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Between Scylla and Charybdis: long-term drivers of EU structural vulnerability*

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This work investigates the European Union's structural vulnerability in an increasingly polarised global economy with ever more 'weaponised' interdependencies. Europe's structural vulnerability is due to different interlinked and mutually reinforcing elements, which are the legacy of a self-defeating export-led growth model and a related economic policy set-up. We define structural vulnerability along four main dimensions – demand, supply, technology and critical raw materials – and discuss its main drivers. Highlighting the key role that Germany plays in shaping the EU growth model, we argue that the vicious circle between demand repression and supply deterioration has constrained innovation and growth, particularly in the southern periphery, making Europe more fragile in the face of external shocks. While acknowledging the recent change in the EU's industrial policy approach, we argue that inadequate coordination at the EU level and the lack of common resources leave it to the fiscal capacity of individual member states to bridge the technological gap, with the real risk of further widening the core–periphery gap and increasing the structural fragility of the Union.

Keywords: *Structural vulnerability, strategic autonomy, industrial policy, core–periphery*

JEL codes: *F02, F15, F45, F55*

1 INTRODUCTION

The debate on deglobalisation has sparked great interest as a result of the world economy being increasingly divided into two 'competing blocks', one centred on the US and the other on China (Baldwin and Freeman 2022; Goldberg and Reed 2023). These two contenders are fighting for control of critical resources, weaponising their technological advantages, introducing measures to cut off competitors and increasing their allies' dependency (Leonard et al. 2019; Drezner et al. 2021; Gjesvik 2022).

In this emerging 'global order' (Rodrik and Walt 2022), the EU is showing a high degree of structural vulnerability (SV), which encompasses both the structural and technological aspects of its growth model. Regarding the former, SV indicates a

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relatively low degree of complexity in sectoral specialisation (Celi et al. 2018), resulting in a weak position in key global supply chains and a higher degree of foreign dependency. Concerning the latter, SV implies a limited degree of technological sovereignty in strategic sectors critical for an economy's welfare and competitiveness. This, in turn, constrains the country's ability to adapt to a changing and challenging geo-economic context (Edler et al. 2023).

European SV persisted for decades but became explicitly evident in the wake of the 2008 financial crisis, the COVID-19 pandemic and the Russo-Ukrainian War, which turned it into an unavoidable economic issue. A high degree of dependence on imports of key products, including gas and oil, critical raw materials (CRMs), essential medical products and equipment, microchips and other technologically advanced equipment, is the most obvious example (Crespi et al. 2021; Celi et al. 2022).

There are multiple symptoms of European vulnerability: weak macroeconomic performance, technological backwardness in critical areas, overreliance on exports, as well as imports regarding strategic inputs (Celi et al. 2020; Germann 2022; Gehringer 2023).

Europe's SV derives from the interrelation between internal and external factors. The excessive weight of exports in total demand and the dependence on imports of technologies and intermediate goods (Crespi and Guarascio 2019) are linked to a 'political stalemate' on crucial decisions – from energy and defence to EU macroeconomic governance and industrial policy. This resulted in a deflationary environment, which has constrained domestic demand (and, in particular, investment), jeopardising the EU's productive and technological capabilities, and has worsened the core–periphery divergence (Storm 2019; Gräbner et al. 2020).

The growing awareness of the risks associated with increasing economic and technological vulnerability has raised concerns about the sustainability of the EU's growth model. The signals of reform are mixed at best, however (Sigl-Glöckner et al. 2023). Concerning fiscal policy, the EU is going back to pre-COVID austerity (Celi et al. 2020), undermining, again, the possibility of stimulating growth and a structural upgrade via domestic demand (Guarascio and Zezza 2023). However, there are some developments in the field of industrial policy (Terzi et al. 2023). A new course of EU policies aimed at strategic industries has been launched by the EU Commission (EC), breaking away from the previous approach based on sectoral and technological neutrality. Against this background, we explore the dimensions and causes of the EU's SV and discuss the adequacy of the new industrial policy in reducing dependency and increasing resilience (Hafele et al. 2023).

The article is structured as follows. Section 2 assesses the EU's structural vulnerability vis-à-vis the two dominant blocks, the US and China, across four dimensions: demand, supply, technology and CRMs. Section 3 explores the multiple channels through which Europe's export-led growth model increased dependence and its interaction with the core–periphery divergence. Section 4 evaluates the potential of the recent shift in the EU's industrial policy strategy to reduce vulnerability. Section 5 concludes the article by discussing policy implications and avenues for future research.

2 THE STRUCTURAL VULNERABILITY OF THE EUROPEAN ECONOMY: AN EMPIRICAL ASSESSMENT

Quantifying Europe's structural vulnerability within a rapidly changing global political order is not a simple task, considering its multi-dimensionality. The aim of this

Table 1 List of indicators

SV dimension	Key indicators	Reference literature
Demand-side	Export share (aggregate and selected/ strategic sectors)	Germann (2022)
Supply-side	Share of imported intermediate inputs Foreign value-added content of gross exports	Baldwin and Freeman (2022)
Technological	Total patent filings in ICT and semiconductors Total patent filings in green technologies	Caravella et al. (2021)
Critical raw materials	Supply risk in CRMs Rare earth production and reserves by country	Rabe et al. (2017), European Commission (2020b)

Source: Authors' elaboration.

section is, therefore, to empirically assess the degree of the EU's resilience (vulnerability) across its four dimensions: from *demand-side* and *supply-side* foreign exposure to the lack of *technological* sovereignty, with a final focus on external reliance on *critical raw materials*. To this end, we rely on various indicators presented in Table 1.

2.1 Demand-side vulnerability

We assess *demand-side* vulnerability by examining the share of exports to countries that are either exposed to geopolitical risks (Caravella et al. 2021; Gehringer 2023) or potential competitors (e.g. China) 'large enough to swallow up entire parts of the industry' (Germann 2022, p. 10). The higher the concentration of exports in a small number of countries, the greater the vulnerability to external shocks.

Given Germany's central role in shaping EU trade dynamics, the remarkable growth of German exports of capital goods and cars to the Chinese market has made China the primary source of dependence for the entire EU (Leonard et al. 2019). In the aftermath of the 2008 crisis, China provided a viable alternative to the collapse of the southern periphery's imports (Celi et al. 2018).[1] At the same time, China has emerged as a major

1. In our analysis, we rely on the distinction between core and periphery, as proposed by Celi et al. (2018; 2020) and further validated by Gräbner et al. (2020). Core–periphery polarisation is driven by the emergence of the 'German manufacturing core' (Stehrer and Stöllinger 2015) – including Germany and the Visegrad countries [the Eastern periphery (EP): Czech Republic, Hungary, Poland and Slovak Republic] becoming key suppliers of German exporting industries – paralleled by the structural weakening of the Mediterranean countries [the Southern periphery (SP): Greece, Italy, Spain and Portugal]. This grouping is not meant to minimise the relevance of other European economies (e.g. France), rather it identifies those countries that play

competitor for countries in the southern periphery, crowding out producers of low- to medium-tech intermediate and final goods.

On the one hand, this reorientation of German exports has had adverse implications for the southern periphery, exacerbating the core–periphery divergence. On the other hand, China, owing to its immense size and rapid technological catching-up, poses a threat not only to industries crucial for the green and digital transition but also to more 'traditional' sectors in which Germany specialises (Germann 2022; Simonazzi et al. 2022). As a result, China has become a vital outlet for some industries and a formidable competitor for others, polarising the stance of German business organisations regarding the protectionist measures included in the 'National Industrial Strategy 2030' (Germann 2022). Sectors less dependent on China or facing more competition from it tend to support protectionist measures, showing little concern for possible Chinese retaliatory measures on German exports. The opposite goes for sectors like the automotive industry, whose growth is substantially linked to Chinese imports (Halevi 2019). However, even in this context, the progress made by Chinese producers of electric vehicles complicates the strategies of Western carmakers. Geopolitics adds another layer of complexity. While China is a crucial market for European exports, the US–China trade war is putting additional pressure on the EU to reconsider its ties with China.[2]

Given Germany's central role in European value chains and its influence in shaping the EU's economic growth (Celi et al. 2018; Stöllinger et al. 2018), we focus on the long-term evolution of German exports as a proxy for Europe's demand-side vulnerability, using the Organisation for the Economic Co-operation and Development (OECD)'s Inter-Country Input–Output tables (ICIO). Figure 1 illustrates the growing importance of the Chinese market for German exports since 2001, the year China joined the WTO. Conversely, the US, while still being Germany's main market, is on a declining trajectory.[3]

Furthermore, Figure 2 reports the evolution of Chinese and US shares in German exports of final goods across specific industrial sectors.[4] The data reveal that, aside from electronics, all major manufacturing sectors have experienced a decline in the US share, accompanied by a sharp increase in China's share in their exports, with the automotive and transport equipment sectors leading the way.

