking with resilience by building slack and regional hubs. Different sectors experience this differentiation notably: electronics, historically almost entirely offshored from Europe, now pursues friendshoring to Vietnam, India or assembling more within Europe for sensitive equipment due to China-related strategic concerns; pharmaceuticals push to reshore active pharmaceutical ingredients after COVID revealed reliance on India and China; automotive leverages EV supply chain reconstruction (batteries, chips) to localize previously imported components. Other sectors like machinery and luxury goods, largely European-made historically, remain so selling globally.[249] The net effect is tailored, sector-by-sector globalization: high-vulnerability, strategically sensitive sectors see regionalization and capacity duplication; others maintain global efficiency patterns. These changes entail costs: building redundancy and relocating factories involve short-term inefficiencies and substantial investment; economic analyses suggest fully fragmented global structures could reduce global

[246] European Commission (2023-2024). "Green Deal Industrial Plan and Temporary Crisis Framework."
[247] Draghi, M. (2024). "The Future of European Competitiveness."
[248] Eurostat (2024).
[249] Draghi, M. (2024). "The Future of European Competitiveness."

GDP growth through lost scale economies, though partial reorganization with careful policy can minimize such impacts.[250] Europe frames its strategy explicitly as "de-risking," not autarky: diversify, secure supply, but maintain trade openness, with businesses echoing this aim to make supply chains safer and more robust rather than abandoning global linkages entirely.[251] This represents the emergence of regional supply webs connected globally rather than single global chains, with selective duplication of capacity in allied locations hedging against geopolitical and logistical risks.

5.2. Firm-Level Adaptation and Productivity Outcomes

The sectoral transformations documented in the preceding section, including digitalisation, energy transition, automation, and supply-chain restructuring, do not translate mechanically into aggregate productivity gains. Sectoral averages conceal profound heterogeneity at the firm level, and it is this micro-level divergence that increasingly determines aggregate outcomes. Over the past decade, a growing body of evidence has documented a widening gap between productivity leaders operating at the technological frontier and a long tail of laggard firms that adopt new technologies slowly or not at all. This divergence is not a temporary adjustment process but a persistent structural feature of advanced economies, and it is particularly pronounced in Europe. Frontier firms invest heavily in intangible capital such as software, data, organisational routines, and worker skills, and they capture disproportionate shares of productivity growth. Laggard firms, often smaller and less well-connected, face higher adoption costs, weaker managerial capacity, and limited access to finance and skills, which delays or prevents the diffusion of best practices. The result is that aggregate productivity growth remains weak even when leading firms achieve strong performance, because the gains are not broadly shared across the firm distribution. This section examines the mechanisms that drive firm-level divergence in Europe, focusing on the role of intangible investment, artificial intelligence adoption, and firm dynamism. It also explores why diffusion has been slower in Europe than in the United States, and what policy interventions might accelerate the transmission of frontier practices to the broader business base.

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[250] IMF, “Global supply chain fragmentation” (2023)
[251] Von der Leyen/European Parliament, “Strategic Autonomy and De-risking” (2023)

5.2.1. The Microcosm of European Transformation

The preceding section documented how, between 2019 and 2025, European industry absorbed a sequence of shocks that reshaped sectoral structures, from forced digitalisation during the pandemic to the energy price shock of 2022 and the progressive reconfiguration of supply chains. At the macro level, a persistent paradox emerged, Europe experienced rapid diffusion of advanced technologies such as industrial automation, cloud computing and digital platforms, yet aggregate total factor productivity (TFP) growth remained weak, typically around 0.5 percent per year in the early 2020s in spite of substantial investment efforts. The sectoral analysis of advanced manufacturing, digital infrastructure and the energy transition showed that the challenge is not the absence of modern technologies, but their uneven absorption across sectors and regions, as well as the constraints imposed by high energy costs and fragmented digital and financial markets.

This section argues that these macro and sectoral outcomes are the surface expression of a deeper microeconomic phenomenon, a strong and persistent divergence between a relatively small group of highly productive frontier firms and a long tail of structurally weaker laggard firms across European economies. Micro data for manufacturing and market services show that, within narrowly defined sectors, productivity and profitability differ by factors of several multiples between firms, even when they operate under the same technology set and policy environment. Aggregate productivity growth has been constrained because gains at the frontier have not been matched by sufficient upgrading or exit among laggards, so that resources remain trapped in low productivity uses. The result is that high levels of robotisation, digital adoption and clean investment at the frontier coexist with modest aggregate performance and rising heterogeneity both across and within member states.[252]

To analyse this divergence, the chapter draws on three complementary sources of firm-level evidence. First, the CompNet micro-aggregated database and its recent productivity reports provide harmonised distributions of productivity, size, wages, investment and trade orientation across firms in the European Union, distinguishing between frontier and laggard groups within each country sector cell.[253] Second, recent International Monetary Fund studies exploit census-type firm panels covering most EU member states, which allow an assessment of firm

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[252] IMF, "Europe's Productivity Weakness, Firm-Level Roots and Remedies" (2025)
[253] CompNet, "New CompNet Firm Productivity Report" (2025)

dynamics, entry and exit, and the contribution of different parts of the distribution to aggregate productivity growth.[254] Third, European Statistical System and Eurostat microdata, including structural business statistics and surveys on digitalisation and technology use, supply systematic information on the digital, intangible and international profiles of firms by size class and country, including small and medium sized enterprises that are often under-represented in commercial datasets.[255]

The objective of the analysis is twofold. On the one hand, it provides a micro-level validation of the patterns identified in the sectoral narrative, by showing that the duality observed between advanced manufacturing winners and vulnerable energy intensive or mid-tech activities is mirrored in the productivity distribution of firms within those sectors. On the other hand, it informs the design of a selective industrial taxonomy by clarifying which types of firms and investment profiles underpin dynamic, high value added activities and which combinations are associated with quasi-zombie configurations where resources are locked into structurally uncompetitive business models. The central hypothesis is that the European productivity paradox is primarily a diffusion problem, frontier technologies and practices are present in Europe, but they are not adopted broadly or deeply enough across the median firm.

5.2.2. Frontier versus Laggard Firms, The Great Divergence

A first step is to define the relevant segments of the firm distribution. In line with the CompNet methodology and recent IMF work, this chapter defines frontier firms as those in the top decile of the labour productivity distribution within each country sector size class, while laggard firms are taken to be the bottom half of the distribution, with robustness checks based on a narrower bottom decile yielding qualitatively similar patterns.[256] Labour productivity is measured as real value added per worker or per hour, with corrections for outliers and sectoral price differences. This relative definition avoids conflating country and sector effects with firm heterogeneity, since in each cell firms face similar external conditions but exhibit very different internal capabilities.

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[254] IMF, "Europe's Productivity Weakness, Firm-Level Roots and Remedies, VoxEU Column and Supporting Material" (2022)
[255] Eurostat, "Digitalisation in Europe" (2024)
[256] CompNet, "Firm Productivity Report, Post-COVID Recovery and Frontier–Laggard Gaps" (2023); IMF, "Europe's Productivity Weakness, Firm Level Roots and Remedies, VoxEU Column and Supporting Material" (2022)

CompNet evidence for the period 2011 to 2022 shows that productivity dispersion within sectors increased across most EU economies, and that the frontier-laggard gap widened particularly after the COVID-19 shock. Before the mid-2010s, the gap between the mean productivity of frontier and laggard firms tended to narrow moderately in several countries, reflecting some catch-up by weaker firms. Between 2020 and 2021, however, the immediate pandemic shock and the uneven recovery produced a sharp divergence, with labour productivity in frontier firms recovering quickly while laggard firms experienced much larger and more persistent declines. On average across the EU, the ratio of labour productivity between frontier and laggard firms in manufacturing and market services is estimated at around three to one, but with striking cross-country variation, in Portugal frontier firms are roughly ten times more productive than laggards, whereas in Sweden the ratio is closer to two to one.[257] These figures confirm that the bulk of the productivity paradox is not a sectoral composition issue but an intra-sectoral dispersion problem.

The profiles of frontier and laggard firms differ systematically. Frontier firms are larger in terms of employment and turnover, typically at least twice the size of laggards within the same country sector cell, and they pay substantially higher wages, in many cases between 50 and 100 percent above laggard firms, reflecting both higher labour productivity and higher skill intensity.[258] They invest more intensively in fixed capital and, crucially, in intangibles such as research and development, software, data assets and organisational capital, and they exhibit higher adoption of advanced digital technologies. The mechanisms through which intangible accumulation and AI deployment amplify frontier advantages are developed in Section 5.2.3.

Laggard firms, by contrast, tend to be small, domestically oriented and financially constrained. Structural business statistics show that micro and small enterprises, defined as those with fewer than 50 employees, account for roughly 30 percent of employment in the EU but a much smaller share of value added, and that this share is even higher in Southern and parts of Eastern Europe.[259] Within this group, many firms operate with low capital intensity, limited formal R&D, and rudimentary digital capabilities, often lacking even basic enterprise software, secure cloud storage or data analytics tools. Surveys conducted in 2023 and 2024 indicate that in countries such as Spain, Poland and Romania, fewer than one third of small firms achieve even

[257] CompNet, "Firm Productivity Report, Post-COVID Recovery and Frontier–Laggard Gaps" (2023)
[258] CompNet, "New CompNet Firm Productivity Report" (2025)
[259] Deutsche Bundesbank, "Euro Area Business Dynamism on the Decline" (2024)

a basic level of digital intensity, defined as the use of at least four core digital technologies, and AI adoption remains negligible outside a narrow band of more productive firms in tradable services and manufacturing.[260] Laggard firms frequently serve local markets shielded from international competition, and rely on low wages, low prices or institutional protection to remain viable, rather than on continual productivity improvements.

Table 5-4 contrasts typical characteristics of frontier and laggard firms, based on CompNet micro-aggregates, IMF firm-level studies and Eurostat digitalisation statistics for the early 2020s. The figures in the table are indicative ranges that capture robust patterns across Germany, France, Spain, the Netherlands, Poland and Sweden, rather than exact point estimates for individual countries.

Dimension	Frontier firms (top 10 percent)	Laggard firms (bottom 50 percent)
TFP and labour productivity level	Around 3 to 5 times higher on average, up to 10 times in some countries	Baseline; often close to or below sector median, sometimes very low
TFP growth, 2015–2022	Positive, typically 1 to 3 percent per year	Stagnant or negative on average; weak recovery after shock
R&D and intangible intensity (share of value added)	Several percentage points higher; often 2 to 3 times laggard rat	Low or negligible; limited spending on R&D, software or organisational capital
Digital technology and AI adoption	High; majority use cloud, advanced analytics, robotics and increasingly AI	Low; many rely on basic ICT only, AI rare outside a few cases
Export share of turnover	Often above 50 percent in tradable sectors	Predominantly local or national markets; low export participation
Average wage level	Roughly 1.5 to 2.5 times higher than laggard firms	Lower wages reflecting lower productivity and skill content
Investment rate (fixed plus intangibles over value added)	High and stable; resilient during shocks	Volatile and pro-cyclical; often cut sharply in downturns

Table 5-4 - Frontier vs. laggard firms: indicative ranges and mechanisms (early 2020s)

[260] OECD Economic Surveys, “European Union and Euro Area 2025” (2025)

The macroeconomic consequence of this divergence is a muted contribution of within-sector reallocation to aggregate productivity growth. Firm-level decompositions for large euro area economies indicate that changes in firm productivity levels account for more than 60 percent of annual aggregate productivity growth, while entry and exit contribute much less in the short run. Yet, over the last decade, two unfavourable trends emerged. First, among low productivity incumbents, the share of firms that manage to move up the distribution has declined, especially in services and mid-tech manufacturing; fewer laggard firms upgrade into the middle of the distribution.[261] Second, at the top of the distribution, high productivity firms remain at the frontier for longer, while new high growth entrants are relatively scarce in Europe compared to the United States, which limits competitive pressure on incumbents and slows diffusion of frontier practices.[262]

IMF firm-level work quantifies these dynamics. Using data for millions of firms across the EU and comparing them with US counterparts, it finds that European frontier firms do innovate and grow, but at a slower pace than US peers, and that the distribution of firm growth rates is narrower, with fewer high growth young firms and an over-representation of small, mature, low growth firms.[263] Entry and exit rates are on average comparable to the United States once micro firms are fully taken into account, but the selection mechanism is weaker, in Europe it is less likely that high productivity firms expand strongly and less likely that low productivity firms exit, especially in countries with more stringent insolvency regimes and heavier administrative burdens.[264] This combination of a long tail of laggards, a modest pace of frontier advance and weak selection generates a dual speed firm landscape, frontier firms pull ahead, but the median firm remains stuck in low productivity equilibria, so that aggregate outcomes mirror the weighted average of very different micro trajectories.

For the sectoral taxonomy developed in this thesis, the implication is that even in sectors classified as potential winners at the macro level, such as advanced manufacturing, clean technologies or digital intensive business services, there exists a wide dispersion between globally competitive frontier firms and domestically sheltered laggards. Support directed at sectors in aggregate will therefore often reinforce incumbents that already perform well,

[261] European Central Bank, “Firm Productivity Dynamism in the Euro Area” (2022)
[262] IMF, “Europe’s Productivity Weakness, Firm-Level Roots and Remedies” (2025)
[263] IMF, “Europe’s Productivity Weakness, Firm Level Roots and Remedies, VoxEU Column and Supporting Material” (2022)
[264] Deutsche Bundesbank, “Euro Area Business Dynamism on the Decline” (2024)

without necessarily lifting the productivity of the long tail. Conversely, in sectors that appear structurally weak, such as traditional low value added manufacturing or certain local services, pockets of frontier firms with strong intangible intensity and export performance may justify targeted support, provided that policies do not simply preserve large numbers of quasi-zombie firms whose productivity remains chronically below viable thresholds.

5.2.3. The Engines of Divergence, Intangible Capital, Artificial Intelligence and Firm Dynamism

The stark divergence between frontier and laggard firms is not merely a function of physical capital or sectoral technological opportunities, it is largely driven by differences in the accumulation of intangible capital and in the ability to deploy complex digital technologies such as artificial intelligence within suitable organisational and institutional frameworks. At the same time, weak business dynamism and insufficient creative destruction slow the reallocation of resources away from structurally weak firms, allowing the long tail to persist even in the presence of clear frontier benchmarks.

Intangible capital is the central differentiator. In the post-2020 literature, intangible assets are increasingly treated as the "missing factor" behind TFP differences: software and data infrastructure enable automation and analytics; design, branding, and customer capital raise markups and scale returns; organisational capital allows firms to redesign processes; and R and D creates new products and production functions.[265] These assets are partly non-rival within the firm and often scale with size, which generates increasing returns and naturally concentrates at the frontier.[266] Because many intangibles are partly non-rival and scale with organisational capacity, they generate increasing returns and tend to concentrate at the frontier, making diffusion structurally difficult even when technologies are available. This is particularly relevant for 2020-2025: the pandemic accelerated digitisation but also raised the payoff to organisational flexibility, supply-chain visibility, and data-driven planning, which are intangible-heavy capabilities.[267] Firms that already possessed these capabilities could convert crisis-driven adoption into durable productivity gains; firms without them experienced adoption as cost, not as transformation.

