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How fragile are European GVCs? The role of functional diversification and implications for industrial policy

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Abstract

This paper examines the relationship between functional diversification and foreign input reliance (FIR) in European countries, with a focus on manufacturing sectors. We propose that greater functional diversification is a key strategy to soften dependency on foreign inputs, thereby mitigating the risks associated with Global Value Chain (GVC) disruptions. We elaborate on recently developed indicators for GVC exposure based on international gross trade flows and test their association with a novel measure of functional diversification, proxied with data on Foreign Direct Investments (FDIs) across value chain activities. Our findings reveal that functional diversification is negatively associated with FIR, particularly from extra-EU sources, indicating that European countries can reduce exposure to GVC disruptions by diversifying value-adding functions. However, this relationship is also found with reference to the intra-EU FIR component, suggesting that functional diversification strategies undertaken at the level of individual member states may end up weakening European trade integration. We conclude that the EU's Open Strategic Autonomy framework should carefully consider coordinated industrial strategies to strengthen the EU's capacity to navigate GVC disruptions without undermining intra-EU trade ties.

Keywords Global value chains · FDI · GVC exposure · Europe · Diversification

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1 Introduction

The global economy has been increasingly characterized by the dispersion of value chain activities across borders and the creation of intricate webs of interdependence among countries (Feenstra, 1998; Timmer et al., 2014). This evolution has opened up new industrialization and growth opportunities, especially for emerging economies that have managed to join global value chains (GVCs) to climb the development ladder (Baldwin, 2016; World Bank, 2020). However, this heightened interconnectedness has also introduced significant risks: while GVCs can mitigate supply shortages when domestic value chains are disrupted, they can make economies more vulnerable to global disruptions such as trade wars, pandemics, and geopolitical tensions, which can severely affect the flow of intermediate inputs, critical components and know-how (Bonadio et al., 2021; Borin et al., 2021; Espitia et al., 2022). For an open economic area such as the European Union (EU), understanding how to balance the benefits of GVC integration with the risks of external shocks is a key challenge (Giovannetti et al., 2023).

While much of the existing literature has focused on diversification of suppliers as a means to mitigate GVC risks (Carvalho et al., 2021), there is limited research on the role of functional diversification of economies involved in global production networks, i.e., the capacity of countries to perform a relatively wide range of value-adding activities within a given value chain.

This paper addresses this gap by examining how functional diversification can allow European manufacturing sectors to soften their foreign input reliance (FIR), thereby mitigating the risks associated with GVC disruptions. We argue that functional diversification favours innovation and enhances the capacity of economies to more flexibly recombine domestic resources, hence facilitating more selective supply chain strategies and limiting the need to resort to riskier non-EU suppliers. To the extent that the latter can be at least partially replaced by more reliable European partners, the EU's exposure to trade disruptions originating outside Europe can be substantially reduced.

By the same token, we suggest that functional diversification strategies, if conducted at the level of individual countries and with limited or no coordination at the European level, may undermine trade and technological interdependence links that have proliferated over a long history of regional integration. In fact, while functional diversification may reduce countries' reliance on non-EU suppliers, there is a risk that increased national-level diversification could undermine trade integration within the EU, weakening internal economic cohesion and threatening the EU's economic strength.

This sort of "dilemma" represents the central issue this paper aims to address: can European countries increase functional diversification to soften reliance on non-EU suppliers without jeopardizing critical intra-EU trade links?

This paper offers three main contributions to extant literature. First, it endorses a shift from sectoral to functional diversification in the analysis of de-risking strategies to deal with the changing configuration of GVCs. We develop this perspective and adapt it to the European context, providing insights into the challenges to be addressed to tackle instability in supply chains. Second, we disaggregate the FIR into

its intra-EU and extra-EU components to explore the exposure of EU member states to other EU countries vis-à-vis potentially riskier extra-EU trade partners. Third, we provide novel empirical evidence on functional diversification of European economies and investigate how such diversification is associated with their exposure to GVC disruptions over the 2003–2018 period.[1]

By examining these issues, this study contributes to the growing body of literature on GVC resilience and European industrial policy, shedding light on how functional diversification can be leveraged to achieve greater self-reliance without undermining intra-EU trade relationships. In particular, we suggest that the EU's path towards Strategic Open Autonomy, aimed at reducing dependence on non-EU suppliers in strategic value chains while maintaining economic openness (European Commission, 2022), should be based on a fully EU-coordinated and inclusive industrial strategy to strengthen the role played by EU economies in GVCs without undermining intra-EU trade ties (Fontana & Vannuccini, 2024).

The remainder of the paper is structured as follows. Section 2 presents the conceptual framework, Sect. 3 discusses the data used and the methodology adopted, and Sect. 4 offers extensive descriptive evidence on the key analytical dimensions considered. In Sect. 5, we illustrate the empirical strategy used to test the association between functional diversification and FIR of European manufacturing sectors, while Sect. 6 shows the estimate results. Section 7 concludes by drawing policy implications in light of the EU's Open Strategic Autonomy agenda.