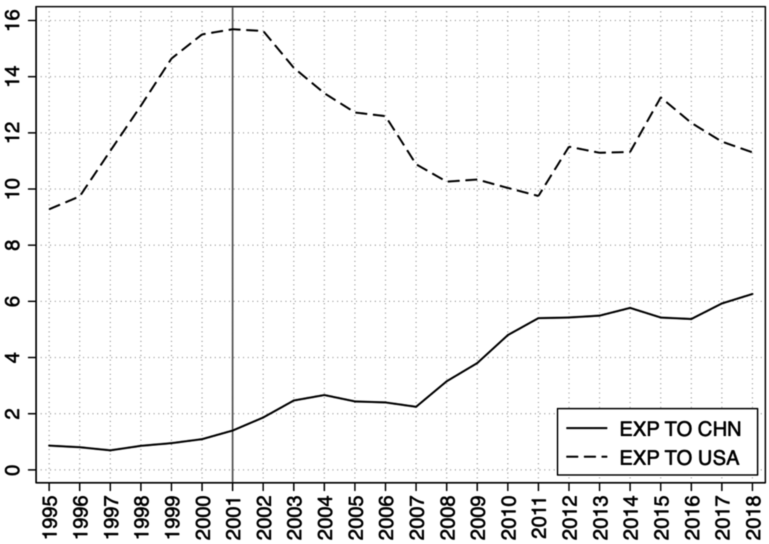
This evidence is in line with the dynamics of European FDIs in China, which are highly concentrated by country of origin, sector and company (Kratz et al. 2022). German firms hold the lion's share of European investment in China, followed by those from the Netherlands, the UK and France. Five sectors – automotive, food processing, pharma/biotech, chemicals and consumer durables – account for almost 70 per cent of all FDIs, with automotive representing nearly one-third of all European

a key role in the hierarchical reshuffling that has characterised the European economy, and its manufacturing sector in particular, in the recent past.

2. German reluctance to follow the US in adopting a confrontational stance towards China reflects the latter's strategic importance as a market outlet for German export.

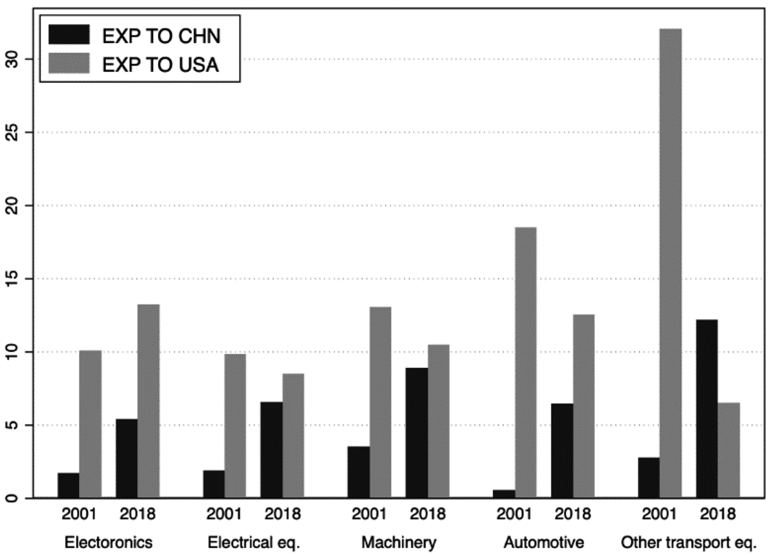
3. That the geography of German exports is a sound proxy of the EU international trade positioning is confirmed by Figure A1. As expected, the evolution of EU export shares to the US and China reflects Germany's pattern.

4. The decision to look at final goods is consistent with Germann (2022). However, the general pattern is confirmed if intermediate goods are included in the analysis.



Source: Authors' elaboration based on the OECD's ICIO tables. The vertical line marks China's accession to the WTO.

Figure 1 Share of China and the US in German exports of final goods



Source: Authors' elaboration based on the OECD's ICIO tables.

Figure 2 Chinese and US shares in German exports of final goods, key sectors, 2001 and 2018 direct investments in China.[5] The Volkswagen Group offers a telling example with the number of deliveries to Chinese customers increasing from 500 000 in 2005 to 4 200 000 in 2018.[6]

Deep bonds – FDIs, JV, complex and long-lasting provider–customer relationships – make decoupling and diversification costly. Decoupling can also be expensive for China, as the benefits of trade extend far beyond importing medium- and high-technology goods. Nevertheless, guided and constrained by a tightly defined industrial policy, Chinese firms have managed to catch-up in key high-tech sectors through R&D partnerships, imitation, reverse engineering and outward FDI, thereby challenging European and German industries in their own market (Li et al. 2020; Altenburg et al. 2022).

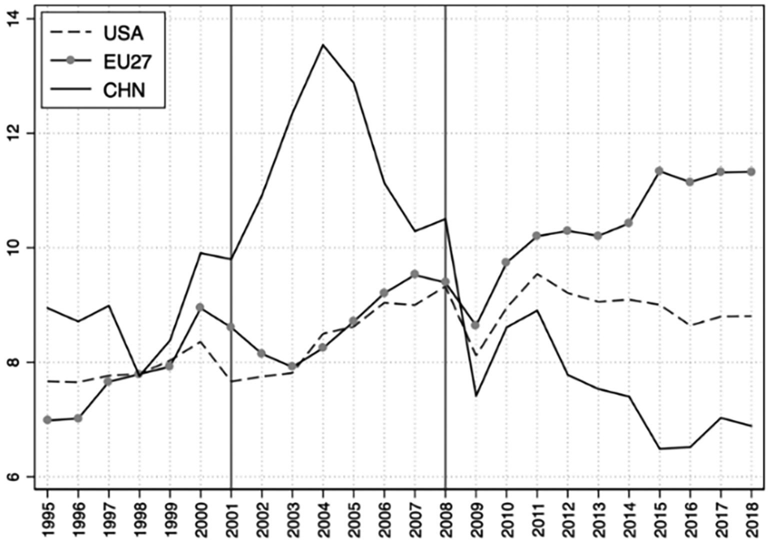
2.2 Supply-side vulnerability

The recent supply chain disruptions caused by the COVID-19 pandemic and the Russo-Ukrainian War have made clear that dependence on a few suppliers can significantly increase the degree of vulnerability, even more so if those suppliers are exposed to specific geopolitical risks (Celi et al. 2022). Diversification strategies, such as trade diversion, may trigger retaliation, especially when demand and supply linkages are intertwined. Furthermore, as in the case of knowledge and technology-intensive intermediate inputs, the development of domestic production capabilities may be a long, expensive and, in some cases, impossible process (Cucignatto and Garbellini 2022; Spieske et al. 2022). Therefore, it matters 'how much', 'from whom' and 'what' is imported, as diversification or import substitution strategies in case of a crisis could be difficult or even impossible.

In light of recent events, the literature on strategic dependencies has been growing rapidly (Bonneau and Nakaa 2020; Baldwin and Freeman 2022; Broeders et al. 2023). We document an increasing degree of Europe's supply-side vulnerability in comparison with the two dominant blocks – the US and China – over the 1995–2018 period. To this end, we employ: (i) production-based indicators,[7] computed using OECD ICIO tables, which trace global intermediate input flows; and (ii) OECD Trade in Value-Added (TiVA) indicators.[8]

Figure 3 reports the share of the total imported intermediate inputs for the EU, the US and China. Two 'turning points' can be observed: China's WTO accession in 2001 and the 2008 crisis. The remarkable growth of Chinese imports, which had begun even

5. The pre-eminence of German companies in the Chinese market is explained by several factors (Kratz et al. 2022): 'German companies were early entrants to the Chinese market and their presence there was actively encouraged and aided over decades by the country's political establishment; they are typically in capital-intensive manufacturing and engineering industries, meaning large fixed investments; and they are present in sectors that have seen strong growth in China over the past decade'.
6. In 2021, the Volkswagen Group produced 36 per cent of its global production in China.
7. ICIO-based intermediate input indicators allow us to measure the dependence on foreign suppliers. Using the revised Pavitt taxonomy (Bogliacino and Pianta 2016), this dependence is further qualified by distinguishing sourcing industries by technological intensity.
8. TiVA indicators allow us to rank economies according to the amount of value-added captured by participating (WHOSE PARTICIPATION? 'national economies') in global trade, providing a proxy of global trade hierarchies. These indicators consent to account for double (or multiple) counting, which explains their growing utilisation to analyse trade performance and strategic dependence.



Note: Vertical lines indicate China's accession to WTO and the 2008 crisis.
Source: Authors' elaborations based on the OECD ICIO database.