[265] OECD, “Intangible assets as drivers of TFP in firm-level studies” (2024)
[266] Bajgar (2021)
[267] OECD, “Pandemic acceleration of digital and organisational change” (2022)

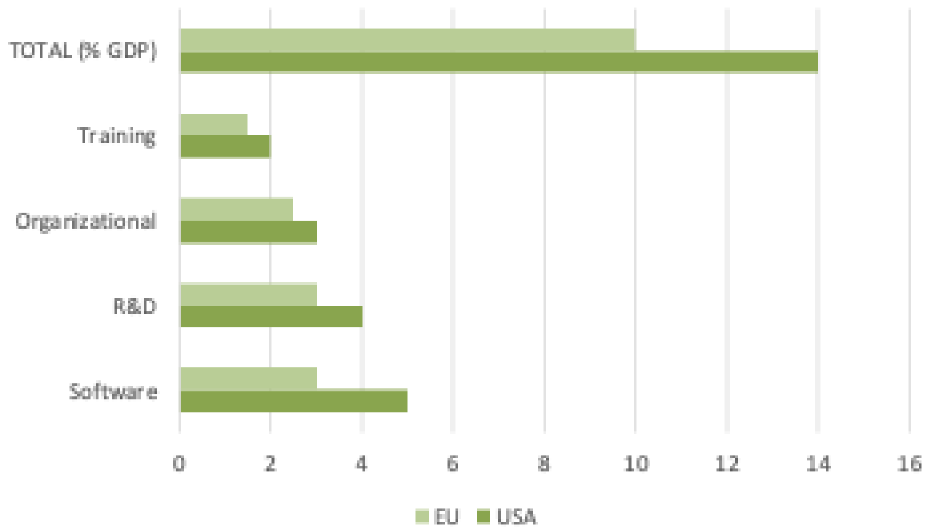

Figure 5-8 - Intangible investments EU vs. US

These patterns are highly uneven across countries and firm types. In countries such as Germany, France, the Netherlands and Sweden, frontier firms in advanced manufacturing and business services invest heavily in R&D, software and data infrastructures, often spending several percentage points of value added more on these items than the median firm, whereas in Spain, Poland or Portugal, intangible intensity tends to be concentrated in a relatively small set of exporters and knowledge intensive service providers.[268] Within each country, large firms and young high growth firms invest substantially more in intangibles than mature small firms, reflecting both their greater capacity to bear risk and their better access to market based financing.[269] The concentration of intangible capital in a narrow segment of the distribution raises concerns for industrial taxonomy, it suggests that sectors labelled as winners often derive their performance from a small number of intangible rich firms, while large swathes of the same sector remain closer to traditional, low innovation business models.

Intangibles also interact with finance. Intangible assets are harder to collateralise, which can constrain investment for smaller firms and for firms in bank-centric financial systems, a relevant feature in parts of the euro area.[270] This mechanism can be a structural reason why laggards underinvest even when technologies are available and subsidised. If policy subsidises

[268] European Investment Bank, “EIB Investment Survey 2023, Climate and Digital Investment in Europe” (2023)
[269] IMF, “Europe’s Productivity Weakness, Firm-Level Roots and Remedies, VoxEU Column and Supporting Material” (2022)
[270] ECB, “Collateral constraints and intangible financing frictions” (2024)

equipment purchase but not data infrastructure, skills, and organisational change, it risks generating "digitised stagnation": firms adopt tools but do not change production functions.[271] From a selective industrial policy perspective, this is an allocation problem. The constraint is not only the level of support but the design of incentives so that public funds purchase capability-building complements rather than marginal hardware.

Artificial intelligence is emerging as a second powerful engine of divergence. Although still in an early deployment phase, AI exhibits all the hallmarks of a technology that amplifies pre-existing differences in capabilities and resources. Recent IMF simulations, combining task-level exposure data with adoption scenarios for 31 European countries, suggest that medium term productivity gains from AI could reach around 3 percent cumulatively over a decade in a central scenario, corresponding to roughly 0.3 percentage points of additional annual growth, with higher gains in richer member states and in sectors with a high share of cognitive and information processing tasks. Central bank surveys and Eurostat data indicate, however, that actual adoption is still limited and highly skewed, in 2023 only about 8 percent of all European firms reported using at least one type of AI, with adoption heavily concentrated among large, digitally advanced firms in services, finance, ICT and export oriented manufacturing.[272]

Harmonised business surveys for Germany, Italy and Spain show that within countries, AI uptake is strongly associated with firm size, productivity and prior digitalisation, large firms with existing cloud and robotics infrastructure are far more likely to experiment with AI than small firms without such foundations.[273] An ECB survey of large euro area firms finds that around three quarters already use some AI applications in their operations, but typically with less than one quarter of employees actively involved, and primarily in support functions such as information retrieval, customer interaction or process optimisation, rather than in core product innovation.[274] This pattern reinforces the argument that AI is currently an intensifier of frontier advantages rather than a broad based leveller. Firms that already possess rich data, advanced digital systems and skilled workforces can integrate AI relatively quickly and capture early productivity and quality gains, whereas laggard firms lack both the necessary data

[271] European Commission, "Evaluation of digital subsidy design and complementarity needs" (2024)
[272] IMF, "Artificial Intelligence and Productivity in Europe" (2025)
[273] Bricongne et al. (2023)
[274] ECB, "AI Can Boost Productivity, If Firms Use It" (2025)

infrastructure and the managerial and technical capabilities to deploy AI effectively, even when basic tools become cheaper.

The third engine of divergence is firm dynamism and the strength of creative destruction. The evidence reviewed above indicates that Europe has a relatively similar average rate of firm entry and exit as the United States, once micro firms are properly counted, but that its growth distribution is narrower, with fewer young high growth firms and greater survival of low growth incumbents.[275] Complementary analyses by the Bundesbank and the ECB document a marked decline in business dynamism in the euro area over the last two decades, measured by lower entry and exit rates and reduced mobility of firms along the productivity distribution, and link this to slower aggregate productivity growth.[276] Entry rates remain particularly subdued in some Southern and continental economies, where demographic ageing, heavy administrative burdens and limited access to equity financing reduce the pool of potential entrepreneurs and slow the expansion of successful young firms.[277]

At the lower end of the distribution, weak selection mechanisms allow many laggard firms to survive for extended periods despite persistently low productivity. Factors include bank forbearance, generous but poorly targeted support schemes during crises, and institutional frameworks that complicate insolvency procedures or discourage asset redeployment.[278] In such an environment, the reallocation of resources from laggards to frontier firms is slower and incomplete, and the aggregate effect of frontier innovation is muted. At the upper end, frontier firms in Europe face constraints to scaling that are less prevalent in the United States, including fragmented product and capital markets, heterogeneous regulation and a smaller effective market size. OECD and IMF analyses highlight that remaining barriers in the Single Market, especially in services and digital activities, and a bank-dominated financial system limit the availability of risk capital for high growth firms, thereby dampening their expansion and the diffusion of their innovations across regions and sectors.[279]

The interaction between intangibles, AI and firm dynamism is central for understanding the European productivity paradox in the period 2019 to 2025. Frontier firms that combine high

[275] IMF, "Europe's Productivity Weakness, Firm-Level Roots and Remedies" (2025)
[276] ECB, "Firm Productivity Dynamism in the Euro Area" (2022)
[277] OECD Economic Surveys, "European Union and Euro Area 2025" (2025)
[278] IMF, "Europe's Productivity Weakness, Firm Level Roots and Remedies, VoxEU Column and Supporting Material" (2022)
[279] OECD Economic Surveys, "European Union and Euro Area 2025" (2025)

intangible intensity, rapid AI experimentation and strong access to European or global markets have been able to sustain or even accelerate productivity growth, despite energy price shocks and supply chain disruptions, by redesigning processes, reducing downtime and optimising resource use. In Germany's and Sweden's advanced manufacturing clusters, for example, leading firms integrated AI-enabled predictive maintenance and quality control into robotised production lines and digital twins, achieving notable reductions in defects and unplanned stoppages even under volatile input conditions.[280] In Poland and Spain, dynamic service and ICT firms leveraged cloud infrastructure and data analytics to scale rapidly across borders, partially compensating for weaker performance in traditional sectors.[281]

By contrast, laggard firms with weak intangible bases and low digital intensity often responded to shocks by cutting investment, postponing digital upgrades and relying on cost compression, particularly wage restraint, to survive. In energy intensive and mid-tech sectors in Southern and Eastern Europe, many firms lacked the organisational and financial capacity to undertake the deep process redesign required to benefit from automation and AI, and instead resorted to partial equipment upgrades without complementary changes, which delivered limited TFP gains.[282] At the same time, subdued entry of new firms into these segments and persistent obstacles to exit allowed many low productivity producers to remain in operation, contributing to the persistence of quasi-zombie sectors that absorb labour and capital without generating commensurate value added.

For a selective industrial taxonomy, these findings imply that the meaningful units of analysis are not sectors in isolation, but the interaction between sectors and firm types. Sectors such as machinery, transport equipment, ICT and knowledge intensive business services contain both frontier firms with high intangible and AI intensity and laggards with traditional, low innovation business models. Similarly, in energy intensive activities, some firms are rapidly investing in process innovation and electrification, while others remain locked in outdated technologies and fragile balance sheets. The taxonomy must therefore distinguish between firm-subsector ecosystems that exhibit strong complementarities between intangibles, AI and dynamism, and

[280] CompNet, "Firm Productivity Report, Post-COVID Recovery and Frontier–Laggard Gaps" (2023)
[281] CompNet, "New CompNet Firm Productivity Report" (2025)
[282] IMF, "Europe's Productivity Weakness, Firm-Level Roots and Remedies" (2025)

those where such complementarities are absent and where policy attempts to preserve existing capacity risk entrenching low productivity equilibria.

6 A Framework for a Selective European Industrial Policy

6.1. Introduction: From Diagnosis to a Contribution on Implementation Discipline

This chapter operationalises the thesis's contribution: it turns the diagnosis of Europe's persistent productivity slowdown into a selective, disciplined, and testable policy logic. The core puzzle is not whether Europe has policy activity, funding, or technology availability. It is why productivity gains remain weak and uneven despite an increasingly interventionist policy environment. The thesis argues that the binding constraint lies in the interaction between structural European frictions (fragmentation, asymmetric diffusion capacity, and a post-2019 shock regime) and an implementation gap: many instruments exist, but they are not consistently embedded in a decision logic that (i) selects where intervention is justified, (ii) protects competition and contestability, and (iii) converts support into measurable diffusion rather than persistence.

The chapter's novelty is the specification of an operating system for selective industrial policy: a three-level architecture (Macro framework conditions, SPSM selection discipline, and BESNI delivery) that can be audited ex ante, monitored during execution, and exited credibly. The remainder of the chapter makes this logic explicit by stating the operational propositions that guide evaluation, mapping current EU approaches against them, and then detailing how the Macro-SPSM-BESNI system closes the implementation gap without sliding into capture, lock-in, or compensatory permanence.

6.1.1. The problem restated: a productivity slowdown that persists under activism

The preceding chapters established that Europe's competitiveness gap is structurally anchored in weak aggregate productivity dynamics, and in particular in a transmission failure: frontier capabilities and technologies exist, but their payoffs do not propagate sufficiently across firms, regions, and supply chains. The result is persistent dispersion: a thin frontier and a long tail of laggards that adopt slowly and often without the complementary organisational change needed for productivity effects.

This persistence matters because it suggests that the constraint is not purely technological. It is institutional and organisational. Europe's system produces too little diffusion throughput and too little scale-up of high-performing organisational forms. Under the post-2019 shock regime (pandemic, supply-chain stress, energy volatility, and geopolitical risk) these weaknesses intensify: stronger firms and regions absorb shocks and invest, while weaker ones delay upgrading, reinforcing divergence.

This diagnosis is summarised below in three operational propositions that define the evaluation criteria for both the mapping of current EU approaches and the proposed framework.

Core operational propositions and evaluation criteria

To make the contribution explicit, the chapter rests on three operational propositions that translate the diagnosis into implementable design constraints.

Proposition 1 (Diffusion as the binding mechanism). In the European context, the central productivity constraint is not the absence of frontier technologies or policy activity but insufficient diffusion throughput: the system converts support into too little adoption, too slowly, across the long tail of firms and supply chains.

Proposition 2 (Selectivity without a stopping rule becomes persistence). "Strategic" labels and prioritisation cannot substitute for an ex ante classification routine and a procedural default that makes non-renewal the baseline absent evidence. Without this, intervention risks drifting toward compensation and incumbency protection under political stress.

Proposition 3 (Delivery without contestability becomes a bottleneck). Ecosystem coordination is necessary for standards, shared interfaces, and capability-building, but any delivery layer that lacks portability, multi-provider access, auditability, and switching rights risks turning coordination into lock-in or gatekeeping.

Unit of analysis. The relevant object for selection and delivery is the ecosystem or value-chain segment (not the sector in aggregate), because diffusion constraints and competitive dynamics operate at segment level.

Testability. The framework is evaluated on measurable outcomes (productivity and diffusion) and on leading indicators that can be audited: adoption and upgrading rates, time-to-deploy, contestability metrics (multi-award coverage, switching/use-rights), and enforceable exit decisions.

These propositions map directly onto the framework's architecture: Macro reforms widen the feasible set for diffusion; SPSM hard-wires selectivity and default exit; BESNI converts priorities into adoption under contestability-by-design. They also provide the reference points used in the next subsection to distinguish what current EU proposal families specify explicitly from what they leave implicit.

6.1.2. The current European approach mapped: what it does address, and what it systematically under-specifies

Europe is not in a "hands-off" regime. Since 2019, the policy mix has expanded across several channels. The mapping below is intentionally descriptive: it summarises what the main proposal families explicitly try to do (scale, resilience, permitting, funding) and then evaluates where they fall short against the operational propositions stated above. The focus is on whether these packages hard-wire (i) a replicable selection routine, (ii) a default stopping rule, and (iii) contestability requirements for delivery mechanisms. In this thesis, these are treated as binding design constraints rather than optional implementation details.

First, integration and framework-condition proposals target the fixed costs of scaling and cross-border deployment. The Letta report frames competitiveness as a Single Market completion problem, with emphasis on services, capital markets and cross-border frictions that prevent firms from scaling, especially in intangible and digital intensive domains.[283] The Draghi competitiveness agenda similarly stresses that Europe's gap is increasingly about productivity and governance capacity, not just fiscal effort, and it links the strategy to deeper market integration and investment feasibility.[284]

Second, crisis-era financing and state-aid flexibility has been used to accelerate investment and de-risk capacity expansion, particularly in energy, clean tech and strategic value chains. This responds to short-run constraints and geopolitical urgency, but it also amplifies a known risk:

[283] Enrico Letta (2024)
[284] Mario Draghi (2024)

support can drift toward compensation and incumbency protection when exit and evaluation are weak, and when scarcity increases political pressure to label activities "strategic".[285]

Third, targeted industrial initiatives increasingly define "strategic" domains and provide legal and financial scaffolding for capacity-building. The Chips Act is the clearest example in deep tech, framing resilience, spillovers and an EU-wide ecosystem objective. These initiatives expand policy space and accelerate capacity formation, but they do not by themselves solve the transmission problem: diffusion throughput, contestability-preserving delivery, and enforceable exit remain under-specified. In operational terms, they combine (i) coordination and governance objectives for the ecosystem with (ii) funding channels and state-aid flexibilities intended to mobilise large-scale investment, plus measures on skills and security of supply[286]. The Net-Zero Industry Act is the clearest example in the green transition, combining faster permitting and demand-side instruments with targets for domestic manufacturing capacity in selected net-zero technologies. Put differently, they strengthen the ability to invest, while the framework developed in this thesis targets the ability to diffuse and reallocate under discipline.[287]

Across these strands, the recurring pattern is not absence of instruments. It is limited conversion of priorities and resources into diffusion and disciplined reallocation, especially under stress. Relative to the propositions above, many packages mobilise investment and coordination but leave three elements insufficiently hard-wired: a replicable selection routine, a procedural default for stopping or scaling down support, and delivery constraints that preserve contestability at ecosystem level. The thesis's contribution is to treat these as binding design constraints rather than as "implementation details".

Concretely, most current packages are strong on at least one of three levers but rarely hard-wire all three at once: (i) enabling investment (funding, permitting acceleration, state-aid flexibilities), (ii) articulating strategic intent (priority areas, autonomy and resilience rationales), and (iii) expanding coordination capacity (IPCEIs, alliances, common projects). Less consistently specified are the procedural disciplines that make selectivity reversible and

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[285] European Commission, "Temporary Crisis and Transition Framework for State aid measures to support the economy following the aggression against Ukraine" (2023)
[286] European Union, "Regulation establishing a framework of measures for strengthening Europe's semiconductor ecosystem" (2023)
[287] European Union, "Regulation on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem" (2024)

delivery contestable: an auditable classification routine that can be rerun and challenged, an evidence-based default that makes non-renewal routine, and minimum portability and multi-provider constraints on any ecosystem-level delivery layer.

This creates the opening for the thesis's contribution: a policy logic that treats diffusion and scale-up as binding mechanisms, couples selectivity to an explicit classification routine, and makes delivery contestable and auditable rather than assumed.

6.1.3. Structural frictions beyond "industry": gold plating, energy fragmentation, and administrative fixed costs

A central refinement of the thesis is that Europe's productivity problem is not only "industrial" in the narrow sense. It is amplified by structural frictions that shape the feasible set for firm investment and ecosystem scaling.