2 Background literature and interpretive framework

In this section, we contextualize the present study in extant literature and adapt the interpretive framework developed by Coveri et al. (2024) to the analysis of exposure to GVC disruptions in an integrated region like the EU. The framework, originally designed to address how functional diversification can affect the capacity to handle GVC-related trade risks in the case of a broader set of countries and macro-regions, will be organized as follows. First, we will sketch a critical assessment of specialization and diversification as key sources of gains from trade. Second, we will reflect on how functional diversification can affect the reliance of economies on foreign supplies, with specific attention to issues particularly relevant for integrated areas in general and the EU in particular.

2.1 Specialization and diversification in GVCs

The role of specialization as a key source of economic benefits has long been emphasized in economics and has received critical attention in trade and development literature. First, as argued in seminal contributions by Rosenstein-Rodan (1943), Prebisch

[1] Since the empirical analysis conducted in this work mainly covers the pre-Brexit period and the effects of the latter on trade relations with the UK have only partially unfolded in the immediately subsequent years, we will refer to the EU as the aggregate of European countries, including the EU27 plus the UK. Hereafter, we will thus use EU and EU27 + UK interchangeably unless specified otherwise.

(1950), Singer (1950), Myrdal (1957), Hirschman (1958) and Kaldor (1967), some paths of specialization are more likely to yield economic development than others. Countries that specialize in industries characterized by greater learning effects and returns to scale are in a better position to undertake sustained economic development (Amsden, 1989; Dosi et al., 1990). Second, gains from specialization vary depending on the aggregation level of the analysis. As stressed by Hausmann (2013), higher specialization of economic agents at the micro level goes together with greater diversification at the macro level. Indeed, while the specialization of individual workers leads to improved efficiency, this may not be true at the firm level (according to the nature and variety of skills held) and even less so at higher levels of aggregation (e.g., at the city, region and country scale). Consequently, while individuals may benefit from specialization, there may well be gains from diversification at more aggregated levels of analysis (Imbs & Wacziarg, 2003).

The structural transformations of the late 20th and early 21st centuries have further complicated the relationship between specialization and diversification. The decline of manufacturing as a share of employment and output—commonly referred to as deindustrialization—has reshaped economic trajectories in both advanced and developing economies (Rowthorn & Wells, 1987). In many cases, this process has occurred prematurely, as highlighted by Rodrik (2016), limiting growth and opportunities for industrial upgrading. At the same time, the growing role of services in manufacturing competitiveness—known in the economics literature as "servicification of manufacturing"—has blurred traditional sectoral boundaries (Francois & Hoekman, 2010; Bernard & Fort, 2015; Baldwin & Ito, 2021). These shifts suggest that both specialization and diversification strategies must account for the expansion of service activities and the challenges posed by industrial decline, especially in the context of internationally fragmented production.

A further line of inquiry on the structural determinants of growth opportunities has been opened by a relatively recent strand of literature adopting an "economic complexity" approach to development trajectories. The core idea put forth in this approach is that countries equipped with a broader set of capabilities can produce a larger number of products, and thus will present a more diversified export basket; by the same token, products which require more capabilities to be produced will be realized and exported by few countries, implying that these products are less ubiquitous. A key implication is that countries that are more able to diversify (especially into complex products) are more likely to undertake sustained development patterns (Hausmann et al., 2007; Hidalgo et al., 2007; Hidalgo & Hausmann, 2009). Moreover, this approach further highlights how specialization and diversification patterns are intertwined. In fact, specialization in high-tech manufacturing entails the development and use of a wider variety of competencies, which is likely to open the way to diversification into complementary product lines. By contrast, specializing in low-tech manufacturing lacks this dynamic feature and creates fewer diversification opportunities.

While the economic complexity literature has highlighted the growth opportunities associated with exporting a greater variety of products, the emergence and evolution of GVCs induces a further re-consideration of the diversification argument.

Indeed, important conceptual and empirical issues must be tackled when dealing with this changing scenario (Coveri & Zanfei, 2023a).

From a *conceptual point of view*, one needs to acknowledge that by merely decomposing the exports of a given country (region or firm) into finer and finer categories of goods to include product parts and components, one can derive no relevant information on what value-adding functions are being undertaken to bring those products to market. A fundamental feature of the international fragmentation of production is that GVC activities *within* individual industries and product lines are associated with different value generation and appropriation opportunities (Mudambi, 2008; Shin et al., 2012; Durand & Milberg, 2020; Coveri & Zanfei, 2023b). In this context, the diversification that matters occurs at the functional level even more than at the industry level.