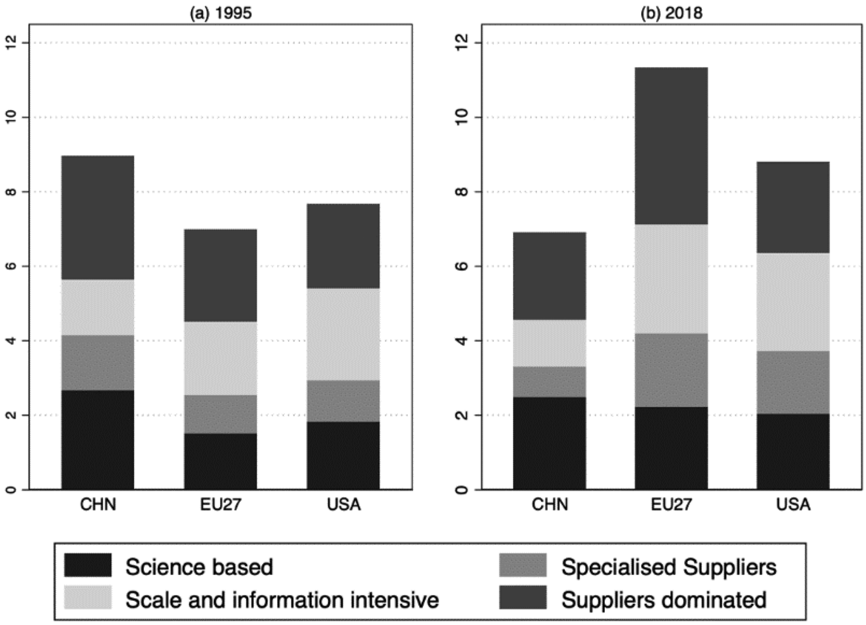
Figure 3 Imported intermediate inputs (as a per cent of total intermediate inputs), 1995–2018

before 2001, halted in 2004 and marked the beginning of an uninterrupted decline, bringing China's share in 2018 to a lower level than at the beginning of the period. This pattern reflects the well-documented process of learning and technological catch-up, enabling China to produce domestically what it had to import in the early years of globalisation (Borin et al. 2021; Altenburg et al. 2022).

The effects of China joining the WTO become more apparent when we examine the imports of its two major trade partners, whose shares rose between 2001 and 2008, before diverging thereafter. In fact, while in the case of the EU we observe an acceleration after the crisis, the US share remains roughly constant. These divergent patterns can be attributed, in part, to different policy strategies. The EU's growing involvement with China and the progressive extension of its value chains beyond the EU's borders reflect a growth model aimed at enhancing competitiveness and efficiency by seeking ever lower costs, both on-shore and off-shore. Conversely, China and, to some extent, the US pursued more interventionist and protectionist industrial strategies aimed at strengthening production capacity and import substitution (Di Tommaso et al. 2020; Barbieri et al. 2021).[9]

The reliance on imported high-tech inputs, which are more difficult to substitute, greatly augments vulnerability. Relying on the revised Pavitt taxonomy of industries (Science Based – SB; Specialised Suppliers – SS; Scale Intensive – SI and Supplier

9. In the US, the 'Buy American Act', enacted to support economic activity after the 2008 crisis, linked government spending in specific sectors to purchases from US companies. In China, industrial policy initiatives helped expand the domestic manufacturing base and technological capabilities in strategic sectors.



Source: Authors' elaborations based on the OECD ICIO database.

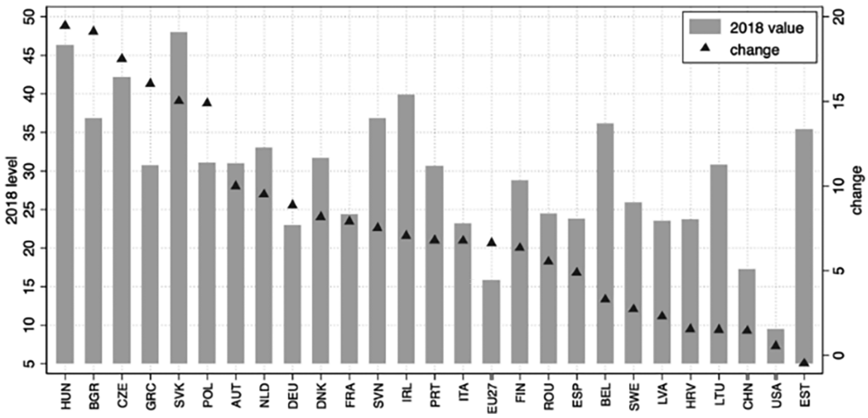
Figure 4 Imported intermediate inputs (as a per cent of total intermediate inputs) by revised Pavitt taxonomy

Dominated – SD) provided by Bogliacino and Pianta (2016), we disaggregate imported inputs based on their technological content. Figure 4 reveals that between 1995 and 2018 China reduced its reliance on imports, whereas the EU significantly increased its dependence across all Pavitt classes. In contrast, the US shows only a marginal increase, primarily in SS industries.

To complement the analysis of imported intermediate inputs, we also examine a country's backward participation in GVCs, measuring the foreign value-added content of intermediate inputs used in domestic production destined for exports (Hummels et al. 2001). Economies with a leading role in GVCs are expected to capture much of the value generated within supply chains; the opposite holds for those specialised in the lower value-added and hierarchically subordinate stages of production as well as those more dependent on the imports of technologically advanced goods. Figure 5 shows the backward participation in 2018 and its change over 1995–2018 by country.

While the level of dependence varies considerably, reflecting also the size of the country, the change (right axis) highlights differences between the EU on the one hand and the US and China on the other.[10] Overall, the EU and, in particular, the

10. The GVC participation index is highly correlated with the size, sectoral/functional specialisation and technological capabilities of a country. Open economies specialised in medium-low tech manufacturing production and fabrication functions (Stöllinger 2021) are more likely to have a large share of foreign value-added in their exports. The opposite holds for economies



Note: The change refers to the period 1995–2018. Cyprus, Malta and Luxembourg have been dropped.
Source: Authors' elaborations based on the OECD TiVA database.

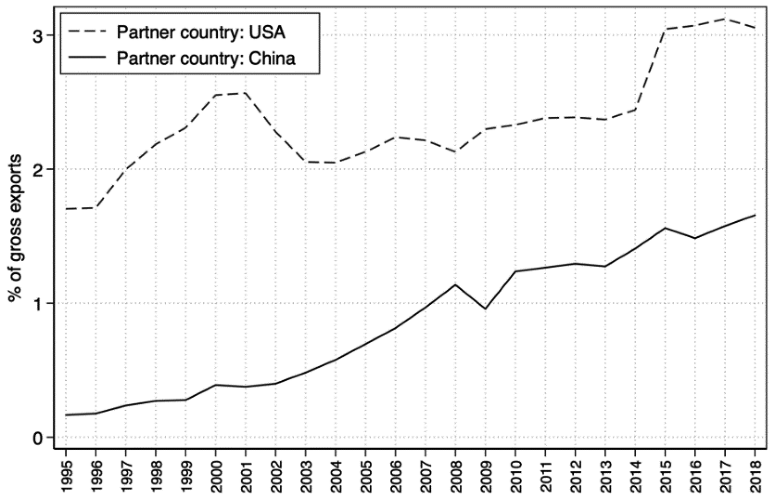
Figure 5 Foreign value-added content of gross exports by country

German manufacturing core (Stehrer and Stöllinger 2015) show a notable increase in the foreign value-added content of exports, in contrast to the US and China. These patterns align with the observed trend of imported inputs and may be attributed to the same interrelated factors, besides the process of eastward delocalisation of production stages to low-cost locations, often referred to as the 'bazaar economy' (Simonazzi et al. 2013).

Figure 6 illustrates the evolution of the shares of US and Chinese value-added activated by EU exports. As a result of their steady growth during the observed period, by 2018 these two blocs accounted for nearly one-third of the EU's total backward linkages. The EU's technological dependence on the US for key high-tech inputs (e.g. digital) and the demand-supply ties linking the German manufacturing core and China (Celi et al. 2020), in conjunction with China's technological catch-up and import substitution policy, can partly explain these trends.

Finally, the same message is conveyed by using an index that serves as a proxy of the gains or losses arising from a country's participation in the GVCs. A country's position in GVCs can be calculated as a ratio between its backward participation (BP) – that is, the foreign value-added activated by *country i*'s export – and its forward participation (FP) – *country i*'s value-added activated by other countries' exports (Koopman et al. 2010). A value higher (lower) than 1 indicates net losses (gains) from the participation in GVCs. In 1995, both the US and the EU (and within the EU, Germany, Latvia and France) recorded net gains. However, two decades later, the situation underwent significant changes. The US maintained its position, joined by China, while the EU and Germany worsened theirs (see Figure A2 in Appendix 1).

characterised by a broad, diverse and technologically advanced production base or for those that are service-oriented.