Gold plating and uneven transposition practices can turn EU-level rules into heterogeneous national compliance burdens, raising non-value-adding costs and uncertainty, particularly for SMEs and service-intensive activities.[288] Even when objectives are aligned, divergent implementation can recreate fragmentation through procedural complexity.

Energy market fragmentation and price dispersion operate as a direct competitiveness wedge and as an investment-risk multiplier. When expected energy costs are high and volatile, the payoff horizon for upgrading shortens, discouraging the complementary investments, skills, organisational redesign, digital integration, that diffusion requires.

Administrative fixed costs, especially in permitting and cross-border investment procedures, reduce the speed of deployment for both productive capacity and enabling infrastructure. Under these conditions, industrial policy can end up funding "intent" rather than delivered capability.

These frictions are not side issues: they determine whether selective intervention is productivity-enhancing or merely compensatory. This is why the chapter treats Macro reforms as gating conditions rather than as a separate, optional agenda.

[288] Magrani et al. (2021)

6.1.4. Why existing proposals remain incomplete: selection without discipline, delivery without contestability

The thesis does not claim that Europe lacks strategies. It argues that current proposals cluster around two partial solutions, each strong on one dimension and weak on another.

A first cluster corresponds to Proposition 2: "strategic prioritisation" without a replicable stopping rule. Sectoral agendas and flagship initiatives can define objectives and mobilise resources, but under stress they face the same political economy problem: the strategic label can substitute for feasibility, and continuation becomes the path of least resistance unless evaluation outputs are designed to force non-renewal. This is visible in the gap between headline targets and segment-level viability. A recent audit of the EU semiconductor agenda, for example, highlights the feasibility challenge of meeting the 2030 target under current funding and governance conditions, which is precisely the kind of constraint a selection framework must make explicit.[289]

The point is not to litigate the target itself. It is that feasibility, segment specificity, and enforceable delivery conditions must be decided ex ante and revisited routinely. SPSM is designed to force that move: it decomposes "strategic" into segment-level classification, applies a discipline filter (viability under a declining support path, enforceable conditionality), and makes continuation procedurally conditional rather than politically negotiated.

A second cluster corresponds to Proposition 3: "delivery expansion" without contestability guarantees. Where diffusion requires standardisation, pooled procurement, shared interfaces and data-based benchmarking, the delivery layer can become a bottleneck. Without portability, modularity, multi-provider access and auditability, ecosystem coordination can morph into lock-in or de facto gatekeeping even if the intent is pro-competitive. This is the practical reason the thesis hard-wires contestability-by-design as a gating condition.

The gap is therefore structural: Europe has many tools and increasingly ambitious objectives, but it lacks an integrated logic that simultaneously disciplines selection, disciplines delivery, and makes exit routine rather than exceptional.

Read as a contribution claim, the thesis's novelty is therefore not "Europe should do industrial policy". It is the specification of the missing operating system: a minimal set of non-negotiables

[289] European Court of Auditors, "Special Report on the EU's semiconductor strategy / Chips Act implementation" (2025)

that make prioritisation auditable, delivery contestable, and exit procedurally normal. A synthetic mapping of how the main EU proposal families align with, or fall short of, these discipline requirements is reported in Appendix A (Table A5.1-1) to keep the main text focused while preserving the full audit trail.

6.1.5. The thesis's contribution: a three-level, disciplined system (Macro-SPSM-BESNI)

The chapter's contribution is an integrated framework with three tightly linked components.

At the Macro level, the framework specifies enabling conditions that expand the feasible set for diffusion and scale-up: deeper market integration where fixed costs matter (services, capital, skills), predictable permitting and procedural timelines for investment, coherent digital interoperability baselines, and energy market design that reduces volatility and supports a rational investment horizon. The point is not to "solve everything" at Macro level; it is to identify which conditions must be in place so that selective instruments deliver productivity rather than rents

At the Meso level, the Strategic Positioning and Selection Matrix (SPSM) operationalises selectivity. It provides a replicable classification of ecosystems or value-chain segments along current economic contribution and future strategic potential, while enforcing a discipline filter (viability under a declining support path, and enforceable conditionality). The novelty is not the idea that prioritisation is needed; it is the insistence that prioritisation must be auditable, reviewable, and paired with default non-renewal.

At the Micro level, BESNI (Business Ecosystem for Sustainable Network Innovation) is introduced as the delivery operator that solves the conversion problem: turning strategic priorities into measurable diffusion throughput and adoption capacity across the long tail of firms. BESNI is managerialised as a single operational interface to reduce fragmentation of delivery, but it is constrained by contestability-by-design to prevent gatekeeping. Coordination is restricted to pre-competitive objects (problem statements, minimal reference architectures, test suites, interoperability KPIs), while procurement scale is captured through multi-award, portability, modularity, and switching rights.

Together, these elements form a closed system: Macro reforms raise the returns to upgrading; SPSM prevents dispersion and enforces discipline; BESNI converts selectivity into adoption and capability accumulation while preserving competition. The rest of Chapter 5 develops each component and then stress-tests the framework on complex ecosystems to demonstrate how the decision logic constrains choices under real-world uncertainty, while remaining auditable and reversible by design.

6.2. The three-level intervention architecture and binding mechanisms

The selective framework is organised as a three-level intervention architecture designed to address the multi-layer constraints identified in the diagnostic chapters. The architecture is built on a simple premise: Europe's productivity problem cannot be corrected through a single lever, because the underlying mechanisms operate simultaneously at the level of market design and integration, ecosystem structure and resource reallocation, and firm capabilities and scaling. The framework therefore treats policy as an **integrated system**, not as a menu. Macro conditions shape the feasibility and returns to meso-level restructuring and micro-level capability building. Meso-level prioritisation prevents dispersion and aligns interventions with strategic potential. Micro-level upgrading ensures that selection translates into broad-based productivity gains rather than isolated frontier performance. The coherence of the framework rests on these binding mechanisms, which are made explicit in Section 5.3.4. It also clarifies that selection must be paired with contestable delivery mechanisms at ecosystem scale, so that priorities translate into measurable diffusion throughput rather than incremental firm-by-firm support.

Conceptually, the architecture treats industrial policy as a system of complementary layers: market design and integration condition returns to restructuring; restructuring conditions the effectiveness of diffusion; and diffusion determines whether selection translates into aggregate outcomes rather than enclave performance.[290]

6.2.1. Macro: Market Integration and Framework Conditions

The macro level establishes the enabling conditions under which selective interventions can generate aggregate productivity gains rather than rents. Its objective is to reduce the structural penalties associated with fragmentation by deepening effective market integration across services, capital, and skills, and by lowering the fixed costs that prevent firms from operating

[290] Rodrik (2004)

and scaling across borders. This involves completing the single market in areas where regulatory heterogeneity and administrative barriers remain economically consequential, including professional and business services, cross-border provision of digital services, and the functioning of capital markets that support scale-up finance. A related element concerns the mobility and allocation of capabilities, especially the portability of skills, certification, and professional qualifications, since diffusion relies on labour mobility as a carrier of practices and tacit know-how. A key implication of the single-market literature is that persistent fragmentation raises fixed costs of scaling, weakens contestability, and biases adoption towards already-capable firms, so macro integration is not 'background reform' but a determinant of micro returns[291].

Macro conditions also include regulatory and procedural framework reforms that determine the speed and predictability of investment. In practice, this implies reducing uncertainty created by divergent permitting regimes, shortening and harmonising approval processes for projects with cross-border relevance, and strengthening interoperability standards that allow firms to adopt technologies and data-driven processes without facing incompatible national regimes. These reforms are not "industrial policy" in a narrow, sectoral sense, but they are decisive for whether selective support becomes productive or merely compensatory.

A further macro precondition concerns digital interoperability and portability. When minimum data standards, API requirements, and enforceable data-migration rights are absent, diffusion instruments risk producing vendor lock-in and national siloing, which reduces cross-border scale and undermines contestability. By contrast, interoperable and portable digital rules raise the returns to adoption and allow both firms and specialised vendors to scale across the Union.

Energy market design is a third macro pillar, because input prices and volatility directly affect the investment horizon of industrial upgrading. A credible competitiveness framework must therefore treat energy not only as a decarbonisation constraint but as a cost and risk parameter shaping capital formation. The macro layer accordingly includes reforms that improve the stability, predictability, and competitiveness of industrial energy prices, while maintaining decarbonisation objectives. This can involve market design that supports long-term contracting and risk-sharing mechanisms, investments in interconnections and grid capacity, and a

[291] European Commission, "The Future of the European Competitiveness: A New Governance Framework for the Single Market" (2022)

technology-neutral approach to low-carbon baseload and flexibility options. In this context, nuclear generation and new modular technologies can be part of the policy discussion where they are feasible and socially legitimate, particularly as complements to renewables in systems that require stable baseload and grid stability. Equally, renewables can contribute to competitiveness only if integrated efficiently through permitting reform, grid expansion, storage and flexibility, and predictable investment frameworks. The key point is that macro energy design determines whether lower-level selective interventions operate in an environment where productivity-enhancing investment is rational.

6.2.2. Meso: Reallocation and Ecosystem Restructuring

The meso level is the strategic core of the framework because it determines where selective effort is concentrated and how restructuring is governed. Its central function is to support reallocation dynamics that are often weak in fragmented systems, by shifting capital, labour, and complementary capabilities away from structurally low-productivity ecosystems toward activities with higher strategic potential. This is not a call for indiscriminate sector picking, but for disciplined prioritisation in which policy explicitly recognises that resources are scarce and that dispersion across too many objectives undermines effectiveness.

At this level, the unit of action is the ecosystem or value-chain segment. Interventions can include restructuring measures that enable scale where scale is a condition for global competitiveness, such as coordination across fragmented production nodes, cross-border integration of supply chains, and consolidation dynamics when fragmentation prevents efficient investment. However, scale is treated as a means rather than an end. For this reason, contestability functions as a binding constraint. The meso layer must ensure that ecosystem restructuring does not harden into protected market power or persistent rent extraction. In operational terms, this implies that any push toward scale and consolidation is accompanied by design features that preserve competitive pressure, entry opportunities, and performance discipline.

This constraint extends to the institutional form of ecosystem-level delivery. If restructuring is paired with implementation mechanisms such as pooled procurement, shared benchmarking, or common capability infrastructures, their design must preserve entry, switching, and multi-provider competition. Otherwise, instruments intended to accelerate diffusion can become new bottlenecks that replicate the very fragmentation and rent dynamics the framework seeks to reduce.

Most importantly, meso-level prioritisation is governed by a transparent selection logic rather than discretionary bargaining. The framework therefore anchors ecosystem prioritisation in the application of the **Strategic Positioning and Selection Matrix (SPSM)**, which is developed in Section 6.3. SPSM translates the diagnostic propositions into a disciplined method for ranking ecosystems and matching the intensity and type of intervention to both current economic contribution and forward-looking strategic potential. This meso layer is thus where diagnosis becomes prioritisation, and where the framework moves from descriptive heterogeneity to structured decision-making.

6.2.3. Micro: Diffusion, Capabilities, and Scale-Up

The micro level is the conversion mechanism through which strategic priorities translate into economy-wide productivity gains. It addresses the dual bottleneck identified in P1 by targeting firm capabilities and the channels through which technologies and practices diffuse. The core emphasis is on the accumulation of **intangible capital** and complementary capabilities, including software and data systems, organisational know-how, managerial practices, workforce skills, and process redesign. These complements determine absorptive capacity and thus whether adoption produces productivity payoffs. Without such complements, technology uptake can be superficial, yielding limited efficiency gains and leaving dispersion intact.

Because diffusion frictions are networked, effective micro-level delivery cannot rely exclusively on isolated firm-by-firm measures. In practice, upgrading at scale often requires ecosystem-level mechanisms that jointly reduce adoption transaction costs, coordinate implementation standards, and aggregate learning through benchmarking, while remaining compatible with competition and portability. This delivery logic prepares the ground for the instrument developed later in the chapter, where network innovation is organised without sacrificing contestability.

Micro interventions also include targeted diffusion mechanisms designed to reach the long tail of laggard firms within ecosystems. The objective is not only adoption, but capability convergence within the ecosystem through demonstrable upgrading of processes and practices. An important additional function is to support transition out of persistent micro-scale local equilibrium where that equilibrium reflects structural constraints rather than efficient specialisation. For many firms, remaining micro is not a strategic choice but a consequence of fixed compliance costs, limited access to standards and certification, weak managerial capacity, and lack of network integration. Diffusion mechanisms can therefore serve a second-order objective: enabling viable firms to professionalise, integrate into larger supply networks, and expand beyond purely local markets when this increases productivity and resilience.

Finally, the micro level includes scale-up support for high-performing firms. This requires removing financial and regulatory barriers that prevent growth, facilitating access to patient capital, and reducing cross-border expansion frictions that keep firms below efficient scale. In the framework, scale-up is treated as a diffusion accelerator. Scalable firms propagate practices through supply chains, set standards, create thicker markets for skilled labour, and increase competitive pressure. This is why micro interventions are essential even when meso selection is correctly executed. Micro is where the productivity payoff is realised and where divergence can either be reduced through diffusion or intensified if only frontier firms benefit.

6.2.4. Cross-level Linkages

The architecture is coherent only if the cross-level linkages are explicit. The macro layer enables meso and micro effectiveness by reducing fragmentation rents and widening the feasible scale of firms and ecosystems. When markets for services, capital, skills, and energy are more integrated and predictable, the returns to scaling and upgrading rise, and selective interventions are less likely to be absorbed by administrative costs or price instability. In other words, macro reforms increase the productivity content of lower-level interventions.

The meso layer then prevents dispersion and ad hoc prioritisation by directing restructuring and support toward ecosystems where the social returns to diffusion, scaling, and capability building are highest. Through disciplined selection, meso-level governance ensures that micro instruments operate in a targeted manner, aligned with strategic priorities rather than distributed uniformly. This is crucial because diffusion policies that are spread thinly across all firms risk becoming generic subsidies, while targeted diffusion within priority ecosystems has a clearer pathway to aggregate impact.

A further linkage runs in the opposite direction: micro-level performance evidence should feed back into meso-level prioritisation. If diffusion throughput, adoption outcomes, and capability indicators do not improve within a defined review window, the implication is not incremental adjustment but reassessment of the ecosystem's classification and the appropriateness of continued support. This feedback channel prevents selectivity from hardening into entitlement and makes periodic review operational rather than rhetorical.

Micro interventions complete the loop by converting enabling conditions and strategic choices into measurable upgrading in absorptive capacity, diffusion outcomes, and scalable firm performance. These outcomes generate the aggregate productivity gains that validate meso-level prioritisation and reinforce the macro objective of restoring competitiveness. If micro interventions fail, the framework remains a set of intentions. If macro conditions are not improved, micro and meso measures risk low returns or rent capture. If meso prioritisation is absent, micro tools become diffuse and politically persistent. The framework is therefore a closed system: each level is necessary but insufficient in isolation, and their interaction provides the internal discipline required for selectivity to be both credible and productivity-enhancing.

6.3. SPSM: Strategic Positioning and Selection Matrix

The Strategic Positioning and Selection Matrix (SPSM) is the analytical core of the selective framework. SPSM operationalises a core lesson of modern industrial policy: selectivity is only defensible when it is anchored in an explicit classification logic and paired with enforceable discipline that limits capture and subsidy persistence[292]. Its function is to translate the thesis's diagnostic mechanisms into a disciplined process for prioritising industrial ecosystems under scarcity and uncertainty. The matrix is designed to address two recurring failures of industrial policy debates in Europe. The first is **categorical vagueness**, where "strategic sectors" are invoked without a replicable method for ranking priorities or specifying the conditions under which support should stop. The second is **ad hoc discretion**, where sector choices are effectively negotiated outcomes that are difficult to justify ex ante and even harder to terminate ex post. SPSM is intended to break this pattern by imposing a structured decision logic that is explicit about what is being classified, what indicators are used, how judgement enters, and how discipline is enforced through conditionality and exit rules.

SPSM should not be interpreted as a black box. It is a **framework for informed strategic judgement**. Its value lies precisely in making judgement **transparent and contestable**, rather

[292] Lerner (2009)

than pretending that a purely technocratic scoring exercise can mechanically determine industrial priorities. In practice, SPSM disciplines judgement by (i) requiring a stable unit of classification, (ii) restricting selection to a minimal and interpretable indicator set, (iii) separating inputs for classification from outcomes the policy aims to improve, and (iv) imposing a pre-quadrant discipline filter to prevent selectivity from degenerating into permanent transfers. The matrix is therefore both an analytical tool and a governance device.

SPSM also disciplines delivery, not only selection. Quadrant assignment is treated as an instruction set for implementation: it determines the intensity, governance burden, and default delivery mode of micro-level instruments, so that prioritisation does not remain an abstract ranking but becomes an auditable pathway from selection to measurable diffusion outcomes.

6.3.1. Object of Classification

SPSM classifies **sectoral ecosystems** or **value-chain segments**, not individual firms. This methodological choice follows directly from the thesis's diagnostic findings: productivity outcomes in Europe are shaped by network structure, interdependencies, and bottlenecks that are not reducible to the attributes of a single enterprise. Diffusion, scale-up, and reallocation operate through channels such as supplier relationships, standards, specialised labour pools, infrastructure constraints, and the presence or absence of anchoring actors who can transmit practices across networks. These features are properties of ecosystems, not of isolated firms.

Classifying ecosystems rather than firms also improves policy discipline. Firm-level selection tends to collapse into discretionary "champion" politics, while ecosystem-level classification allows policy to target structural constraints and externalities. For example, an advanced manufacturing segment may be constrained less by the performance of one lead firm than by shortages of certified suppliers, missing testing capacity, fragmented standards, or unreliable input prices. An ecosystem lens captures these constraints and makes it possible to design interventions that strengthen the environment for scaling and diffusion, rather than subsidising an incumbent's balance sheet.

This approach is particularly relevant given the thesis's emphasis on frontier-laggard divergence. Ecosystems contain heterogeneous firm types: frontier firms with high intangible intensity and export exposure coexist with laggard firms in the long tail that often lack complementary organisational capital. The ecosystem lens accommodates this heterogeneity while keeping the unit of classification stable. In practical terms, SPSM answers the question: **which ecosystems merit prioritised restructuring and capability-building effort**, conditional on discipline and exit rules, because they plausibly generate system-wide returns through diffusion, scale, and spillovers.

6.3.2. Axes and Indicators (replicable scoring)

SPSM positions each ecosystem along two axes, current economic contribution (Axis A) and future strategic potential (Axis B). Rather than constructing a maximal dashboard, the framework uses a replicable minimum set that is interpretable, difficult to game, and aligned with the mechanisms discussed in the thesis. Table 6-1 reports the indicator set used to operationalise both axes and the rationale for each component.

Axis A captures **present economic weight and systemic footprint**, while **Axis B** captures **forward-looking strategic potential** under the post-2019 regime. Two methodological rules apply. First, **TFP is excluded** from the selection axes because it is an outcome the framework seeks to improve, so using it as an input would create circular selection logic. Second, **contestability is enforced as a binding delivery constraint** rather than a scored indicator: prioritisation can justify intervention, but it cannot justify closed architectures, single-provider lock-in, or mechanisms that weaken entry and switching options.

Axis	Indicator	What it captures	Rationale / notes
Axis A: Current economic contribution	Value added contribution	Share in EU value added	Macro relevance and present "weight" of the ecosystem
	Employment contribution	Employment scale (direct; including linkages where feasible)	Systemic footprint and distributional relevance
	Export intensity / trade balance contribution	Role in external competitiveness and balance-of-payments relevance	Exposure to global demand and competitiveness channel
	Supply-chain criticality	Input centrality and propagation risk if disrupted	Network centrality and systemic importance
Axis B: Future strategic potential	Expected global demand growth	Positioning in expanding markets / durable tailwinds	Forward-looking growth opportunity
	Innovation and spillovers	R&D intensity; enabling technologies; spillovers	Potential to generate cross-ecosystem returns
	Relevance for green and digital transitions	Contribution to decarbonisation and digitalisation objectives	Strategic alignment with post-2019 regime constraints
	EU position in the value chain	Feasibility of upgrading; dependencies; bottlenecks in stages/inputs	Strategic dependency and realistic capability-building
Methodological constraint	TFP is not an Axis A indicator	TFP is treated as an outcome for evaluation and renewal, not a selection input	Avoids circularity: selection inputs separated from outcomes the policy aims to improve
Design constraint (not scored)	Contestability-by-design	Entry/switching options, interoperability/portability, avoidance of single-provider lock-in	Treated as a binding delivery condition; enforced through instrument design, not scoring.

Table 6-1 - SPSM axes and indicators (replicable minimum set)

6.3.3. Scoring protocol

Using the indicators in Table 6-1, SPSM applies a qualitative or semi-quantitative scoring protocol that classifies ecosystems as low, medium, or high on each axis. This format is deliberate. It recognises that some strategic variables are not meaningfully reducible to a single continuous metric, while also avoiding the vagueness of purely narrative prioritisation. The discipline of the protocol lies in **declared criteria** and the requirement to document the basis for each classification.

A defensible protocol has four elements:

- **First**, the scoring criteria for each indicator must be stated in advance, even if thresholds remain approximate. For example, “high export intensity” may be defined relative to sector peers or to EU averages, while “high supply-chain criticality” can be defined by input centrality within production networks or by the presence of downstream dependence that generates propagation risks.
- **Second**, the protocol requires **triangulation**. The rationale for assigning “high” strategic potential should not depend on a single proxy. If an ecosystem is classified as high on innovation and spillovers, the justification should be consistent across more than one source type, such as R&D intensity and observed enabling linkages to other sectors.
- **Third**, judgement must be explicitly recorded. SPSM does not pretend to eliminate discretion, but it forces discretion to be **auditable**. This feature matters under the shock regime, where political pressure to label activities “strategic” rises precisely when scarcity is binding.
- **Fourth**, scoring is subject to **periodic review** on a defined cadence. Ecosystems are not permanently “strategic champions” or “marginal”. Demand conditions, technological trajectories, geopolitical constraints, and EU capabilities change. Without review, selectivity becomes entitlement. Review also allows the framework to respond to learning, including lessons from earlier policy cycles in which projects were announced but not delivered.

To make review operational, SPSM should be accompanied by a short evidence pack for each ecosystem position, updated on a defined cadence. A practical default is annual light-touch monitoring of core indicators and milestones, combined with a deeper re-assignment review every 2 to 3 years, or earlier when shocks materially change feasibility. This prevents periodic review from becoming rhetorical and makes reclassification a normal governance routine.

6.3.4. Discipline filter (pre-quadrant assignment)

SPSM applies a discipline filter before quadrant assignment to ensure that selection does not become subsidy persistence. This is where the framework operationalises the governance lesson from the post-2019 shock regime: selectivity is credible only if it is paired with enforceable discipline.

Viability test: the relevant criterion is not "no support", but **viability under a declining support path** with credible milestones. This formulation matters because many strategically relevant ecosystems face transitional cost shocks, especially when input prices shift sharply, as highlighted in your discussion of energy-intensive industries under the post-2022 price regime. The viability test therefore asks whether an ecosystem has a plausible trajectory toward competitiveness once support declines, not whether it can survive immediately without any intervention. Milestones can include demonstrable improvements in productivity, delivery of investment plans, energy efficiency and decarbonisation benchmarks where relevant, and measurable capability upgrades.

Conditionality test: any intervention must be linkable to **clear, measurable, and enforceable KPIs**. Conditionality is not a rhetorical commitment; it is the mechanism that converts public support into capability accumulation and productivity payoffs. The conditionality test also forces instrument design to be realistic: if performance cannot be measured or enforced, support should not be granted under the SPSM logic.

Contestability and lock-in test: because many selective instruments operate through standards, procurement, and implementation interfaces, a third discipline test is required, support must be **structured** so that it **does not create a new bottleneck or entrench a single gatekeeper**. In practice, eligibility for support requires enforceable interoperability and portability provisions, modular architectures that **separate non-differentiating compliance layers from competitive layers**, and **procurement formats that preserve multi-provider rivalry**. If these safeguards cannot be credibly imposed, the risk of capture and policy persistence rises sharply and the ecosystem should not receive selective support under the SPSM logic.

Essentiality modifier: strategic essentiality, such as security of supply for critical inputs, can modulate instrument choice and urgency, but it **does not bypass** viability or conditionality. This constraint is essential to avoid turning "essentiality" into a political blank cheque. In practice, essentiality can justify redundancy, stockpiling, or risk-reduction measures, but the framework still requires milestones and exit conditions. Earlier discussion of supply vulnerabilities provides the motivation for this modifier, but the discipline filter prevents it from becoming a loophole.

6.3.5. Quadrants: objectives, instruments, conditionality, exit rules

A common rule applies across all quadrants: **support is periodically reviewed and includes a default sunset clause**, renewed only on evidence of performance. The emphasis on spillovers, cross-border relevance, and documented market failures is consistent with the logic already embedded in EU frameworks for large, transnational projects, where legitimacy hinges on positive externalities and verifiable commitments rather than open-ended support[293]. This rule is a governance anchor. It reduces the risk that quadrant assignment becomes an entitlement and ensures that the framework remains adaptive under changing conditions. More broadly, the productivity rationale for prioritisation relies on the idea that competition and selection pressures, when combined with capability upgrading, shape reallocation and aggregate performance, making the 'discipline filter' a structural component, not an administrative add-on.[294]

A second common rule concerns delivery. Quadrant assignment determines the default implementation mode, including whether ecosystem-level delivery mechanisms are activated to accelerate diffusion, pooled procurement, and network-enabled innovation. Where such mechanisms are used, they are subject to contestability-by-design requirements and are reviewed under the same sunset logic as any other support. This prepares the ground for the delivery instrument developed in Section 6.4.

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[293] European Commission, "Revised IPCEI Communication" (2022)
[294] Bloom et al. (2019)

Table 6-2 summarises the quadrant logic in terms of objectives, default instrument bundles, and the associated governance and exit rules.

Quadrant	Objective	Instrument bundle	Governance, KPIs, exit, delivery
A) Strategic Champions (High A, High B)	Global leadership; capability deepening.	Scale finance; strategic procurement; standard-setting; enabling infrastructure; risk-sharing.	Capture risk → performance conditionality + contestability + clawbacks. KPIs: delivery; upgrading; spillovers. Delivery: multi-provider/portability/anti-lock-in.
B) Rising Stars (Low A, High B)	Accelerate scale-up and upgrading.	Capability building; scaling support; fixed-cost reduction (growth/compliance); market integration.	Milestones (trajectory funding). KPIs: adoption; scale-up. Exit: sunset if no credible scaling path. Delivery: scale-through-adoption.
C) Legacy Anchors (High A, Low–Medium B)	Managed transition (not preservation).	Conditional modernisation; diversification; reskilling; transition energy measures tied to milestones.	Transition plan + phase-out. KPIs: efficiency; conversion; diversification. Delivery: transition-only; subordinate to phase-out.
D) Marginal Sectors (Low A, Low B)	Orderly reallocation.	No production subsidies; labour mobility; reskilling; asset conversion; adjustment support.	No productive support. KPIs: reallocation outcomes. Delivery: not activated.

Table 6-2 - SPSM quadrants - objectives, instruments, and governance logic

Strategic Champions (A) require the tightest anti-rent architecture because incumbents are strong and the political value of “champions” is high. In operational terms, conditionality should be milestone-based and enforceable, with clawbacks where public risk-sharing is not matched by verifiable social returns. KPI design should distinguish delivery (capex and implementation), capability upgrading (e.g., process quality and productivity improvements), and spillover commitments that justify EU-level legitimacy.

Rising Stars (B) are governed as trajectories rather than incumbents. The central test is scalability: whether adoption intensity and intangible investment translate into integration into export markets and advanced supply chains. Sunset is triggered when repeated reviews fail to identify a credible scaling path, even if individual projects are delivered.

Legacy Anchors (C) are treated as transition cases. Conditionality should be tied to a measurable transition plan with explicit phase-out logic, so that support cannot drift into preservation. KPI design should prioritise conversion milestones and efficiency improvements and should treat ecosystem-level delivery only as an accelerator of restructuring, not as a mechanism to extend incumbency.

Marginal Sectors (D) imply a categorical separation between adjustment support and productivity support. Policy can legitimately fund reallocation and social buffers, but not productive subsidies. Where indicators are used, they should track reallocation outcomes (placement, reskilling completion, asset conversion) under time-bounded programmes.

To illustrate how the SPSM logic translates into a concrete positioning outcome, Table 6-3 provides a worked classification of four representative ecosystems, reporting their Axis A and Axis B scores, the implied quadrant, and the concise rationale underpinning each assignment.

Ecosystem	Axis A Score	Axis B Score	Quadrant	Rationale
Semiconductors (Advanced Nodes)	High	High	A) Strategic Champions	High value-add, critical enabling function, high R&D and geopolitical value.
Batteries (Next-Gen Cells)	Medium (borderline)	High	B) Rising Stars	Currently small EU share, but high demand growth, geopolitical relevance, and enabling function for EVs.
Energy-Intensive Basic Materials	High	Low-Medium	C) Legacy Anchors	High employment and value-add, but facing structural cost pressures and lower future growth potential without transformation.
Low-Value-Add Textiles	Low	Low	D) Marginal Sectors	Low productivity, low innovation potential, and high competition from low-cost imports.

Table 6-3 - illustrative SPSM Classification of Selected Ecosystems

Ecosystem-level delivery mechanisms are not activated in this quadrant, consistent with the framework's commitment to reallocation rather than productivity support.

Having established the SPSM classification logic and its governance anchors, the next section specifies the delivery layer required to convert quadrant-specific support into diffusion throughput under contestability constraints.

6.4. BESNI: Business Ecosystem for Sustainable Network Innovation

The preceding sections established a selective framework in which strategic focus is disciplined at the Meso level through SPSM and enabled at the Macro level through deeper market integration and coherent framework conditions. The Micro level must then solve an operational problem: how to convert strategic prioritisation into measurable diffusion, capability accumulation, and scalable adoption across the long tail of firms, without reproducing familiar policy failures such as capture, lock-in, and persistence of support. This section introduces **BESNI**, defined here as a **Business Ecosystem for Sustainable Network Innovation**: a managed ecosystem operator that reduces non-value-adding adoption frictions, aggregates fragmented demand into scalable procurement, and builds a translational pipeline between research and deployment. The BESNI operator is designed around the ecosystem view that value creation and adoption often depend on complementary components, interfaces, and coordinated upgrading, so that diffusion is constrained less by the availability of a single technology than by system-level bottlenecks and capability gaps.[295] "Sustainable" is understood in a dual sense: **institutionally sustainable** (self-disciplined, non-entitlement, non-subsidy-dependent) and, where relevant, aligned with the green and digital transitions. "Network innovation" refers to the structured generation, validation, and diffusion of innovations through shared standards, data-driven benchmarking, and interoperable adoption pathways. Its credibility rests on a binding design condition: **contestability by design**. BESNI is managerialised as a "single operational interface" while remaining structurally open to entry, switching, and competitive pressure.

[295] Jacobides et al. (2018)

6.4.1. Unique and Stable Definition

BESNI is defined as a managed operator that provides a single operational interface for ecosystem upgrading. Organisationally, it is "one firm" in an operational and managerial sense: it has professional management, explicit accountability, and a revenue model tied to verified value creation rather than to entitlement. Functionally, it is not a loose coordination platform. It is a repeatable implementation mechanism deployed within an ecosystem or value-chain segment, performing three tightly linked roles: (i) a **capability commons** for diffusion of non-R&D intangibles, (ii) a **demand aggregation and procurement interface** that enables "scale-through-adoption," and (iii) a **data trust and translational innovation hub** that connects research actors to deployable solutions.

The "single interface" framing addresses a core implementation gap in diffusion policy: fragmented initiatives struggle to assign responsibility, measure throughput, and enforce discipline. A managed operator resolves this by consolidating delivery capacity and making diffusion auditable. However, managerial concentration also creates predictable risks: gatekeeping, lock-in, and rent extraction. For this reason, BESNI is defined not only by its functions but by the institutional constraints under which it must operate. **Contestability by design** is not an add-on; it is the condition that reconciles ecosystem-level coordination with competitive pressure, ensuring that network innovation increases rivalry on quality and execution rather than reducing competition.