Note: As shown in Figure 5, the foreign value-added content of EU exports was around 15 per cent in 2018.
Source: Authors' elaborations based on the OECD TIVA database.

Figure 6 Foreign value-added content of EU exports: US and China

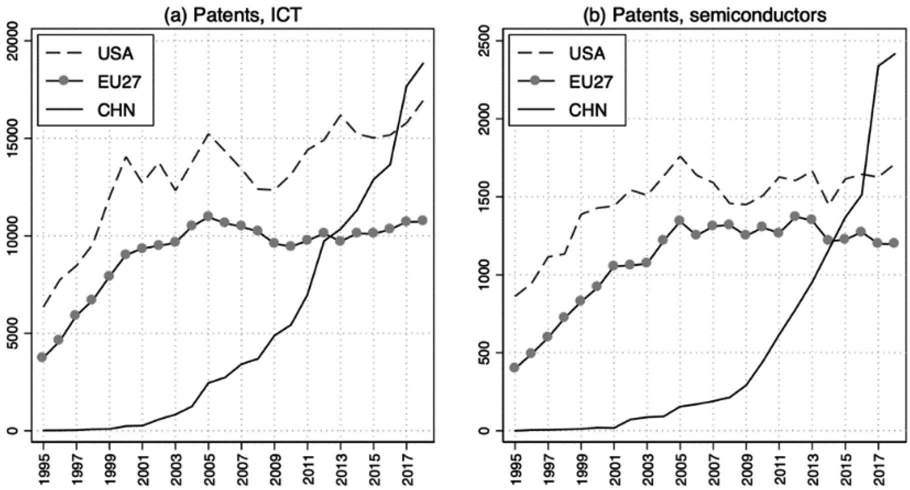
2.3 Technological dependency

Digital and green technologies constitute another crucial dimension of the EU's structural vulnerability. The former are integral to the functioning and success of virtually every economic activity. No industry or service can operate effectively today without a digital interface. As a result, companies (and countries) that dominate key ICT domains (e.g. cloud, AI and semiconductors) can wield substantial power over those who depend on them. However, the vulnerability resulting from excessive reliance on fossil fuels has been exacerbated by the Russo-Ukrainian War (Celi et al. 2022; Goldberg and Reed 2023), emphasising the urgent need to boost the share of domestically produced renewable energy and accelerate the 'green transition', especially in energy-intensive sectors (European Commission 2023). Nevertheless, this transition is hampered by the EU's import reliance on key technologies and critical raw materials (IEA 2021; 2022a; 2022b).

We assess the degree of the EU's technological backwardness, a third dimension of its SV, by relying on patent data. Although patents offer only a partial and imprecise measure of innovation performance, they can serve as a proxy for a country's technological capabilities. We use data on patent applications filed by the EU, the US and China in at least two IP offices[11] worldwide in the ICT and green sectors.

Figure 7 shows China's dramatic catching-up and Europe's stalemate in the digital domain. In 2017, China was the country holding the largest number of patent

11. The European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the US Patent and Trademark Office and the State Intellectual Property Office of the People Republic of China.



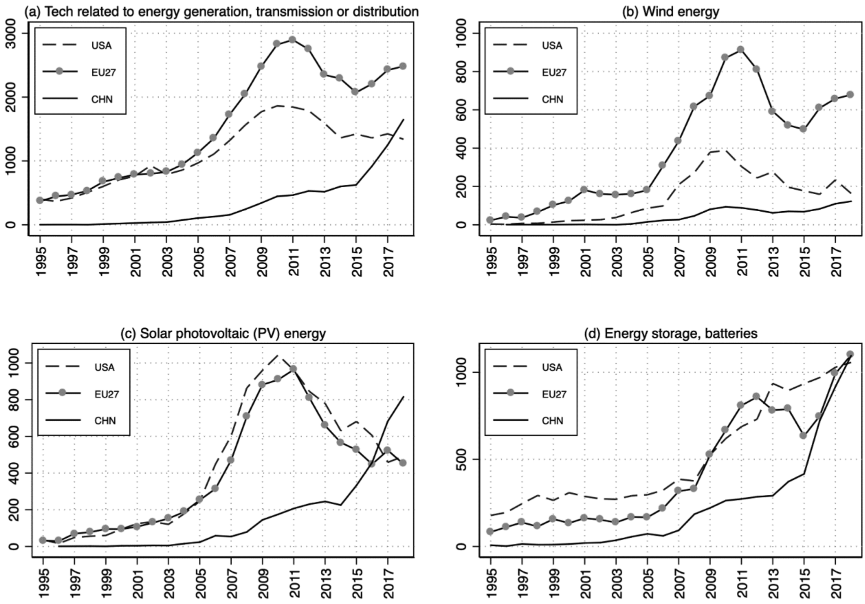
Source: Authors' elaborations based on the OECD Patent statistics.

Figure 7 Total patent filings in ICT and semiconductor technologies by country, IP5

applications in ICT (panel a) and semiconductor technologies (panel b), with the EU lagging far behind China and increasing its gap with the US. Given their ubiquity and relevance in developing innovation in all sectors, backwardness in digital technologies can undermine Europe's long-term growth prospects.[12] Due to its linkages with cybersecurity and the military industry (Mancheri et al. 2019), the semiconductor industry is also a security issue, which explains the ongoing 'chip war' (Miller 2022), with the US attempting to prevent China from gaining complete autonomy in semiconductor manufacturing.

Recognising the importance of strengthening its strategic autonomy (Edler et al. 2023),[13] the EC has launched a number of initiatives (e.g. the European Chips Act, 2030 Digital Compass and Digital Strategy) to address the growing gap with the US and China (Caravella et al. 2021). However, the cumulative nature of digital technologies and the insufficient scale of the EU's efforts make the target challenging to achieve (Crespi et al. 2021). China, instead, has managed to substantially narrow the gap with the US in less than two decades (WIPO 2022). Once a laggard, China is now at the global frontier of technological development in this strategic domain, reaping the rewards of successful implementation of coordinated industrial policies (Barbieri et al. 2021).

12. These figures could underestimate the dependency of Western economies on the Asian region, considering that the US imports 100 per cent of its advanced logic chips (90 per cent from Taiwan and 10 per cent from South Korea).
13. UNCTAD (2019) has documented how AI investments and patents are concentrated among few MNCs, mostly based in the US and China. Analogous evidence on artificial intelligence (AI)-related technologies has recently been provided by Rikap and Lundvall (2021) and Fanti et al. (2022).



Source: Authors' elaborations based on the OECD patent statistics.

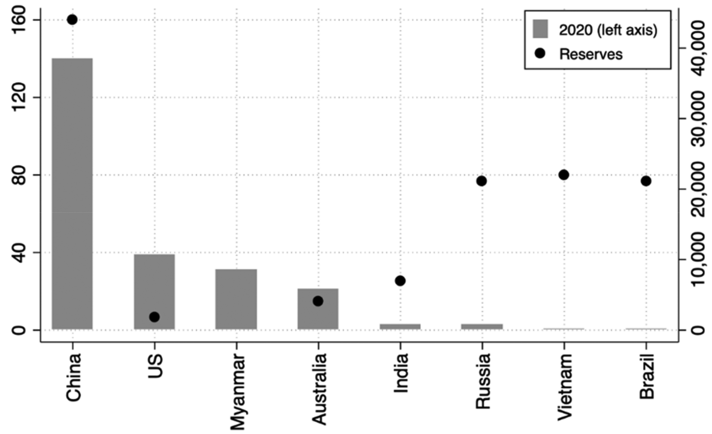
Figure 8 Patents in green technologies, 1995–2018

As US and Chinese multinationals became exclusive providers of a number of key digital goods and services (Rikap and Lundvall 2021), Europe's digital backwardness has increased.[14]

Climate change mitigation technologies offer a more nuanced picture (Figure 8). Europe leads in 'energy generation, transmission and distribution' and in wind energy patents, consolidating its position vis-à-vis the US and China between 1995 and 2011 (Figure 8, panels a and b). However, as in the case of digital technologies, the EU and the US are losing ground to China, with the partial exception of wind-related patents. In 2017, China led in patents related to solar photovoltaic (PV) energy (Figure 8, panel c) and narrowly outperformed the EU and the US in energy storage technologies (Figure 8, panel d).

Patent analysis reveals that Europe and the US are struggling to keep up with China's pace of innovation, becoming dependent on Chinese producers controlling key segments of many 'green' supply chains (Caravella et al. 2024). This technological leadership reflects manufacturing leadership as well. China's dominance in the production of solar PV panels is particularly noteworthy, as it accounts for nearly 80 per cent of the global output, surpassing its domestic demand by more than double.

14. A striking example of this process is Gaia-X. The German-French project started in 2019 with the aim of developing a European sovereign digital infrastructure alternative to the cloud computing technologies of leading American and Asian technology corporations. Conversely, this initiative ended up relying even more on US-based companies, showing that the EU's accumulated gap is not easy to fill (Maaser and Verlaan 2022).