BESNI fits within a European development logic without requiring public ownership. The EU-level role is enabling rather than proprietorial: it can support interoperability rules, portability standards, competition-safe data governance, and cross-border scaling conditions that lower the cost of operating and contesting BESNI-like operators. In addition, because BESNI exhibits scale effects but also risks gatekeeping, the EU can act as a market designer by setting a licensing regime that limits and segments the number of BESNI operators per ecosystem or value-chain segment, with fixed-term authorisations, periodic re-tendering, and explicit switching and handover protocols. This preserves economies of scale up to the point where they are productivity-enhancing, while preventing operator concentration from hardening into lock-in. Yet BESNI remains privately run and disciplined by performance verification, bounded surplus capture, and credible exit, and it operates not only as an adoption enabler but also as a translational innovation actor that sustains an applied pipeline between research and deployable solutions.

6.4.2. Target Profiles and Participation Logic

BESNI is designed primarily for **SMEs and mid-cap firms** that are not at the technological frontier but face binding constraints in adoption, implementation, and organisational upgrading. These firms typically underinvest in non-R&D intangibles such as software and data systems, advanced training, cybersecurity hygiene, process redesign, and managerial practices, not because returns are absent, but because adoption is costly, uncertain, and coordination-intensive. BESNI targets precisely these frictions. Frontier firms can participate, but the instrument is not designed to subsidise their R&D. Its rationale is ecosystem upgrading through diffusion and execution.

The participation logic is dynamic rather than static. **In early phases, participation is particularly attractive because the reduction in non-value-adding cost is large.** Standardised compliance processes, shared interoperability baselines, pooled procurement, and implementation playbooks can immediately reduce duplicated effort, vendor search costs, integration failures, and unit prices. Over time, these "standardisation dividends" diminish. Once baseline compliance and basic digital plumbing are in place, the marginal benefit of more standardisation declines. At that point, BESNI can remain valuable only if it shifts its centre of gravity toward **continuous upgrading and innovation throughput**, meaning the ability to define problems credibly, run pilots, scale solutions, and refresh practices as technology and regulation evolve. This temporal profile is not a weakness. It is an endogenous discipline mechanism: if BESNI does not innovate, members will observe diminishing returns and exit.

A second dynamic mechanism concerns data. **BESNI's output quality improves with membership scale, up to a governance threshold.** A larger membership base improves the representativeness of performance data, increases the robustness of benchmarking, and yields more credible problem statements for translational R&D. This creates a data network effect: the value of the shared learning infrastructure rises as more firms participate. The implication is not that unlimited scale is optimal. Beyond a certain point, governance costs, heterogeneity, and information exchange risks rise sharply. The correct response is modularisation: separating data domains and value-chain segments, and using minimum aggregation thresholds, time lags, and audit rules to prevent the data trust from becoming a channel of competitive coordination.

The strategic rationale for participation is also interpretable through game theory. The membership decision resembles a **coordination game with tipping points** rather than a pure prisoner's dilemma. When few firms participate, the benefits of pooled demand, shared standards, and credible benchmarking are limited, and the temptation to wait is large. When many participate, the ecosystem shifts to a higher-efficiency equilibrium where adoption becomes easier and vendor solutions become more scalable. Importantly, this is not a soft cooperative narrative. It is a competitive logic: if participation yields execution capability and lower unit costs, a firm that joins while others do not can gain advantage. Yet when many join, the equilibrium does not collapse into uniformity. If contestability is preserved, competition shifts from avoiding adoption to **competing on quality, customer value, and continuous improvement**, which is precisely the environment in which Schumpeterian dynamics are more likely: upgrading, reallocation, entry of specialised solution providers, and exit of persistently non-adaptive incumbents.

6.4.3. Addressed Barriers and Core Mechanisms

BESNI is built to overcome a specific set of market and coordination failures that produce diffusion stagnation.

First, **information frictions** are pervasive among non-frontier firms. Many firms face high costs in identifying relevant technologies, evaluating vendors, and understanding implementation requirements. BESNI reduces these costs by standardising problem definitions, maintaining vendor scorecards, and providing implementation playbooks. The value is not merely advisory. It is operational: it reduces error rates, failed deployments, and integration dead ends that discourage future adoption.

Second, diffusion is constrained by **coordination failures**. Adoption often requires complementary investments that a single firm cannot efficiently coordinate, such as common data standards, interoperable interfaces, or shared compliance modules. BESNI solves this by building a **capability commons**: a non-differentiating layer of shared standards, minimal reference architectures, and replicable implementation routines. This does not standardise competitive strategy. It standardises the plumbing that makes adoption feasible.

Third, there are **positive externalities**. Investments in training, data practices, and organisational redesign generate spillovers across supply chains and local labour markets. Left to private incentives alone, such investments are often underprovided, especially among smaller firms. BESNI partially internalises these externalities by providing shared infrastructure and by linking its own remuneration to verified improvements rather than to indefinite support.

Fourth, European ecosystems suffer from **fragmented demand**, particularly for specialised digital solutions. Many vendors cannot scale because demand is atomised, procurement is duplicated, and integration requirements differ across firms and jurisdictions. BESNI addresses this by aggregating demand into framework agreements and pooled procurement. This has a direct diffusion effect through lower unit prices and reduced transaction costs. It also has a structural effect: it can create a lead-market dynamic that allows specialised European vendors to scale through adoption rather than through subsidy.

A concrete example illustrates the mechanism. Consider a regulated ecosystem where firms must comply with sector-specific reporting and interface with public administration systems. Individually, SMEs may be unable to justify investing in a robust compliance-grade software platform that implements the relevant regulatory logic and integrates with public sector interfaces. Through BESNI, demand can be pooled around a shared "core compliance" module, with mandatory interoperability requirements and data portability. The vendor gains predictable scale, which justifies product maturity and support infrastructure. Member firms gain lower unit costs and higher implementation reliability. Critically, the design must avoid turning the vendor into a de facto monopolist. For this reason, pooled procurement must be implemented with contestability mechanisms such as multi-award frameworks, modular architectures, and periodic re-bidding.

Two boundaries are essential. **BESNI is not designed to subsidise operating costs or permanently cover fixed costs.** Its purpose is to catalyse additional capability accumulation and adoption execution. It also cannot be a mechanism for implicit cartelisation. The aggregation of demand and data must be strictly separated from any coordination on commercial strategy, pricing, customers, or capacity. This separation is enforced in governance design, discussed below.

6.4.4. Governance, Contestability, and Competition Safeguards

The central problem BESNI must solve is institutional: how to build a managed operator that produces scale and learning effects without becoming a gatekeeper. The answer is **contestability by design**, implemented across three distinct markets: among BESNI operators, among vendors, and for member firms.

Table 6-4 summarises the contestability safeguards across these three domains and the associated operational instruments.

Contestability domain	Safeguard objective	Operational instruments
Among BESNI operators	Contestable operator market (switching + renewal discipline)	Standard portability (open specs); contractual data export + handover protocol; fixed-term operating licences with re-tendering.
Among vendors	Prevent vendor lock-in (multi-award + re-bid)	Multi-award procurement + periodic re-bidding; mandatory interoperability & modular architecture; contractual data portability; vendor performance scorecards (delivery/quality/uptime).
For member firms	Prevent gatekeeping (verify value + credible exit)	Published value-verification routines (baseline + counterfactual); overhead caps and degressive fees; throughput KPIs; credible exit rights (data portability + contract termination).
Data trust governance	Limit misuse and anticompetitive leverage	Purpose limitation; access controls; audit trails; separation of roles (operator vs evaluator); antitrust compliance protocols; independent oversight.

Table 6-4 - Governance and contestability safeguards

(i) **Contestability among BESNI operators**. A European upgrading system should allow multiple BESNI-like operators to emerge within an industry or across segments of a value chain. Operator contestability does not imply unlimited entry. Because BESNI coordination benefits from minimum scale, but excessive concentration increases the risk of gatekeeping, the system should be organised around a bounded number of operating licences per ecosystem or segment. Licences should be awarded through competitive procedures, scoped to clearly defined segments, and time-bounded by default, so that renewal remains performance-conditioned and non-renewal is procedurally normal. Where the efficient scale would otherwise push toward a single operator, modularisation and shared interoperability baselines should be used to keep switching feasible and to prevent the operator layer from becoming a structural bottleneck. In practice, contestability requires **low switching costs** and renewal discipline: if an operator does not deliver, member firms must be able to exit without losing data, standards compatibility, or operational continuity. In practice, this is ensured through portability requirements and finite-term operating arrangements with performance-conditioned renewal (Table 6-4). Modularisation is also important: where governance becomes heavy, the operator can be decomposed into segment-level BESNI units with shared interoperability baselines, preserving contestability while retaining coordination benefits.

(ii) **Contestability among vendors**. Vendor contestability is the central safeguard against lock-in. BESNI should not award a single exclusive contract that becomes a permanent industry standard. Instead, procurement should rely on **multi-award frameworks** in which two or three vendors are qualified for the same functional scope, and member firms retain choice within the framework. This preserves scale economies through standardised contracting while maintaining rivalry. Contestability is reinforced through periodic re-bidding on a defined cadence and through open qualification based on passing an ecosystem test suite (Table 6-4). The key point is that scale leadership remains possible, but cannot harden into an unchallengeable bottleneck, because interoperability, portability, modularity, and performance discipline are enforced as binding conditions rather than discretionary best practices.

(iii) **Contestability for member firms**. Member firms must retain credible exit options. This requires transparent value verification and an overhead discipline mechanism, so that participation does not become a de facto tax with weak accountability. Operationally, this is implemented through published verification routines and auditable baselines, combined with overhead caps, throughput-oriented KPIs, and enforceable exit rights (Table 6-4). The purpose is to prevent a familiar failure mode: institutional persistence and administrative growth while measurable outcomes stagnate.

Finally, the data trust introduces a distinct risk: information exchange and antitrust exposure. The governance design must include strict firewalls: anonymisation thresholds, minimum aggregation levels, and time lags that prevent real-time intelligence. Sensitive variables such as prices, customers, capacity utilisation, and commercial strategy must be excluded. Access should be mediated through clean teams and independent audits. The benchmark system must be designed for capability upgrading, not for commercial coordination.

6.4.5. Standardised Sectoral R&D Pipeline

Structured collaboration with universities and applied research partners is consistent with the view that industrial upgrading benefits from institutionalised channels for applied experimentation and transfer, provided incentives remain performance-audited and the net benefit to participating firms dominates the operator's fee.[296]

In this design, BESNI is not merely a broker between firms and academia. It provides continuity of applied experimentation by hosting testbeds, maintaining evaluation protocols, and, where appropriate, developing pre-competitive reference components in-house or with partners, so that innovation throughput remains continuous rather than project-based.

A key upgrade in the BESNI concept is the explicit integration of universities and research institutes into an applied deployment pipeline. The purpose is not to replace private innovation. It is to reduce the gap between research outputs and scalable adoption by improving problem definition, test environments, and deployment pathways.

The mechanism depends on a precise standardisation rule: **standardise interfaces and evaluation, not technology.** BESNI standardises four objects.

[296] Mazzucato (2013)

Object	Definition	Purpose
Problem statements	Standardised definition of operational context, binding constraints, measurable targets, and required data scope.	Prevents vague projects and makes solutions evaluable and relevant; reduces the risk of vendor-led goal shifting toward proprietary lock-in.
Minimal reference architectures	Minimum requirements for data models, APIs, security baselines, auditability, and portability (not a prescribed technology stack).	Defines what any solution must comply with to be deployable within the ecosystem; standardises interfaces and evaluation, not technology.
Replicable test suites	Standardised tests for compliance, interoperability, portability, and minimum security and performance thresholds.	Provides a non-political basis for qualifying new vendors and research outputs; keeps entry open and contestable.
KPI taxonomy	Standardised metrics for diffusion, capability accumulation, operational performance, and innovation throughput.	Enables comparable measurement across projects and ecosystems; supports internal discipline and cross-ecosystem learning.

Table 6-5 - Standardization objects in the BESNI R&D pipeline

Table 6-5 summarises the four standardised objects and their function in the BESNI pipeline. The key principle is that standardisation is limited to interfaces, evaluation, and portability conditions, so that solutions remain contestable and do not crystallise into indirect lock-in.

With these four elements in place, BESNI can run a translational pipeline: benchmarking identifies a performance gap, which becomes a standardised challenge; universities and research institutes can propose solutions that are evaluated against the test suite; pilots are run in a controlled testbed; and solutions that succeed can be scaled through the procurement interface. IP remuneration is handled through royalties and licensing conditions. For enabling technologies that function as ecosystem infrastructure, non-exclusive licensing should be the default, paired with portability requirements that preserve contestability. This prevents the R&D channel from becoming an indirect lock-in mechanism.

6.4.6. KPI Set and Revenue Model (Firm-first Surplus)

Because BESNI is a managed operator, it requires a transparent KPI system and a revenue model that aligns incentives with ecosystem upgrading rather than with institutional persistence. The key discipline principle is **firm-first surplus**: member firms must retain the dominant share of value created, and BESNI's share must be bounded, capped, and degressive over time.

Table 6-6 summarises the KPI stack and the revenue logic that operationalise this principle. Two design rules are binding. First, verification must be explicit and auditable: baselines are defined ex ante and benefits are recognised only when measurable and independently verifiable. Second, revenue extraction must remain bounded: success fees and savings shares are capped, degressive, and subject to a no-double-counting rule, so that the same benefit cannot be monetised through multiple channels.

Component	Content	Design rules / notes
KPI layer: diffusion throughput	Time-to-pilot; time-to-scale; adoption rate; coverage of benchmarked processes/sites.	Measures delivery speed and breadth (guards against "institutional growth without outcomes").
KPI layer: capability accumulation	Training completion; process maturity milestones; interoperability compliance; data quality readiness.	Tracks whether adoption builds durable capabilities rather than one-off installations.
KPI layer: operational performance	Uptime/reliability; implementation lead times; incident rates; support responsiveness.	Used for vendor discipline and service-quality enforcement within multi-award frameworks.
KPI layer: productivity-linked outcomes	Quality-adjusted cost/productivity proxies relevant to the ecosystem (e.g., yield, scrap, energy intensity, cycle time).	Outcome-focused; should use auditable baselines and avoid attributing macro trends to the programme.
KPI layer: innovation throughput	Test-suite pass rates; number of qualified solutions; reuse across firms; replication at scale.	Ensures the pipeline produces replicable outputs and keeps entry open to new vendors.
Revenue stream 1: membership fee (baseline)	Low, capped participation fee linked to verified service delivery.	Capped and degressive; designed to cover coordination overhead without becoming a tax.
Revenue stream 2: performance-based service fees	Fees tied to measurable throughput and verified adoption services (e.g., onboarding, integration, training).	Paid only on verified delivery; degressive with scale; prevents rent extraction without outcomes.
Revenue stream 3: procurement savings share	Small share of verified procurement savings from pooled purchasing/standardised contracting.	Savings must be quality-adjusted and benchmarked; apply a no-double-counting rule with other fee streams.
Cross-cutting rules	Firm-first surplus principle; transparent verification routines; auditability.	No-double-counting across streams; fees degressive with scale; overhead caps; portability and exit rights remain binding.

Table 6-6 - BESNI KPI set and revenue model (firm-first surplus)

A critical implication of this revenue model is institutional. Transparent baselines, ex ante definitions, and bounded success fees reduce disputes, lower switching costs, and make entry and exit more fluid. In other words, the same rules that reduce disputes also strengthen contestability.

6.4.7. Explicit Linkage to SPSM and Macro Complementarities

BESNI is not a standalone mechanism. Its deployment is disciplined by the Meso level and enabled by the Macro level.

At the Meso level, SPSM determines where BESNI should be prioritised. Ecosystems classified as rising and strategically promising should receive early deployment because diffusion and vendor scaling have the highest strategic payoff there. Ecosystems classified as structurally important but with lower future potential should receive BESNI only when it supports a measurable transition, such as capability upgrading or diversification into adjacent activities. Ecosystems classified as marginal should not receive BESNI as a productive support mechanism, consistent with the framework's commitment to reallocation rather than preservation.

At the Macro level, BESNI requires a coherent environment to scale solutions beyond national boundaries. Interoperability rules, data governance principles, and a functioning single market for digital services and capital are not peripheral. They determine whether vendors can scale across borders, whether portability constraints are enforceable, and whether adoption remains trapped in national silos. In this sense, Macro reforms are not competing with Micro instruments. They are preconditions that increase the returns to Micro-level diffusion mechanisms.