Note: Data on smaller producers and reserves have been dropped. For USGS, Chinese figures underestimate China's control of this supply chain, given that REE production quota are official figures, which are not representative of the total production (grey miners, illegal production and so on).
Source: Author's own elaboration on Rare Earths data of the US Geological Survey (USGS), Mineral Commodity Summaries, January 2022.

Figure 9 REE mine production and reserves, 2020 (thousand metric tons of REO equivalent)

China's substantial investment in this sector, exceeding US$ 50 billion, a figure nearly ten times that of the EU, has led to the creation of almost 300 000 jobs (IEA 2022a).

Energy storage, particularly lithium-ion batteries, tells a similar story. China, once a laggard, accounted for 76 per cent of battery production capacity in 2021, while both the EU and the US share amounted to only 7 per cent (IEA 2022b). The global leader in lithium-ion batteries, Chinese company Contemporary Amperex Technology (CATL) confirmed its leadership in 2022, with 37 per cent of the global market, according to data from South Korea's SNE Research, and supplies car manufacturers such as Daimler, Volkswagen, BMW and Tesla. Owing to their centrality in fundamental value chains (e.g. cell phones and electric cars), batteries are at the centre of another 'war'. Nevertheless, even technology and production leadership cannot guarantee resilience against the risks related to dependency on key components or raw materials in specific segments of the supply chain.

2.4 Critical raw materials

Access to CRMs and Rare Earth Elements (REEs[15]) represents one of the major risk factors in the green and digital transition. Virtually all key goods and components in

15. These metals are composed of a group of seventeen chemical elements, fifteen *lanthanides* plus *yttrium* and *scandium*, characterised by similar physical and chemical properties. Despite their name, REEs are relatively abundant, significantly more than other commonly exploited elements. In nature, REEs do not exist as individual native metals, occurring together in numerous accessory minerals, including silicates, carbonates, oxides and phosphates (Balaram 2019).

digital devices and green technologies (e.g. semiconductors, li-ion batteries, solar modules and magnets) rely on them. At the same time, the uneven distribution of mines and the significant environmental costs of extraction, market concentration, the need for complementary goods, technologies and capabilities required for processing, make CRMs a hard-to-access strategic asset (European Commission 2021a). Unsurprisingly, the debate on energy security – traditionally linked to oil and natural gas supply – has shifted to clean energy and related technologies, with a particular emphasis on the risks associated with inadequate sourcing of CRMs (IEA 2021).

Indeed, most CRMs are asymmetrically distributed and are economically and environmentally costly to extract and process. Europe is highly dependent on imports: it neither mines nor processes the CRMs needed to satisfy its own demand (European Commission 2020c) and relies on a small number of suppliers who may leverage their market power, thereby threatening to put entire industries at risk (Rabe et al. 2017; Cucignatto and Garbellini 2022). Table A1 in Appendix 1 reports the EC's list of CRMs (2020b) and their relative supply chain risk, risky stage of production, main applications in the EU and key suppliers. Approximately 43 per cent of the CRMs listed are considered at medium, high and very-high risk, although one item, REEs, is considered at very-high risk (Figure 9 illustrates the geographical distribution of REE production and reserves).

REEs are essential for producing a number of strategic goods and technologies,[16] from common digital devices (e.g. smartphones) to batteries, EVs and wind turbines, and the EU is almost entirely dependent on China, which supplies nearly 98 per cent of its REEs imports (see Table A1 in Appendix 1). This makes diversification hardly achievable, casting doubts on Europe's ability to achieve its ambitious climate goals and strategic autonomy (Crespi et al. 2021).[17] Even in industries in which the EU's technological capabilities are close to the frontier (e.g. wind energy), such a dependency may compromise Europe's strategic autonomy and risk undermining its future growth prospects.

Finally, CRMs and REEs are crucial not only for the green transition but also for the development of military technologies and weapons (Mancheri et al. 2019; Kenlan 2020). For instance, neodymium is used for missile guidance systems, samarium for nuclear reactor control rods and lasers, praseodymium for aircraft engines and satellite components, lanthanum for night-vision goggles and promethium for missile batteries.

In summary, Europe's structural vulnerability is due to different interlinked and mutually reinforcing elements, raising questions about whether these vulnerabilities are inevitable in an open economy and to what extent they are the legacy of the EU's policymaking over the decades. Related to this is the question of whether and how a different economic and industrial policy can alleviate constraints, ensuring greater resilience.

16. In 2019, neodymium and praseodymium accounted for only 20 per cent of REEs' market volume, but 75 per cent of the total value. These REEs, along with dysprosium, samarium, gadolinium and cerium, are used in permanent magnets for electricity generators and EVs. This points to their critical role in pursuing environmental objectives in sectors such as automotive.
17. The EC has recognised the critical importance of CRMs in the context of green technologies (European Commission 2021a). Out of the 137 products for which the EU is considered import-dependent, 99 are raw (and processed) materials and chemicals related to green technologies, with significant supply chain risks.

3 THE LONG-TERM DRIVERS OF EUROPE'S STRUCTURAL VULNERABILITY

Mainstream economics, which describes trade and specialisation patterns as the result of optimisation schemes leading to efficient resource allocations, is of little help in understanding the key dynamics underlying Europe's structural vulnerability (Dosi and Tranchero 2021), as documented in the previous section. This can best be explained by out-of-equilibrium factors (Dosi et al. 2015), such as country-specific institutions and policies supporting innovation and competitiveness, heterogeneous distribution of demand-pull and technology-push drivers, idiosyncratic and path-dependent technological capabilities (Rosenberg and Nathan 1982; Scherer 1982; Cimoli et al. 2009).

In what follows, we present an alternative explanation for Europe's SV, which combines elements of the Post Keynesian, 'structuralist' and evolutionary traditions (Kaldor 1981; Dosi et al. 1990; Celi et al. 2018), focusing on the interplay among three drivers: *domestic demand repression, flawed economic policy set-up and core–periphery divides*.

It has been claimed that the EU (and Germany) have fallen into a 'Middle-Income Technology Trap' (Andreoni and Tregenna 2020). How is it possible that Germany has gone from the European powerhouse to the sick man of Europe in such a short time?

The causes of the EU's low growth and technological backwardness are many, but an important role was certainly played by the economic paradigm that guided the formation of the EU and later the Economic Monetary Union (EMU), which differed radically from the US economic policy (Vianello 2013). The EU's economic model promoted the liberalisation of labour, product and capital markets and advocated price flexibility as the only means for achieving growth. The dogma of competitiveness, typical of the export-led model, translated into a prioritisation, by companies and governments alike, of policies aimed at cost reduction. These included wage moderation at home and offshoring to low-cost locations, exemplified by Germany's eastward expansion strategy (Halevi 2019; Storm 2019). Wage moderation and fiscal austerity atrophied the domestic market (Storm and Naastepad 2015). The austerity regime that characterised the EMU was transmitted to all EU countries via exchange rates, trade links and financial markets.[18] Reliance on market forces resulted in a stagnation of public investment across the EU, leading to a severe deterioration of physical and social capital in both debtor and creditor countries.[19] As a consequence, only exports were left to support growth. Fiscal austerity, partially suspended from the outbreak of the COVID-19 pandemic to the energy crisis following the war in Ukraine, was soon re-established.[20] The new fiscal rules set to replace the Stability and Growth Pact (SGP) and the Fiscal Compact (FC) will make demand constraints even stronger, particularly for member states with a high debt-to-GDP ratio. Besides exacerbating the EU's structural vulnerability documented in the previous section, the new self-inflicted fiscal austerity conflicts with the objectives of the new European industrial policy, through which the EC aims at accelerating the digital and green transitions.[21]

18. Although the impact of austerity has been stronger in EMU countries and, in particular, in the southern periphery, the strong integration of the non-EMU economies into the EU's production-trade structure has facilitated the spill-over of the effects of austerity.
19. Germany, for instance, included the debt brake in the constitution in 2009, which has led to budget surpluses and a severe deterioration of the capital stock.
20. See: https://www.consilium.europa.eu/en/press/press-releases/2023/12/21/economic-governance-review-council-agrees-on-reform-of-fiscal-rules/.
21. For a first assessment, see Guarascio and Zezza (2023) and Zettelmeyer (2023).