The EU also has a role in enabling the emergence of BESNI-like operators without forcing a specific institutional blueprint. A European upgrading mechanism can support standard templates for interoperability and portability, competition-safe guidance for data trusts, certification schemes for test suites, and cross-border regulatory simplification that reduces the cost of scaling both operators and vendors. This is enabling infrastructure, not public ownership.

As an illustrative example of a complementary incentive that does not alter BESNI's internal incentives, an EU-level **Royalty Buydown Facility** could progressively cover part of university royalty payments for SMEs and early adopters of validated solutions that meet the ecosystem reference architecture and test suite. This reduces adoption costs and increases the expected returns to applied research, without routing public funds through BESNI or making BESNI dependent on subsidies. It is best understood as a macro-complement that lowers a specific friction, not as a structural component of the BESNI mechanism.

In sum, BESNI provides the operational micro-foundation required for selective industrial upgrading: it captures early gains from standardisation and procurement while forcing a long-run shift toward continuous innovation and diffusion throughput. Its institutional viability depends on contestability, transparent value verification, and a firm-first surplus rule that prevents the operator from becoming the next protected layer in Europe's already crowded governance landscape.

6.5. Sequencing and Feasibility Constraints

The selective framework is intentionally not designed for simultaneous rollout across all levels and instruments. Its internal logic implies a sequencing problem: the expected returns to meso-level prioritisation and micro-level delivery depend on whether macro conditions make scale, diffusion, and contestability feasible. Under fragmentation and the post-2019 shock regime, attempting to implement the full framework at once would raise administrative complexity, increase the scope for capture, and dilute enforcement capacity. A realistic implementation path therefore treats sequencing as a discipline device. It stages reforms so that early moves tighten the governance envelope, reduce fixed adoption frictions, and create the baseline conditions under which selective delivery mechanisms can operate without becoming new bottlenecks.

Two principles guide the sequencing. First, early actions should be high leverage and horizontally enabling: they should lower barriers to cross-border scaling, reduce uncertainty in investment and permitting, and impose minimum interoperability and portability conditions that preserve contestability. Second, selective delivery should expand only through a monitored pipeline. SPSM should first be institutionalised as a repeatable classification routine with auditable rationale, and ecosystem-level delivery mechanisms such as BESNI should then be activated only where quadrant logic justifies them and where their design passes the discipline filter, including the contestability and lock-in safeguards introduced in Section 6.4.

6.5.1. Sequencing Logic (Short/Medium/Long Term)

Sequencing is treated as a design constraint because reforms that expand the feasible set, including market integration, permitting predictability, and energy risk, condition the returns to selective instruments. Without macro gating conditions, meso selection and micro diffusion risk becoming compensatory rather than productivity enhancing. Tables 6-7 to 6-9 summarise the sequencing roadmap across the framework's layers and make the gating checkpoints explicit.

In the short term, the objective is to lock in enabling conditions and discipline before large scale selectivity begins. Priority should go to reforms that cut non value adding fixed costs for scale and diffusion, notably targeted single market completion in cross border services and patient scale finance, and permitting reforms that reduce uncertainty and shorten approval timelines for cross border relevant investment.

Layer	Objective	Minimal deliverable	Gating checkpoint
Macro (market-making)	Create binding enabling conditions; reduce non-value-adding fixed costs; hard-wire discipline before scale-up.	Targeted single market completion (cross-border services; scale finance); permitting predictability reforms.	No large-scale selectivity without enabling reforms that reduce administrative friction and uncertainty.
Cross-cutting digital baselines	Make interoperability and portability non-negotiable to prevent interface gatekeeping.	Data export rights; minimum API/documentation requirements; modular reference architectures.	Ecosystem-level delivery prohibited unless portability/interoperability baselines are enforceable.
SPSM (governance routine)	Prepare a replicable selection routine.	Publish scoring protocol and evidence-pack template; define cadence and default sunset clause.	No classification without declared criteria and audit trail requirements.
BESNI (pilot)	Test delivery mechanisms in a limited number of ecosystems.	Pilot BESNI-style delivery with minimal reference architectures and test-suite requirements; set multi-award procurement rules.	No expansion without credible exit rights and verifiable throughput metrics (time-to-pilot; adoption coverage).

Table 6-7 - Sequencing roadmap: Short term (0-24 months)

In the medium term, the objective shifts to a disciplined selection-to-delivery pipeline. SPSM should become a repeatable routine with a defined cadence, compact ecosystem evidence packs, and shock-triggered early review, so that reassignment and exit become normal governance events rather than political crises. Delivery mechanisms should then be activated only in a limited number of ecosystems where expected diffusion returns are high, with success judged by throughput rather than coverage and with contestability treated as binding.

Layer	Objective	Minimal deliverable	Gating checkpoint
Macro (market-making)	Shift from enabling conditions to removing scaling frictions.	Strengthen cross-border diffusion channels; capital-market and scale-up enablers; competition enforcement for ecosystem operators.	Do not expand delivery mechanisms where contestability safeguards cannot be credibly enforced.
SPSM (institutionalise)	Normalise re-assignment and exit as routine governance.	Annual monitoring of core axis indicators; deep reassignment every 2–3 years; shock-triggered early review.	Non-renewal by default unless evidence thresholds are met.
BESNI (throughput focus)	Prioritise throughput over coverage.	Benchmark → challenge → pilot → scale pipeline; measurable reduction in adoption frictions; increased non-R&D intangible accumulation.	Lock-in prevention is binding: multi-award, switching rights, enforceable portability, auditable performance metrics.
Research translation (optional add-on)	Reduce invention-to-deployment gap without direct transfers.	EU royalty buydown facility for validated university solutions; licensing-cost reduction with preserved royalty income.	Only for solutions that pass test suites and deliver verified adoption/impact benchmarks.

Table 6-8 - Sequencing roadmap: Medium term (2-5 years)

The medium term is also the appropriate stage to integrate research translation more explicitly, because ecosystem delivery mechanisms can reduce the gap between invention and deployment. A concrete example is an EU royalty buydown facility that temporarily reduces licensing costs for validated university-developed solutions, lowering adoption costs for firms while preserving royalty income for research actors. In this configuration, BESNI does not require direct budgetary transfers; it acts as the deployment and verification layer that benchmarks impact, improves pilot-to-scale conversion, and ensures that diffusion is not confined to frontier firms.

In the long term, the objective moves to structural endgames that require time, capital, and political coordination: energy infrastructure integration, deeper capital-market integration, and selective consolidation where fragmentation blocks efficient scale, provided contestability safeguards remain credible. The framework should converge toward a portfolio logic: intensive, performance-conditioned delivery support for a small set of genuinely strategic ecosystems, phase-out discipline for legacy anchors, and reallocation/adjustment policies for marginal sectors.

Layer	Objective	Minimal deliverable	Gating checkpoint
Macro (structural endgames)	Stabilise cost/risk environment for industrial investment.	Energy infrastructure integration (interconnections; grid capacity); deeper capital-market integration; selective consolidation where warranted.	Consolidation only where contestability safeguards remain credible.
SPSM (portfolio routine)	Maintain a standing prioritisation system under changing conditions.	Stable criteria with updated indicators as frontier shifts; transparent reporting; continued auditability.	Reclassify under shocks; treat persistent underperformance as a trigger for exit and reallocation.
BESNI (mature operator market)	Move from pilots to a contestable operator market.	Multiple qualified operators; open entry via test suites; focus on innovation throughput once standardisation dividends decline.	Sunset/rotate support as ecosystems move quadrants; prevent institutional persistence without outcomes.
Portfolio logic (allocation)	Concentrate intensive support where genuinely strategic.	Intensive, performance-conditioned delivery for few strategic ecosystems; transition pathways with phase-out for legacy anchors; reallocation/adjustment for marginal sectors.	No continued productive support for marginal sectors; explicit phase-out discipline for legacy anchors.

Table 6-9 - Sequencing roadmap: Long term (5+ years)

6.5.2. Feasibility Constraints

A sequencing logic is only credible if it acknowledges constraints that are structural rather than managerial. The first constraint is heterogeneous state capacity across member states and the associated presence of political veto points. Even when objectives are shared, administrative capability to execute complex permitting reform, to enforce portability standards, or to monitor KPI-based conditionality varies widely. This implies that the framework must privilege reforms that can be implemented at EU level where possible, and otherwise allow coalitions of the willing to move first without requiring immediate uniform adoption. In practice, this means designing interoperability baselines and evidence pack templates that are modular and extensible, so that early movers can generate proof of concept and reduce uncertainty for later adopters.

A second constraint concerns legal and political compatibility with competition policy and state aid rules. Ecosystem-level delivery mechanisms, especially those involving pooled procurement, shared standards, and implementation interfaces, can generate efficiency gains but also create suspicion of cartelisation or de facto gatekeeping. The feasibility condition is therefore design discipline. Delivery mechanisms must be visibly competition-safe, which requires non-exclusive procurement formats, multi-provider access, switching rights, portability guarantees, and auditable pricing and performance metrics. Where these safeguards cannot be credibly imposed or enforced, the framework should treat activation as infeasible, even if an ecosystem scores highly on strategic potential. This is a core implication of the revised discipline filter: feasibility is not only economic, but also institutional and legal.

A third constraint is measurement and enforceability. The framework's primary outcomes, notably TFP growth, adjust slowly and are subject to noise. This creates a governance risk: political pressure to declare success or to continue support can outpace the availability of clean outcome measures. The feasibility response is to bind delivery to intermediate indicators that are harder to manipulate and easier to audit, such as adoption and diffusion throughput, non-R&D intangible investment proxies, training coverage, pilot-to-scale conversion, and compliance with portability and interoperability requirements. The framework should treat these indicators not as replacements for outcomes, but as the mechanism that makes conditionality enforceable before aggregate measures converge.

A fourth constraint is energy and input-price uncertainty. Even a disciplined selective framework can deliver low returns if the investment environment is dominated by volatility and persistent cost disadvantages. This makes macro energy market design a feasibility lever, not a background variable. The revised framework therefore implies a pragmatic stance: selective support should not compensate indefinitely for structural input-price disadvantages. Instead, energy design reforms that improve stability and predictability are needed to make capability investments rational, while ecosystem-level support in energy-intensive activities must remain conditional on measurable transition pathways and credible phase-out discipline.

Finally, there is an endogenous feasibility risk: delivery mechanisms themselves can become the new low-productivity layer if they grow bureaucratic, become politically protected, or drift into rent extraction. This risk is structurally addressed by the revised framework through contestability-by-design requirements and by embedding exit discipline not only for supported ecosystems, but also for the delivery operators and interfaces used to implement support. Feasibility, under this interpretation, is not a one-time assessment. It is maintained through periodic review, re-tendering, and the credible possibility of organisational restructuring when contestability deteriorates or when performance milestones are not met. A disciplined pilot logic follows the ‘learning’ rationale of industrial policy: start with limited scope, measurable milestones, and an explicit option value of termination, scaling only what survives evaluation.[297]

6.6. Critical Appraisal, Trade-offs, and Failure Modes

This section functions as an internal stress-test of the selective framework. A critical appraisal is not ancillary: the innovation-policy literature documents recurring failure modes, capture, persistence, and weak evaluation, so a credible selective framework must specify non-negotiables that survive political stress.[298] The aim is not to dilute the proposal into a balanced but ambiguous compromise. It is to identify the binding constraints and operational non-negotiables that preserve discipline under political pressure and under the post-2019 shock regime. A selective system fails less often because its diagnosis is wrong than because its delivery mechanisms become capturable, inertial, or structurally incompatible with competition and exit. The appraisal therefore focuses on the points where the framework is most vulnerable:

[297] Lerner (2009)
[298] OECD, “Beyond Industrial Policy: Emerging Issues and New Trends” (2013)

the tension between scale and contestability, the governance depth required for credibility, the antitrust boundary of ecosystem coordination, the political economics of reallocation, and the divergence risk if diffusion throughput does not materialise.

6.6.1. Structural Trade-offs in a Selective Framework

This section stress-tests the framework against the trade-offs that most often turn selectivity into capture, lock-in, or compensation. The aim is to surface the binding constraints that keep support productivity enhancing under EU fragmentation and heterogeneous state capacity. Table 6-10 summarizes these trade-offs and the embedded design levers; the paragraphs below clarify the economic logic and the specific governance risks.

Trade-off / risk	Failure mechanism	Binding implication	Embedded levers
Scale vs contestability	Scale concentrates interface and procurement control, enabling gatekeeping and lock-in.	Scale admissible only with contestability-by-design.	Multi-award; portability; modularity; re-tendering; audited fees/KPIs.
Speed vs governance depth	Fast rollout increases capture and irreversible vendor choices.	Sequence first, then scale under gating checkpoints.	Declared criteria; evidence packs; review cadence; pilot-first BESNI.
Coordination vs antitrust	Coordination drifts into cartel behaviour or proprietary standards.	Coordinate only on pre-competitive objects; exclude price/output coordination.	Problem statements; reference architectures; test suites; interoperability rules.
Exit vs political legitimacy	Reallocation triggers resistance; adjustment becomes disguised subsidy.	Separate productivity support from adjustment support.	Default non-renewal; phase-out; reskilling/mobility tools.
Frontier gains vs divergence	Frontier accelerates while long tail stagnates; dispersion rises.	Micro-level must maximise diffusion throughput.	Adoption KPIs; organisational upgrading; diffusion carriers; portability.

Table 6-10 - Structural trade-offs and binding design levers

Scale versus Contestability

The framework requires scale for three reasons. First, diffusion often needs carriers: institutions and organisational forms that can replicate practices across networks rather than across isolated firms. Second, adoption entails fixed costs, especially for non-R&D intangibles such as compliance tooling, data integration, and organisational redesign, so aggregating demand through ecosystem mechanisms can reduce unit costs and accelerate uptake. Third, BESNI's benchmarking and diagnostic value increases with participation, because larger samples improve data quality and the informativeness of benchmarks.

Scale, however, creates predictable failure modes: a delivery operator can become a gatekeeper, procurement scale can drift into single vendor dominance, and benchmarking can harden into mandatory dependence.

Binding implication: scale is admissible only under contestability by design, operationalised through multi award discipline, portability, modularity, auditability, and periodic re tendering.

Speed of delivery versus governance depth

The post 2019 regime rewards speed because shocks create binding constraints quickly, and slow responses can leave ecosystems stranded in high cost equilibria when energy prices, supply disruptions, or geopolitical constraints shift relative prices. Yet speed also increases the probability of capture and lock in. Rapid rollout tends to privilege organised incumbents and vendors that can deploy immediately, and it weakens the ability to impose enforceable conditionality ex ante.

Binding implication: implementation must be sequenced and pipeline based, so that SPSM routines, auditability, and contestability constraints are in force before delivery mechanisms scale.

Ecosystem-level coordination versus antitrust and state-aid compatibility

Ecosystem coordination can be economically valuable. Joint procurement can reduce nonvalue adding costs and standardize compliance burdens, while precompetitive standardization can lower integration and litigation costs and accelerate diffusion where interoperability is binding. Coordination can also improve the feasibility of structured university collaboration by aggregating problem statements, datasets, and test environments for applied research.

At the same time, coordination sits close to antitrust boundaries. It becomes problematic if it extends to output pricing, capacity decisions, market allocation, exclusionary conduct, or if standardization hardens into proprietary interfaces and non-portable data that control access to customers and compliance pathways.

Binding implication: coordination is permitted only on precompetitive and contestable objects, and **explicitly excludes coordination on prices, capacity, market shares, or market allocation**. The EU Royalty Buydown Facility fits this principle because it reduces adoption costs of university origin IP without channeling funds to BESNI or granting privileged control over access to subsidised IP.

Targeted reallocation versus political legitimacy

Selective frameworks are not only technical devices. They impose distributional consequences, and the SPSM logic implies that some ecosystems should not receive productivity support and should instead undergo managed reallocation. This creates political resistance in regions and sectors with high employment concentration, where local institutions depend on incumbents, or where fragmentation rents are embedded in regulation. The credibility risk is predictable: either exit rules are not enforced, or adjustment support becomes a disguised continuation of production support.

Binding implication: the framework must separate productivity support from adjustment support through explicit institutional boundaries, with time bounded reallocation tools and default non-renewal for productive support.