Demand indeed is a key driver of growth: it sustains productivity, fosters learning and facilitates the accumulation of capabilities (Kaldor 1981). In addition, it reduces investment uncertainty, encouraging the expansion of the productive capacity and easing the process of 'creative destruction' (Hötte 2023). Markets tend to underincentivise innovation, even more so radical innovations with uncertain returns. Public procurement, however, can play an important role in shaping the transformation of production systems and stimulating technological upgrading (Crespi and Guarascio 2019). As seen in the US and China (Yang et al. 2020; Deleidi and Mazzucato 2021), innovative public procurement proved to be a fundamental engine of innovation and industrial renewal. Conversely, by viewing public spending solely as a cost to be contained, the EU's fiscal framework has exacerbated the perverse link between suppressing demand and weakening supply. Austerity policies have 'killed' demand and public investments, which, given the strong complementarity between public and private investment, especially in times of high uncertainty, have led to a general slowdown in private investment in innovative sectors. By limiting public investment in good times and reducing it pro-cyclically in difficult times, the EU's policy has penalised long-term growth, especially in already vulnerable areas like the southern periphery.

The export-led cum domestic deflation model may have affected the EU's long-term sustainability in a subtler way. From the introduction of the euro to the 2008 crisis, Europe – and, in particular, the southern periphery – was the main outlet for German exports. The reorientation of German FDI and trade towards the Visegrad block (Czechia, Hungary, Poland and Slovakia) following the EU's enlargement to the East, has favoured the emergence of the Central European manufacturing core (CEMC) (Stehrer and Stöllinger 2015) and the diversion of input demand from the southern to the eastern periphery (Simonazzi et al. 2013; Gräbner et al. 2020). When imports from the southern periphery plummeted due to the crisis and austerity, China's WTO membership (sponsored by the US) offered a propitious solution to redirect German exports to a new and growing market. China's entry into the game has had asymmetrical implications for Germany and Southern Europe, a major buyer of German capital goods and a formidable competitor for Italy and other peripheral economies (Celi et al. 2018). It has been said that 'China saved Berlin from the contradictions of its own European policy', allowing it to carry on its 'mercantilist agenda' and accumulate mounting trade surpluses, despite the growing impoverishment of the south.[22]

However, the apparent success of this model, which penalised the southern periphery so much, might have long-term negative repercussions for the core as well. Besides making possible the continuation of the austerity policies and, therefore, the weakening of the internal market, a possible by-product of the Chinese boon is that, with its huge market for German capital and engineering goods – high quality, complex industries but not at the frontier of the newest innovations – it may have induced overconfidence and complacency on the part of the German industry and government, overshadowing the urge to innovate. Amid conflicting inter-industry interests, the great economic (and political) power of the export industry, based on sectors of traditional German specialisation (chemical, automotive, engineering and electrical equipment), may have prevailed, blocking the reform of the economic model and thwarting the opportunities for diversification into new areas.

22. The quote is taken from an article ('Europe is learning that you can't separate trade and politics') by Martin Sandbu (2022) published in *The Financial Times*. Last access 16 March 2023.

The transition towards renewable energy is a case in point. The highly energy-intensive export industry influenced energy policy to suit its interests. As pointed out by Plehwe (2022): '*ambitious greenhouse gas reduction goals have been subject to backsliding and political horse trading to protect strong industrial interests both in the national arena and in the E*'. Given the economic relevance of German exporters and their interdependence with suppliers located in Central-Eastern (and Southern) Europe, their lobbying pressure influenced the scope and the speed of the EU's energy policy implementation. This may explain why, despite championing global policy efforts on climate change and introducing incentives to promote renewable energy, the EU was still highly dependent on fossil fuel imports at the outbreak of the Russo-Ukrainian War (Celi et al. 2022). Relatedly, the EU's delayed entry into the world of new digital and green technologies led to an underestimation of the importance of controlling the value chain up to the raw materials critical for their production, such as lithium, which is not needed for traditional diesel engines.

Radical (and pervasive) technological changes can favour the emergence of new competitors and the disruption of existing oligopolies, reshaping the global production landscape. The Chinese automotive industry serves as a compelling example: by developing electric cars, it became a world leader across the entire value chain, posing a threat to incumbents in their respective markets. It did so by anticipating possible developments, directing investments in the desired direction and developing the necessary skills and competence. It shrewdly exploited foreign investment to enable Chinese companies to develop capabilities (Teece 2019), which have been used to gain a stronger foothold in the global market and to capture value in the industry, such as electric (BYD and Geely), shared (Didi Chuxing) and autonomous vehicles (Baidu). The Chinese experience shows that selective industrial policies do not need to systematically pick losers, as is (too) often argued. Ultimately, Western carmakers had to scramble to catch-up, bringing reverse-engineering expertise and know-how back to their production sites in Europe, leveraging their strong complementary assets, such as respected brands and well-honed dynamic capabilities (Simonazzi et al. 2022).

Conversely, in the context of the German manufacturing industry, path dependency likely sealed the fate of the incumbents. To protect the investments and the experience accumulated with the old technology, German companies delayed investment in new, promising technologies for too long (Paba 2022). The formidable expansion of the Chinese market may have done the rest, breathing new life into saturated segments. What Chinese commentators said about their country's companies participating in joint ventures (JV) with foreign firms could also apply to German companies investing and exporting in China: 'spoilt children' who, because of guaranteed profits, had no incentive to grow and innovate.[23]

The final consideration concerns the lack of an EU industrial policy in recent decades comparable to the ones put forth by the US and mainly China (see the next section). For a long time, the EC equated industrial policy with competition policy,

23. Quoted in Paba (2022). The author seems to agree with the view that the Chinese policy of imposing JV hindered the creation of national champions: according to him, exploiting the clout that brands still commanded, especially in the premium class, foreign producers could retain control of most of the huge increase in the domestic production and sales of traditional, internal combustion engine cars. However, as argued in Simonazzi et al. (2022), dependency is mutual: sales in China became an essential part of OEMs' overall production. In 2021, GM produced 51 per cent of its global production in China, Honda 38.5 per cent, VW 36.7 per cent, BMW 28.1 per cent and Daimler 26.2 per cent.

marginalising measures aimed at creating, strengthening and protecting specific (strategic) industries. The explicit ban on State aid under the EU's competition law[24] limited selective industrial policy at the national level, but let more subtle, covered forms of industrial policies to continue in the core. Countries like Germany and France have actively supported their companies and industrial sectors to protect and advance their national economies (e.g. Germany's Industry 4.0 initiative), thereby exacerbating internal divides in the absence of an EU-wide industrial policy (Celi et al. 2020). This hands-off approach proved particularly harmful for the development of sectors and technologies at the frontier of innovation, which require selective industrial policies and coordinated, long-term actions (Andreoni and Chang 2019). Ultimately, it reduced the incentive to diversify Europe's production matrix beyond the consolidated core of the (German-led) export industries.

However, with new digital technologies pervading all industries, the core industry itself is being undermined. Digital platforms are penetrating all sectors, from retailing and tourism to advanced manufacturing and high-tech services, reaping huge profits (Germann 2022). The incapacity to master these technologies entails the risk of reducing the efficient European manufacturing machine to a mere producer of goods, on par with middle-income countries, thus exacerbating Europe's backwardness in all technological domains.

Overall, the European growth model stood on two vulnerable and interdependent bases. Externally, Germany's export-led model came to rely on cheap imports – Russian energy, Eastern European manufactured inputs and Chinese consumer goods – and growing Chinese markets. Internally, the austerity doctrine and the long-lasting core – periphery divide weakened the demand-pull engine of growth and delayed industrial restructuring. Thwarting opportunities of diversification, this model has weakened the EU's technological capabilities, increasing its import dependence and jeopardising its long-term competitiveness.

4 THE NEW EU INDUSTRIAL POLICY: TOO LITTLE, TOO LATE?

First the financial crisis and then the pandemic undermined the economic model on which the EU's economic policy was based: old certainties in the macroeconomic and economic policy fields are collapsing. The approach that inspired the European industrial policies has evolved from a theory of efficient markets, mandating non-intervention, to a 'horizontal' approach progressively integrated with an explicit attempt to intervene 'vertically' in the structure of production, targeting strategic technologies and supply chains (Mosconi 2022). This change has been accompanied by an evolution of economic theory, which recognises that markets, left to their own devices, continue to do what they do best: confining countries to their specialisation. As a result, previously absent concepts in the European debate, such as the need for public investments and selective industrial policies, are back to the fore. This section examines whether the *new industrial policy* put forth by the EC in the last few years[25] is adequate to

24. The primacy of the competition law over European and national industrial policies results from the drafting of the treaty, the regulation implementing the competition rules and the merger regulation.
25. The EU's new approach to industrial policy is characterised by increased activism on the part of the European Commission. This shift can be made to coincide with the *Renewed EU*

narrow Europe's structural vulnerability, reduce its technological gap and address its internal inequalities.

Before this shift, industrial policy was primarily conceived as competition policy, with the goal of increasing efficiency in the existing industries by applying the new digital technologies (as illustrated by the Industry 4.0 plan) rather than building strategic autonomy in the new sectors (Edler et al. 2023). The profound ongoing process of reconfiguration of global value chains has switched the emphasis towards innovation and structural change, with a number of actions directed at ensuring the EU's autonomy in digitalisation and green technologies (Dullien and Hackenbroich 2022; Terzi et al. 2023).