Frontier acceleration versus divergence risk

Selectivity can increase divergence if diffusion throughput fails. Supporting strategic champions and rising stars can raise the frontier while leaving the long tail unchanged, producing higher dispersion, especially if delivery mechanisms prioritise visible success stories and neglect the organisational constraints that prevent laggard upgrading.

Binding implication: BESNI's micro level design must prioritise long tail upgrading, using diffusion throughput and capability accumulation as primary KPI families, and ensuring scale mechanisms remain compatible with switching, modularity, and multi award discipline

6.6.2. Distinct failure modes and how the framework anticipates them

This section identifies the recurrent failure modes that tend to undermine selective industrial policy under shocks and heterogeneous administrative capacity. The purpose is not to claim error free design, but to hard wire error correction and credible exit. Table 6-11 summarises the main

Failure mode	Failure mechanism	Binding implication	Embedded levers
Capture and persistence	Shock rhetoric expands "strategic" labels; exit erodes.	Non-renewal by default; enforceable conditionality.	Discipline filter; clawbacks; review cadence; audit trail.
Operator/vendor bottlenecks	BESNI or vendors become mandatory intermediaries; lock-in.	Exit must apply to operators and vendors; contestability as gating.	Re-tendering; switching rights; interoperability/portability; modularity.
Misclassification and inertia	Outdated assumptions persist; downgrade becomes politically costly.	Design for error correction, not error elimination.	Evidence packs; declared criteria; periodic reassignment; shock triggers.
State capacity mismatch	Weak monitoring/enforcement creates two-speed governance.	Use replicable templates and pilots to build capacity.	EU templates; modular compliance; pilots; coalitions-of-the-willing.
Compensation loop (macro dominates)	Energy/input shocks make upgrading irrational; aid becomes compensation.	Macro gating + phase-out discipline.	Market integration; permitting predictability; phase-out for legacy anchors.
Under-participation and weak data quality	Firms free-ride or withhold sensitive data; benchmarking loses value; participation stalls.	Participation must be rational and confidentiality protected.	Audited fee formulas tied to savings; non-exclusivity and switching rights; early demonstrators; confidentiality-by-design (anonymisation, aggregation thresholds, access controls, audit trails).

Table 6-11 - Core failure modes and embedded mitigations

The mitigation is not coercion. It is design that makes participation rational and credible: transparent fee formulas tied to audited savings, non-exclusivity and switching rights that reduce perceived lock-in risk, and demonstrable early wins that shift expectations. Confidentiality-by-design is also necessary because firms will not contribute meaningful data if it exposes commercially sensitive information. Data governance must protect secrets while still enabling benchmarking, which requires clear rules on anonymisation, aggregation thresholds, access rights, and auditability.

6.6.3. A discipline checklist: operational non-negotiables

A selective framework remains credible only if it can say “no” in operational terms. The following checklist expresses the non-negotiables as gating questions.

- **Viability:** Is competitiveness plausible under a declining support path, or does the activity require persistent transfers to survive?
- **Enforceability:** Are KPIs measurable, auditable, and linked to consequences, including clawbacks and default non-renewal?
- **Contestability:** Are switching rights real, with data portability, modularity, and multi-provider or multi-award procurement structures?
- **Fee alignment:** Are BESNI fees capsated, progressive or declining as the ecosystem matures, and calculated on verified savings or verified performance improvements, with net benefits to firms dominant by design?
- **Competition-safety:** Is coordination strictly limited to pre-competitive objects (problem statements, minimal architectures, test suites, KPI definitions), with explicit exclusion of output pricing, capacity, and market allocation?
- **Review cadence:** Is there an explicit review schedule, with reclassification paths and shock triggers?
- **Credible exit:** Is exit politically and administratively credible, including the ability to close or restructure delivery operators, not only to end sector support?
- **Macro feasibility:** Are enabling conditions plausible (energy, capital markets, permitting, digital standards), or is the design drifting into compensation?
- **Data governance:** Are confidentiality, access rights, benchmarking protocols, and portability rules specified in a way that sustains participation without creating information rents?

6.6.4. Boundary conditions and scope limits

The framework does not eliminate deep political conflict over distribution, geography, and industrial identity. It does not substitute for EU integration where national vetoes persist, particularly in capital markets, services, or energy governance. It cannot guarantee growth under a collapse of global demand, nor can it fully neutralise a structural energy disadvantage if it persists. These limits do not invalidate the framework. They define its domain of applicability and protect it from drifting into compensatory policy. The framework is designed to improve the quality of selective choices and the discipline of delivery under realistic constraints, not to promise outcomes independent of macro and geopolitical realities.

Having identified the binding trade-offs, failure modes, and non-negotiables that preserve selectivity under pressure, the next sections formalise how governance and evaluation operationalise these constraints (Section 6.7) and apply the stress-test logic to concrete ecosystem cases to illustrate how selection and delivery behave under real-world conditions (Section 6.8).

6.7. Governance, Accountability, and Evaluation Architecture

A selective framework is only as credible as its governance. In the European context, the core problem is not the absence of instruments, but the predictable drift from selectivity to entitlement once political pressure, shock rhetoric, and incumbent bargaining enter the system. Section 6.7 therefore specifies the institutional design required to keep the framework **disciplined**, **contestable**, and **auditable** across cycles. Governance here is treated as an economic mechanism: it determines whether SPSM remains a classification routine rather than a negotiating table, and whether BESNI remains a performance operator rather than a bottleneck or a protected intermediary.

6.7.1. Design principles and decision rights

The governance architecture rests on four non-negotiables. First, **separation of roles**: classification (SPSM), instrument allocation, delivery (BESNI and market actors), and evaluation cannot sit in the same hands without creating capture and self-validation loops. Second, **traceability**: every classification and renewal decision must be backed by a documented rationale and a minimal evidence pack, so that discretion is not eliminated but is made auditable. Third, **default non-renewal**: continuation requires affirmative evidence, not political inertia. Fourth, **credible exit**: the system must be able to terminate support not only for ecosystems, but also for delivery operators and vendors if contestability and performance conditions degrade. The governance architecture follows a simple principle: credibility requires separating strategic classification, delivery, and independent evaluation, because concentrating these functions increases discretion and weakens the enforceability of exit.[299]

Operationally, this implies a clear assignment of decision rights. SPSM classification and quadrant assignment belong to an independent function with a narrow mandate: maintain a replicable routine, enforce the discipline filter, and publish decisions and rationales in a standard format. Operating licences for BESNI operators should be administered through competitive EU-level procedures under a bounded, segment-scoped regime, with a limited number of authorisations per ecosystem or value-chain segment. Licences should be fixed-term by default, with performance-conditioned renewal and mandatory handover protocols, so that non-renewal becomes a normal procedural outcome rather than a politically exceptional event. Instrument implementation can be decentralised, but only within gating conditions defined centrally (contestability, portability, KPI enforceability). Evaluation must be structurally independent from both classification and delivery.

6.7.2. SPSM governance as a routine, not a bargaining arena

SPSM requires institutionalisation as a repeating cycle. Each cycle produces an **ecosystem evidence pack** containing: (i) Axis A and Axis B indicator values and sources, (ii) the recorded judgement for low, medium, high classification on each axis, (iii) application of the discipline filter (viability and conditionality feasibility), and (iv) the implied policy posture by quadrant, including explicit exit logic. The objective is not technocratic precision but disciplined transparency: the same template forces comparability across ecosystems and reduces the scope for narrative-driven exceptions.

Two procedural constraints keep SPSM from becoming inert or captured. The first is a fixed **review cadence** (for example, annual light-touch updates and a deeper reassessment every two to three years) combined with predefined **shock triggers** that mandate reclassification when conditions change materially (input price regime shifts, demand

[299] Juhász et al. (2024)

collapses, major technology discontinuities, or repeated delivery failure). The second is methodological separation between **selection inputs** and **evaluation outcomes**: outcomes such as TFP improvement are used to assess effectiveness and renewal, not to justify initial selection, avoiding circularity and "rewarding" ecosystems only because they are already high-performing.

6.7.3. BESNI as an ecosystem operator with contestability-by-design

In this framework BESNI is a delivery operator, structured as a managed ecosystem firm, not a public fund. Its legitimacy rests on two properties: **performance linkage** and **contestability**. Performance linkage is achieved through a success-fee or revenue-sharing model tied to **verified savings and verified operational improvements**, with a hard constraint that net benefits remain structurally higher for participating firms than for BESNI. Contestability requires that BESNI cannot become a gatekeeper through proprietary standards, non-portable data, or exclusive procurement channels.

Three design rules operationalise this. First, BESNI coordination is limited to **pre-competitive standardisation**: problem statements, minimal reference architectures, interoperability requirements, test suites, and performance KPIs, explicitly excluding output prices, capacity, and market allocation. Second, procurement scale must be implemented through **multi-award frameworks**, switching rights, and portability clauses, so aggregated demand does not collapse into single-vendor dependency. Third, BESNI itself must be contestable: entry of competing BESNI operators must be feasible, and a failing operator must be replaceable through re-tendering of core services, governance reset, split, or closure. In practice, this implies a bounded licensing regime: entry is enabled but not unlimited, with a limited number of segment-scoped operating licences awarded by tender, time-bounded by default, and subject to periodic re-tendering to preserve scale benefits without allowing operator concentration to harden into gatekeeping. Exit management becomes politically feasible when it is proceduralised ex ante (default non-renewal, milestone-based continuation) and backed by transparent evaluation outputs rather than discretionary renegotiation.[300]

[300] Lerner (2009)

This is also where EU-level enabling policy fits without turning BESNI into a quasi-public monopoly. The EU role is to define baseline interoperability and data-governance rules that make switching feasible, and to remove adoption frictions that are operator-neutral.

6.7.4. Measurement architecture and independent evaluation

Evaluation must be treated as a core control system rather than a reporting add-on. The framework therefore uses a two-layer KPI stack: **ecosystem-level outcomes** and **delivery-throughput indicators**. Outcomes remain anchored in **TFP growth** as the primary metric and labour productivity as a complementary metric for robustness and interpretability, consistent with Section 6.1. Delivery-throughput indicators are required because outcome metrics move slowly and can be confounded by shocks; they measure whether the mechanism is functioning in real time. For BESNI, throughput KPIs should include diffusion coverage within the long tail, verified reductions in non-value-adding costs, adoption of interoperable solutions, measurable upgrading in organisational practices, and evidence that switching remains feasible (for example, successful migrations or multi-vendor coexistence in core compliance layers).

A credible evaluation design requires counterfactual thinking. The evaluation function should predefine comparison groups where feasible, using matched non-participants, phased rollouts, or difference-in-differences logic at the ecosystem level. The objective is not perfect identification but a disciplined approach that can detect failure early enough to trigger corrective action. Crucially, the evaluator must have **audit access** to underlying data needed to verify both savings claims and KPI attainment, while preserving commercial confidentiality through aggregation and controlled access.

6.7.5. Remediation, escalation, and exit rules

Governance must define what happens when performance is weak or when contestability degrades. The framework therefore uses a simple escalation ladder. First, **remediation**: time-bounded corrective plans when KPIs are missed, with clearly stated milestones. Second, **sanctions and clawbacks** where applicable, especially when support is linked to deliverables that did not materialise. Third, **reassignment**: ecosystems can be downgraded in SPSM and instruments can be withdrawn or redesigned. Fourth, **operator exit**: if BESNI becomes a bottleneck or violates contestability constraints, the system must be able to retender core functions, split responsibilities, or terminate the operator’s role. Exit is not a rhetorical threat; it is the mechanism that prevents governance from degenerating into permanent mediation.

This governance architecture closes the loop implied by the framework's logic. SPSM provides disciplined selection and periodic reclassification. BESNI provides diffusion and adoption capacity through contestable, pre-competitive coordination and procurement scale, funded through auditable success-based fees. Independent evaluation provides the evidence required for renewal. Exit rules ensure that failure leads to reallocation rather than persistence. With governance specified, the framework can then be stress-tested on concrete ecosystems, which is the purpose of the next section.

6.8. Application to Illustrative Ecosystems: SPSM Classification, Instrument Bundles, and Stress-Test Logic

Section 6.8 applies the framework to a small set of illustrative ecosystems already discussed in the diagnostic chapters. The purpose is not to add new evidence, but to demonstrate how the SPSM routine, the discipline filter, and the delivery logic (including BESNI as a contestable ecosystem operator) jointly translate diagnosis into tractable policy postures. The exercise is intentionally "operational": each case specifies (i) an SPSM placement at the ecosystem or value-chain-segment level, (ii) the binding constraints that determine whether support is admissible, (iii) the implied instrument bundle across Macro, Meso, and Micro, and (iv) measurable success conditions with credible exit paths.

A central implication of the framework is that classification must be performed at the level where bottlenecks and spillovers actually operate. For this reason, each case is treated as a value-chain segment or ecosystem cluster rather than as an aggregate sector label. This avoids policy errors that arise when a single "strategic" tag is applied to heterogeneous activities. It also forces explicit decisions on feasibility: an ecosystem can be strategically important and yet fail the viability or conditionality tests, in which case the correct response is redesign or exit, not persistence.

6.8.1. Battery value chain ecosystem (illustrative "Rising Star" with hard feasibility gating)

A battery ecosystem segment plausibly scores **high on Axis B** because demand tailwinds and transition relevance are structural, while its **Axis A weight** can remain limited relative to established industrial anchors, especially when domestic capacity materialisation is partial and uneven. This places the ecosystem, in many configurations, in the **Rising Stars** quadrant, but only conditionally. The discipline filter is decisive here: the viability test is not satisfied by announcements, but by deliverables under a declining support path (commissioning milestones, yield and cost benchmarks, supply-chain integration, and verified capability formation). The conditionality test is feasible only if ecosystem performance can be measured beyond installed nameplate capacity, which is a weak proxy under delivery risk.

The implied policy posture is therefore selective and milestone-driven. At the **Macro** level, the framework emphasises gating conditions that determine whether scaling is rational: cross-border permitting speed, grid and interconnection reliability, and a regulatory environment that supports interoperable digital compliance for industrial operations. At the **Meso** level, SPSM selection narrows effort to specific bottleneck segments (for example, cell manufacturing capability, quality control and metrology capacity, critical input processing, or recycling loops) rather than treating "batteries" as a single object. Restructuring logic prioritises integration and scale where it is necessary for competitiveness, while contestability constraints prevent the ecosystem from hardening into protected incumbency. At the **Micro** level, BESNI is used as a diffusion and adoption throughput mechanism inside the chosen segments: procurement scale for interoperable software and testing solutions; pre-competitive standardisation of problem statements (yield improvement, traceability, compliance reporting), minimal reference architectures, and test suites; and benchmarking that targets long-tail suppliers and mid-sized firms to raise ecosystem-wide capability rather than producing a thin layer of frontier plants.

This case also illustrates how applied R&D integration can be made operator-neutral. Success is defined by a KPI set that is hard to game: verified throughput and yield improvements, measurable reductions in non-value-adding compliance costs, diffusion coverage across the supplier base, and evidence of contestability (multi-award procurement, successful switching, data portability compliance). Exit triggers are equally explicit: repeated failure to reach commissioning and performance milestones, inability to enforce conditionality, or delivery operators drifting into gatekeeping.

6.8.2. Semiconductor ecosystem (segment-specific classification and contestability-intensive delivery)

Semiconductors are strategically enabling across the economy, but the framework does not treat "semiconductors" as one ecosystem. Different segments can map to different quadrants because Europe's position, feasibility, and spillover structure vary sharply across the chain. The Chips Act provides a concrete policy anchor for how the EU frames capacity-building, resilience, and spillovers in semiconductors, but the framework requires segment-level viability and measurable delivery conditions rather than headline capacity targets.[301] Some segments can plausibly be treated as **Strategic Champions** (high Axis B and potentially high Axis A in their systemic footprint) where Europe has credible capabilities and spillover leverage; other segments remain **Rising Stars** where strategic potential is high but scale, talent, or capital constraints bind; and some activities may fail viability if competitiveness depends on indefinite compensation.

This case highlights two governance points. First, the SPSM discipline filter prevents the "strategic" label from substituting for feasibility: essentiality can modify urgency and instrument choice, but cannot bypass deliverability and enforceable KPIs. Second, the delivery layer is unusually exposed to lock-in risk because digital toolchains, standards, and compliance architectures can become quasi-infrastructure. The binding response is contestability-by-design as a gating condition rather than a best practice. Macro reforms focus on market integration, capital markets depth for scale finance, and fast, predictable permitting for relevant investments. Meso decisions concentrate on segments where upgrading is feasible and socially valuable, with contestability constraints embedded in any scale push (no exclusive vendor infrastructures, no irreversible procurement dependencies). Micro delivery uses BESNI logic where it is economically coherent: standardising pre-competitive problem statements and test suites; coordinating procurement in a multi-award format to avoid single-provider dependency; enforcing portability and interoperability in data and compliance layers; and targeting diffusion

[301] European Commission, "European Chips Act" (2023)

channels that raise the absorptive capacity of specialised suppliers and mid-caps, not only frontier incumbents.

Success conditions must therefore include both performance and openness: measurable diffusion throughput across the supplier ecosystem, verified reductions in adoption friction for interoperable solutions, and demonstrated switching feasibility. Exit is triggered by either performance failure (no verified upgrading) or governance failure (collapse of contestability into gatekeeping).

6.8.3. Energy-intensive basic materials (illustrative "Legacy Anchor" with phase-out discipline)

For the energy transition portfolio, the key stress-test is the coexistence of 'Rising Stars' technologies with 'Legacy Anchors' exposed to energy-price risk, where the difference between productivity support and adjustment support becomes a binding governance requirement.[302] Energy-intensive basic materials, such as aluminium and related segments, often retain high Axis A weight because they are embedded in downstream value chains and can be employment and input-central, while their Axis B strategic potential can be structurally constrained under an adverse and volatile energy cost regime. This often places them in the **Legacy Anchors** quadrant, potentially with an essentiality modifier when supply security and systemic input roles are binding. The framework's implication is not preservation, but managed transition: support is admissible only if it purchases a measurable transition path rather than compensating operating losses.

Macro gating conditions are unusually decisive in this case because the investment horizon is dominated by energy price level and volatility. The framework therefore treats energy market design, long-term contracting capacity, grid investment, and permitting speed as prerequisites for rational upgrading. At the meso layer, the intervention logic focuses on restructuring toward efficient scale where it improves competitiveness, while preventing protected rent extraction; the objective is to enable reallocation and transition, not to freeze the ecosystem. At the micro layer, BESNI-type mechanisms are used to reduce non-value-adding costs and to accelerate diffusion of measurable efficiency upgrades: interoperable energy management systems,

[302] IEA, "World Energy Outlook / Energy Market Report" (2025)

process optimisation toolchains, traceability and compliance architectures, and benchmarking that identifies reproducible efficiency gaps across plants and suppliers.

The KPI logic is explicitly transitional: energy intensity and process efficiency improvements, verified operational upgrading, measurable diffusion coverage across the ecosystem, and compliance with contestability requirements. The exit logic is a programmed phase-out if the transition does not materialise, combined with a strict separation between productivity support and adjustment support. If the only feasible posture becomes permanent compensation under structurally adverse conditions, the framework requires reclassification and withdrawal of productive support.

6.8.4. What the application demonstrates

Across the cases, the practical lesson is that selectivity is not primarily a question of naming priorities, but of enforcing gating conditions that keep the system from becoming compensatory. Empirically, adoption constraints and capability dispersion remain observable in EU enterprise data (digital/AI uptake, ICT intensity), reinforcing why diffusion throughput and absorptive capacity are treated as KPI objects rather than assumed by policy intent.[303] SPSM provides a disciplined, reviewable classification routine; the discipline filter forces feasibility and enforceability to be decided explicitly; BESNI provides a delivery logic that can raise diffusion throughput and adoption capacity, but only if it is contestable by design and auditable in both performance and fees; macro conditions determine whether micro and meso interventions generate productivity rather than rents. The framework therefore behaves as intended only when the cases are treated as ecosystems with measurable mechanisms, not as sectors with politically resilient labels.

[303] Eurostat, "ICT usage in enterprises, AI adoption" (2024)

7 Conclusion limitations and future activities

7.1. Conclusion

This thesis started from a stylised but empirically grounded fact: over the past two decades, the European Union has experienced a persistent productivity slowdown while the United States has remained at the technological frontier and China has sustained rapid upgrading. The resulting prosperity gap is not best interpreted as a temporary cyclical deviation, but as a structural outcome of Europe's difficulty in generating high-growth firms, diffusing innovation beyond a narrow frontier, and scaling production in strategic sectors. In this setting, the key analytical challenge is not whether Europe should imitate either the US market-driven model or the Chinese state-led model. It is whether it can craft a distinctive path to renewed industrial dynamism that is compatible with its multi-level governance, heterogeneous national models, and political constraints.

The central research question asked whether a selective industrial policy can be a viable strategic response to Europe's competitiveness and productivity problem. The thesis' answer is conditional but clear: selectivity is defensible only if it is treated as a governance proposition rather than a slogan. In practical terms, this means that selective intervention can contribute to higher productivity only when embedded in credible discipline devices, including conditionality, measurable performance criteria, time-bounded support, and explicit exit rules. These features are designed to reduce rent extraction and prevent the preservation of persistently unproductive capacity.

The analysis supports three main findings. First, Europe's weakness is primarily a Total Factor Productivity problem rather than a simple capital-deepening issue, pointing to a deeper failure of innovation translation, technology diffusion, and allocative efficiency. Second, Europe's industrial predicament is consistent with a "middle-technology trap" dynamic. Competitive pressure erodes traditional medium-technology manufacturing advantages while the transition into high-technology, knowledge-intensive sectors remains incomplete and uneven across member states. Third, the core bottleneck is not a lack of technological availability in the abstract, but the institutional and market mechanisms through which technologies scale and diffuse. These mechanisms are stronger in the US, via unified markets and deep capital, and are actively engineered in China, via a coordinated techno-industrial state, while remaining structurally weaker and more fragmented in the EU.

On this basis, the thesis contributes by moving from diagnosis to operational design. It distinguishes between the analytical problem of prioritisation, namely what domains to support, and the institutional problem of diffusion-throughput, namely how support translates into adoption and productivity gains at scale. This distinction matters because many policy debates collapse the two, assuming that selecting a "strategic" sector automatically generates diffusion, learning, and scale. The thesis instead treats diffusion as a separate and binding constraint, particularly in an institutional environment where fragmentation, heterogeneous capabilities, and implementation frictions can dissipate policy effort.

The prescriptive core of the thesis is therefore not a generic call for "industrial policy", but a structured framework that links selection to delivery. Selective Industrial Policy, as defined here, is targeted intervention aimed at accelerating the development of specific sectors, technologies, or firms critical to long-term competitiveness. Its credibility depends on governance features that impose discipline and evaluability. BESNI (Business Ecosystem for Sustainable Network Innovation) is introduced as a delivery architecture designed to operationalise selectivity at scale by targeting the ecosystem complements that condition diffusion and upgrading. These complements include skills pipelines, testing and certification capacity, interoperable standards, data and digital infrastructure, and organisational know-how. In other words, the thesis reframes selectivity as "picking mechanisms" as much as "picking domains". The policy problem is to ensure that prioritisation is paired with institutions and complements that raise absorption capacity across the firm distribution, not only outcomes at the frontier.

Policy implications follow directly. If Europe's competitiveness gap is in large part a scale-and-diffusion problem, then any credible strategy must treat market integration and capital allocation as enabling conditions rather than separate policy files. A deeper and less fragmented single market reduces the fixed costs of scaling across borders and increases the returns to innovation by enlarging the addressable market. More effective channels of financing are necessary to support the growth of high-potential firms and to fund the complementary investments that make diffusion possible. At the same time, governance capacity is non-negotiable. Without transparent criteria, monitoring, and exit rules, selectivity is vulnerable to capture and may reduce productivity by locking in incumbents. Finally, heterogeneity across member states is not a footnote but a design constraint. A framework that ignores differences in institutional logics and capabilities risks either under-delivering in lagging areas or subsidising inefficient capacity. A framework that acknowledges heterogeneity can be modular, allowing differentiated instruments while preserving European-level coherence.

Overall, the thesis argues that Europe's path to competitiveness cannot rely on a single lever. Horizontal reforms that improve the operating environment are necessary but not sufficient if diffusion and scaling remain structurally blocked. Conversely, selective intervention without discipline and delivery capacity can easily become a vehicle for rent preservation. The proposed approach is an attempt to navigate this narrow corridor. It treats selective industrial policy as potentially viable, but only under an architecture that makes it measurable, time-bounded, and oriented toward diffusion-driven productivity gains.

7.2. Limitations

The thesis has limitations that constrain the generality and testability of its conclusions.

A first set of limitations concerns measurement and comparability. Productivity, especially Total Factor Productivity, is difficult to measure consistently across countries and sectors, and is sensitive to methodological choices, data quality, and structural differences in economic composition. Similarly, diffusion and scaling processes are often observed through proxies rather than direct measures. These constraints imply that the thesis' empirical grounding should be interpreted as triangulation of evidence rather than as a single definitive quantitative test.

A second set of limitations is methodological. The thesis is primarily institutional and comparative in nature. It draws on conceptual frameworks and cross-system contrasts (EU versus US, China, and India; and within Europe, among Germany, France, and Italy) to motivate causal mechanisms and identify constraints. However, it does not estimate a unified causal model that isolates the marginal contribution of specific policy levers. This is partly intrinsic to the object of study. Multi-level governance, co-determined institutions, and policy endogeneity make clean identification difficult without quasi-experimental designs or detailed microdata linked to policy variation.

A third set of limitations concerns scope and perimeter. The comparative focus is intentionally selective, emphasising a limited set of benchmark economies and three large European member states as representative institutional models. This choice supports analytical depth but limits coverage of other EU contexts, including smaller economies and member states with different growth models. In addition, the thesis treats the legal and regulatory environment functionally, as a set of constraints and enabling conditions for policy design, rather than providing a comprehensive legal analysis of instruments such as state aid, competition enforcement, procurement frameworks, or detailed treaty constraints. This is appropriate to the thesis' objective but leaves open an important implementation layer.

Finally, the proposed framework is an operational design rather than an evaluated policy programme. Its plausibility derives from consistency with the diagnosed constraints and from the integration of discipline devices, but its effectiveness cannot be validated without real-world pilots, implementation data, and ex post evaluation.

7.3. Future Activities

Future work should follow a disciplined agenda that makes the framework more testable, more implementable, and more robust to institutional constraints.

A first line of activity is empirical validation focused on diffusion and scaling. This would entail building or integrating datasets that better capture technology adoption, organisational upgrading, and the growth dynamics of firms across countries and sectors. The objective would be to move from proxy-based reasoning to sharper measurement of diffusion-throughput and to assess which complements, such as skills, standards, finance, infrastructure, and managerial practices, most strongly mediate the translation of innovation into aggregate productivity gains. Where policy variation exists, quasi-experimental designs could be used to estimate impacts of specific programmes on adoption and performance, thereby providing evidence for which mechanisms deserve prioritisation.

A second line is policy prototyping through structured pilots. The framework's key promise is not that it can be described coherently, but that it can be executed with evaluability and discipline. This requires pilots that are explicitly designed with ex ante metrics, conditionality, and exit rules. Pilots should focus on domains where diffusion constraints are binding and where ecosystem complements are clearly identifiable, allowing BESNI-type delivery architectures to be tested under realistic governance conditions. The evaluation goal would be to determine whether delivery-layer interventions meaningfully increase adoption and productivity outcomes beyond what horizontal measures achieve.

A third line is institutional and legal design refinement. Because European industrial strategy is constrained by multi-level governance and heterogeneous national models, future work should specify how roles and responsibilities are allocated across European and national levels to minimise implementation frictions, duplication, and capture risk. This includes examining how discipline devices can be credibly enforced within EU institutional constraints, how monitoring and benchmarking can be structured to preserve comparability, and how modularity can be used to accommodate heterogeneity without fragmenting the single market. A complementary extension would deepen the compatibility analysis with EU competition and state aid frameworks, focusing on how to design selectivity that is both effective and legally sustainable.

In closing, the success criterion implied by this thesis is concrete. A European competitiveness strategy should be judged not by the volume of spending, the number of initiatives, or the ambition of declarations, but by whether it increases productivity in a diffusion-driven way. This means more firms adopting and effectively using frontier technologies, more high-growth firms scaling across borders, and a stronger capacity to translate innovation into broad-based gains. The contribution of this thesis is to propose a framework that treats those outcomes as design targets, measurable, time-bounded, and institutionally grounded, rather than as aspirational by-products of policy activism.

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Appendix A (Table A5.1-1)

Policy family (stylised)	What it tries to fix (mechanism targeted)	Typical instruments / governance mode	Binding gaps that remain (why under-delivery persists)	What this thesis adds (distinct contribution)
Horizontal "framework" reforms	Reduce fixed costs and uncertainty; improve allocative environment	Harmonisation agendas, permitting reform, administrative simplification, competition policy updates	Often necessary but not sufficient: improves the feasible set but does not tell where to concentrate scarce effort; tends to remain slow and politically fragmented; weak link to diffusion outcomes	Macro layer as gating conditions: treats market integration, permitting predictability, and energy-risk design as prerequisites that condition returns to selective tools; makes "macro" explicitly the first stage in a sequencing logic
Mission-oriented / strategic autonomy agendas	Build capacity in "strategic" domains; reduce dependencies	Targets, alliances, large programmes, resilience framing, strategic procurement	Risk of categorical vagueness ("strategic" as label), weak termination rules, and drift into persistence; can prioritise capacity announcements over deliverable capability	SPSM + discipline filter: forces segment-level classification, viability/conditionality checks, and default non-renewal; "essentiality" can modulate urgency but cannot bypass feasibility
Large transnational	Internalise spillovers;	Large consortia,	Governance burden and	Keeps the legitimacy logic

project frameworks	justify scale by cross-border externalities	state-aid-compatible design, milestones, reporting commitments	compliance complexity; variable evaluation quality; risk of incumbent capture and limited diffusion beyond core participants	(spillovers, cross-border relevance) but inserts harder discipline: explicit exit logic, measurable KPIs tied to diffusion/throughput, and contestability constraints on delivery operators and vendor interfaces
Financial de-risking and investment mobilisation	Reduce cost of capital; accelerate scale-up investment	Guarantees, blended finance, public banks, tax credits, subsidies	Mobilises money but can miss the bottleneck: capability and adoption capacity; risk of subsidising investment that does not translate into productivity due to weak complements	Treats finance as complementary, not sufficient: micro layer targets adoption execution, organisational upgrading, and diffusion throughput so that capital translates into TFP/labour productivity gains
Innovation/R&D-first policy	Push frontier innovation; increase technological supply	R&D grants, research programmes, innovation hubs	Frontier can advance without shifting the mass: transmission failure; weak translation from invention to adoption; long tail remains unchanged	BESNI as translational delivery: converts research outputs into deployable solutions via standardised problem statements, test suites, and procurement scale; targets long-tail upgrading

SME digitalisation support (firm-by-firm)	Improve adoption of digital/AI tools	Vouchers, training, advisory schemes	Fragmented, low accountability, hard to measure; high variance in implementation quality; limited scale economies; can become "subsidy drizzle"	Ecosystem-level delivery: shifts from firm-by-firm to value-chain segment logic; pooled procurement + benchmarking + playbooks; KPI discipline on diffusion throughput
Energy transition packages	Lower emissions while preserving competitiveness; manage cost shocks	Subsidies, CfDs, infrastructure plans, standards	Tension between decarbonisation and cost competitiveness; risk of turning into permanent compensation for adverse price regimes; uneven national energy market conditions	Makes energy a macro feasibility gate: selective support is allowed only if it buys measurable transition paths, with phase-out discipline for Legacy Anchors; separates productivity support from adjustment support
Skills and labour market initiatives	Address skill mismatch; enable diffusion via mobility	Training, reskilling, qualification frameworks	Often disconnected from ecosystem priorities; slow feedback on productivity; portability barriers persist	Integrates skills as carrier of diffusion inside the three-level architecture: macro portability + micro capability KPIs inside BESNI programmes linked to priority ecosystems
Competition/state-aid governance adjustments	Preserve contestability while allowing intervention	Updated guidance, conditional approvals	Grey zone for ecosystem coordination and pooled procurement; risk of cartel-like	Competition-safe coordination rule-set: restricts coordination to pre-competitive objects (problem

			outcomes or gatekeeping infrastructure	statements, reference architectures, test suites, interoperability KPIs) + contestability-by-design (multi-award, portability, switching rights)