This new agenda is based on three pillars: supply diversification, incentives to encourage private investment and industrial JV, and constant monitoring of areas of greatest dependence.[26]

Recent proposals, such as the *Fit for 55,* the *REpowerEU*, the *Critical Raw Materials Act* and the *EU Chips Act*, enrich the framework of initiatives for climate neutrality, energy autonomy and digital sovereignty. Even the need to protect the internal market has been considered, with the introduction of an *FDI Control Framework* aiming to provide member countries with a coordinated mechanism for screening new foreign investment to prevent predatory takeovers or other threats to European strategic interests without undermining the open nature of the Union's industrial strategy.

The EU's new approach to industrial policy thus represents *a major U-turn but it still retains key features of the past.* The instruments still largely rely on a 'horizontal approach' (Landesmann and Stöllinger 2019). There is no common European fund (like the Next Generation EU, which must remain an exception): the bulk of resources must come from individual countries. These resources are allocated to green transition and digitisation through infrastructures (e.g. high-speed broadband coverage) and fiscal incentives for enterprises to adopt new digital and green technologies. In the context of weak productive and technological capabilities, these measures risk increasing import dependence.

In contrast, 'Buy American' clauses, which require the purchase of intermediate goods and technologies produced by domestic firms, aim at maximising the structural impact of public intervention (Di Tommaso et al. 2020). In exchange for these strong conditionalities, the amount of support made available by the US programmes is remarkable, risking to derail Europe's strategy. The US launched the *Inflation Reduction Act* (IRA) aimed at increasing industrial and technological capacity, with a significant share of resources channelled to attract, among others, companies operating in the semiconductor and lithium-ion battery industries, as well as in the renewables industry.

Therefore, while the EC is slowly adjusting its approach, its fiscal incentives and regulations are hardly competitive with the vertical and selective strategies implemented in China and the US, which employ massive public investment and direct government actions (e.g. 'mission-oriented' programmes, trade restrictions and strong conditionalities) to strengthen or, as in the Chinese case, create industrial capabilities in sectors at the technological frontier (Lundvall and Rikap 2022).

Industrial Policy Strategy (2017) – marked by the establishment of the *Important Projects of Common European Interest* (IPCEI) – and even more with the Communication on the *New Industrial policy* of 2020 (European Commission 2020d; Terzi et al. 2023).

26. A detailed description of the EC's strategy can be found at: https://single-market-economy.ec.europa.eu/industry/strategy_en.

The EU's *Chips Act* provides a telling example. This measure targets the semiconductor industry with the commitment to mobilise up to €43 billion by 2030 (European Commission 2022b), an amount seemingly comparable to the one recently allocated by the US for the *CHIPS and Science Act* (US$ 52.7 billion). A closer examination, however, reveals some distinctions. Notably, no additional resources are provided, as the funding mainly comes from *Horizon Europe* and *Digital Europe Programme.* Moreover, this €43 billion figure relies on the activation of private investments. In fact, public investments account for roughly €11–13 billion only (Dachs 2023). Finally, we should remember that the digital transformation started in the US some 30 years ago, giving it undisputed leadership, especially in the design segment. Conversely, despite China's huge and incomparable financial efforts, amounting to US$ 150 billion of public investment over a decade, its production capacity is still confined to the low-end assembly segment.[27] Nevertheless, the US and China now collectively account for 90 per cent of the market capitalisation value of the world's 70 largest digital platforms (UNCTAD 2019).

What are the chances of success for the EU's policy, squeezed between countries, such as the US and Taiwan, dominating the higher end (design and fabrication) and others, such as China, with excess capacity in the production of lower end segments (assembly, production of low-end chips, memory cards, etc.)? Some scholars (García-Herrero and Weil 2022, among others) argue that rather than focusing on the fabrication segment, where the EU's comparative advantage is uncertain and the risks of dissipating considerable financial resources are high, the EU's *Chips Act* should focus on the design segment and related R&D activities. However, it is doubtful that separating R&D from production represents a viable solution; moreover, this could increase the EU's exposure to the risks of bottlenecks resulting from geopolitical conflicts and CRMs' scarcity, besides widening the internal gap between EU countries/regions endowed with different technological capabilities. If properly coordinated, the single market is large enough, and the EU has sufficient financial and human resources to elicit a diversification strategy in the final stage of the production chain.

Transition to green technologies poses different challenges. The *REpowerEU* plan targets three fundamental objectives: greater energy efficiency, an acceleration in the use of renewable sources and diversification of suppliers. However, the EU is highly dependent on critical raw materials, extracting only 1 per cent and processing only 8 per cent of the feedstocks needed for lithium-ion batteries (European Commission 2021b). For this reason, the EC proposed a *Critical Raw Materials Act* to ensure the security of supply by diversifying sources and strengthening international engagement, facilitating extraction, processing and recycling (European Commission 2022a). This would require a challenging shift in the EU's external stance, aiming to establish a mutually beneficial and sustainable relationship with producing countries, moving away from the old 'extractivist' model and implementing multi-dimensional partnerships designed to support decarbonisation, socioeconomic development and human security in both the EU and its partner countries (Quitzow et al. 2022).

27. Despite deploying immense public resources to develop the (capital- and technology-intensive) segment of high-end chip fabrication, a number of (state-owned) enterprises have gone bankrupt, demonstrating that in highly competitive high-tech sectors, even substantial financial resources are insufficient to guarantee success in upgrading the supply chain. Moreover, the export restrictions imposed by the US, including some key inputs for the design segment, compound the difficulties that China faces in its attempt to catch-up in the semiconductor industry.

Furthermore, CRM bottlenecks are not the only risk in the EU's *REpowerEU* plan. The tax incentives provided to increase the share of green energy production (e.g. installation of PV panels) may increase the import dependency on strategic inputs and components. Aware of this risk, the EC has recently introduced the *Green Deal Industrial Plan for the Net-Zero Age*, which sets an overall target for EU domestic manufacturing in strategic net-zero technologies, aiming to reach at least 40 per cent of the EU's annual deployment needs by 2030 (European Commission 2023).

One of the most worrisome characteristics of the new industrial policy is that it still thinks 'in silos'. Structural transformations are neither an easy nor painless process. While declaring its ambitious climate change mitigation goals, the EC paid little attention to the disruption it would cause for some sectors or regions. A holistic approach to green and digital transitions should have considered the issues of how to address the costs for businesses, workers and entire clusters displaced by transitions. The fact that this has largely been left unattended or left to countries or regions explains the growing hostility to these policies. This issue is related to internal cohesion: EU industrial policies must avoid further widening inequalities between and within countries. If national fiscal policies are bound by some form of Stability Pact, an EU-wide policy is needed to ensure that the most affected sectors are not left on their own and that less developed regions are not left behind.

The Next Generation EU (NGEU) was the first tangible attempt to provide an EU financial instrument, but it reinforces the role of national policies rather than promoting a more coordinated European approach to intervention. Moreover, the easing of State aid rules risks favouring less fiscally constrained countries, increasing divergences. National policies must be coordinated to avoid a race-to-the-bottom competition to attract investment. A financial institution, similar to the European Investment Bank, that can finance public investments on a European scale, is not yet on the agenda (Pianta et al. 2020). The CHIPS and Science Act in the US could serve as an example, at least on paper. As noted by Parilla et al. (2023), policies should focus on programmes creating 'spill-over benefits' for communities, including investments in workforce, education and infrastructure, rather than policies like direct tax abatements that benefit individual firms.

5 CONCLUSIONS

This work adds to the growing literature focusing on the sources of the EU's structural vulnerability and the policies capable of mitigating it (Leonard et al. 2019; Crespi et al. 2021; Edler et al. 2023). We assessed Europe's vulnerability, identifying four interconnected channels and exploring its relationship with the EU's economic model. We argue that the EU's pro-cyclical fiscal framework 'killed' demand and reduced public and private investment. The vicious circle between demand repression and supply deterioration has constrained innovation and growth, particularly in the southern periphery, whose stagnation has negatively affected the potential of the EU market, deepening the core–periphery divide. The latter has made it more difficult to achieve a common policy, making Europe as a whole more fragile in the face of external shocks.

The lack of an EU-wide selective industrial policy has also contributed to the EU's technological backwardness in new frontier technologies. We have assessed the recent change in the EU's industrial policy approach, acknowledging a significant shift towards a more selective stance based on the identification of strategic sectors. However, the market-based horizontal logic still persists, with incentives remaining the dominant instrument, EU-level coordination still being inadequate and no European champions in sight. Moreover, the amount of EU resources is not comparable to those put forth by the US and China, particularly when considering the relative technological gap. Left to the fiscal capacity of individual member states, technological dependence risks grow in the EU's economy, especially in the southern periphery, where industrial capacity has been most affected by recent crises.

The EU's single market is large enough, and the EU has sufficient financial and human resources to counter the oligopolistic dominance of incumbents in new technologies. However, regulation and subsidies alone will not suffice. The EU's long tradition in environmental regulation has not prevented it from being overtaken by China, just as its anti-monopoly regulation in the digital field has not stimulated the emergence of a national industry. What the EU needs is an industrial policy capable of shaping markets, based on public investment and procurement, to attract private investment, ensure coordination between countries and the inclusion of SMEs. The outcome will depend as much on the ability to reform its macroeconomic model as on the implementation of industrial policies capable of ensuring maximum cohesion between and within countries and regions.

Much will depend on Germany. Its export-led model relied on Russian resources and Chinese markets. Its political and financial links, however, lie with the Atlantic Alliance. The foreign policy of the German government towards China is clashing with the conspicuous economic interests of German companies, such as Volkswagen or BASF. It is doubtful that Germany is willing to permanently subordinate its industry, technology and trade strategies to Washington. It cannot go alone in the international arena, but Germany can go either taking care of the development of the whole EU or as the leader of a (weakened) economic empire. Past experience has demonstrated the short-sightedness of the latter option. If the engine of growth falters, distributional conflicts within and between societies intensify, fuelling a global trend towards protectionism. In such a world, there can no longer be any 'world champions' in exportation. Germany, and hence Europe, must rethink their economic model.

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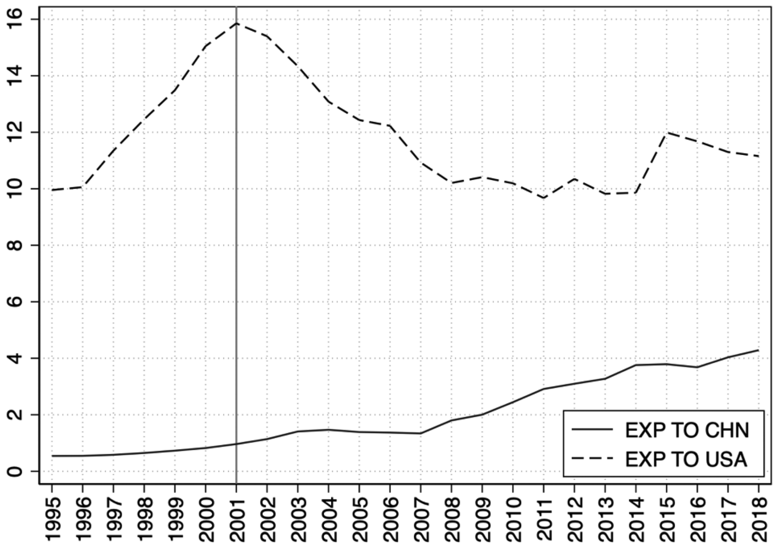
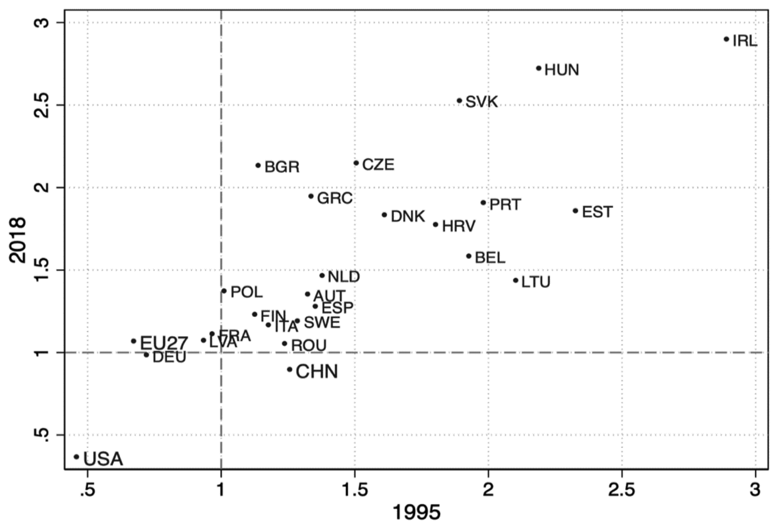
APPENDIX 1



Source: Authors' elaboration based on the OECD's ICIO tables. The vertical line marks China's accession to the WTO.

Figure A1 Share of China and the US in EU exports of final goods



Source: Own elaborations based on the OECD TiVA database.

Figure A2 GVC positioning (1995–2018)

Table A1 Overview of critical raw materials

Critical raw materials	Supply risk	Stage at risk	EU major Applications	Global suppliers (per cent)	EU27 suppliers (per cent)
REEs*	VH	Processing	Automotive catalyst, Glass	CHN (86)	CHN (98)
Magnesium	H	Processing	Automotive, Steel industry	CHN (89)	CHN (93)
Niobium	H	Processing	Construction, Automotive	BR (92)	BR (85)
Borate	H	Extraction	Glass, Ceramics, Fertilisers	TR (42)	TR (98)
Germanium	H	Processing	Infrared optics, Optical fibres	CHN (80) FI (10)	FI (51)
Scandium	H	Processing	Solid Oxide FC, Aerospace	CHN (66)	UK (99)
Cobalt	M	Extraction	Superalloys, Hard materials	CD (59)	CD (68), FI (14)
Strontium	M	Extraction	Drilling fluids, Magnets	ES (31)	ES (100)
Platinum**	M	Processing	Autocatalysts, Jewellery	ZA (71)	–
Palladium**	M	Processing	Autocatalysts, Electronics	RU (40)	–
Rhodium**	M	Processing	Autocatalysts, Chemical	ZA (80)	–
Iridium**	M	Processing	Electronics, Electrochemical	ZA (92)	–
Ruthenium**	M	Processing	Electronics, Chemical	ZA (93)	–
Nat. Graphite	M	Extraction	Refractories, Li-ion batteries	CHN (69)	CHN (47), BR (12)
Lithium	L	Processing	Glass, Ceramics, Cement	CL (44) CHN (39)	CL (78)
Silicon Metal	L	Processing	Chemical, Aluminium alloys	CHN (66)	NO (30) FR (20)
Titanium	L	Processing	Paints, Polymers, Aerospace	CHN (45)	NO (25), ZA (18)
Indium	L	Processing	Flat panel display, PV cells, SC	CHN (48)	FR (31), BE (26)
Vanadium	L	Extraction	HSLA & Special steel, Storage	CHN (39)	AT (52), RU (32)
Tungsten	L	Processing	Mill cutters, Mining, Construc.	CHN (69)	CHN (26)
Gallium	L	Processing	Int. circuits, CIGS solar, LED	CHN (80) DE (8)	DE (35), UK (28)
Hafnium	L	Processing	Superalloy, Plasma cutting, SC	FR (49)	FR (84)

(continued)

Table A1 (continued)

Critical raw materials	Supply risk	Stage at risk	EU major Applications	Global suppliers (per cent)	EU27 suppliers (per cent)
Antimony	NA	Extraction	Flame retardant, L-A battery	CHN (74)	TR (62)
Baryte	NA	Extraction	Drilling fluids, Filler in rubber	CHN (38)	CHN (38)
Bauxite***	NA	Extraction	Transport, Construction	AU (28)	GN (64)
Beryllium	NA	Extraction	Electronics, Transport, Defence	US (88)	US (55), KZ (23)
Bismuth	NA	Processing	Chemical, Low-melting alloys	CHN (80)	CHN (49)
Coking coal	NA	Extraction	Steel, Electricity	CHN (55)	AU (24)
Fluorspar	NA	Extraction	Steel, Aluminium	CHN (65)	MX (25)
Nat. Rubber	NA	Extraction	Automotive, Machinery	TH (33)	ID (31)
Phosp. Rock	NA	Extraction	Mineral fertiliser	CHN (48)	MA (24)
Phosphorus	NA	Processing	Chemicals, Electronics	CHN (74)	KZ (71)
Tantalum	NA	Extraction	Capacitors, Sputtering targets	CD (33)	CD (36)

Note: The supply risk is classified as VH – *Very High*; H – *High*; M – *Moderate* and L – *Low*. All the materials classified as VL – *Very Low* have been excluded (nickel, copper, manganese, zirconium, tellurium and chromium).
* Rare Earth Elements (HREEs): dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium, cerium, lanthanum, neodymium, praseodymium, promethium and samarium.
** Platinum Group Metals (PGMs).
*** Bauxite is the primary raw material used to produce aluminium metal.
Source: The list of 47 individual CRMs [1] and the main global [5] and EU suppliers [6] are taken from European Commission (2020b), as well as the stage at risk [3], which refers to the production stage. Suppliers' data refer to the 2012–2016 period. The associated supply risk [2] comes from European Commission (2020a). The EU's current main applications for each material are taken from European Commission (2020c).