Our emphasis on functional diversification connects to the literature on the "smile curve hypothesis", which highlights how value capture opportunities differ across GVC stages. In particular, actors performing the most intangible-intensive activities at the upstream (e.g., R&D, design) and downstream (e.g., branding, marketing, after-sales services) ends of the value chain are typically assumed to capture higher value than those carrying out midstream activities like manufacturing and assembly (Mudambi, 2008). This framework provides a valuable lens to further explore the intricate relationship between specialization, diversification, and value chain dynamics. In fact, this stream of research has highlighted that specializing in high value-adding activities at the upper segments of the value chain, such as R&D or marketing, often requires countries to develop a diverse set of complementary capabilities. This process can foster functional diversification, enabling economies to broaden their technological and organizational portfolios and opening up greater development opportunities (Hausmann & Rodrik, 2003; Lee & Gereffi, 2021). By contrast, specialization in midstream manufacturing—characterized by lower value-adding activities and less pronounced dynamic returns—rarely drives such diversification. Economies focused exclusively on these functions risk falling into middle-income traps, lacking the innovative momentum and adaptability needed to thrive in GVCs (Felipe, 2012; Agénor, 2017; Stöllinger, 2021; World Bank, 2024).

What remains largely implicit in this strand of literature is the connection between changes in the value chain positioning of economies and their exposure to potential GVC disruptions. While entering more knowledge-intensive activities is a key avenue to greater value capture, a large variety of upgrading patterns can be followed. For instance, functional upgrading might be obtained by de-specializing in low value-adding activities to free resources that can be used to perform higher value-adding functions (what might be dubbed *substitutive upgrading*). Alternatively, countries might pursue the expansion of their range of capabilities by supplementing with higher value-adding activities those they already perform (*additive upgrading*). Of course, the latter strategy is constrained by resource endowments and investment capacity and could result beyond the possibilities of individual countries. Nonetheless, an *additive upgrading* strategy is more likely to strengthen the capacity of the economy to deal with disruptive events, as the economy will have a broader range of domestic capabilities and more options to combine creatively in response to such events.

Hence, in the context of GVCs, functional diversification can act both as a buffer against external shocks and as a pathway to higher value-adding positions along the value chain. This synergy highlights that specialization and diversification are not strictly opposing strategies but can evolve together, particularly when economies prioritize innovation and knowledge-intensive activities. By combining these strategies, countries' participation in GVCs can be more robust to external shocks while promoting economic growth. This is the line of argument we will develop in Sect. 2.2 below with specific reference to the case of integrated regions like the EU.

When it comes to empirical studies, the measurement of functions has long been quite challenging. Let alone the approaches based on the detailed qualitative case studies concerning the GVC of specific products or industries (e.g., Dedrick et al., 2010), works using input-output based measures of the international fragmentation of production (Johnson & Noguera, 2012; Koopman et al., 2014; Timmer et al., 2014) do help identify the foreign input content of exports in a given sector, but fail to capture *what* value-adding activities are performed in that sector (de Vries et al., 2021).

Empirical research has recently addressed the functional profile of economies more explicitly. Timmer et al. (2019) have opened a new line of analysis by providing a methodology to compute the 'functional specialization in trade' based on the occupational categories of workers employed in the production of exported goods. Their approach consists in measuring the amount of value added associated with specific tasks embodied in goods and services exchanged along GVCs (Buckley et al., 2020). Another strand of contributions makes use of data on foreign direct investments (FDIs) undertaken in different value chain functions (such as R&D, fabrication operations, sales and after-sale activities) to analyze the cross-border dissemination of functions within GVCs controlled by large multinational corporations (Stöllinger, 2019; Zanfei et al., 2019). These works developed indicators of 'functional specialization in FDI' and applied them in analyses at the country-industry level (Stöllinger, 2021) and at both country and subnational region level (Coveri & Zanfei, 2023b; Coveri et al., 2024a, b).

Overall, these contributions have provided novel methodologies to gauge the functional positioning of economies along GVCs by means of functional specialization indicators. However, they have largely overlooked the role played by the level of functional diversification of countries and industries, as well as its potential connection with the exposure to GVC disruptions. Exploring this connection is the subject of the next subsection.

2.2 Functional diversification, GVC risk exposure and the case of integrated regions

The discussion above paves the way for the analysis of how functional diversification affects the ability of countries to deal with supply chain disruptions. Our study relies on three main building blocks.

The first conceptual block has to do with *innovation*. The key argument is that economies performing a relatively wide variety of value-adding activities can be better placed to generate valuable knowledge and capabilities. As suggested by Pisano and Shih (2012), strategies based on the offshoring of manufacturing may be advan-

tageous for individual firms, but this is much less the case when the analysis is carried out at the level of the economic system as a whole. In fact, such strategies may lead to the erosion of "industrial commons", which the authors identify with the "webs of technological know-how, operational capabilities, and specialized skills that are embedded in the workforce, competitors, suppliers, customers, cooperative R&D ventures, and universities and often support multiple industrial sectors" (Pisano & Shih, 2012, p. 13). Furthermore, the pursuit of cost reduction through production offshoring while specializing in a circumscribed range of functions—albeit strategic such as Design, R&D and headquarter services—may hamper the capacity of firms to exploit internal and external economies of agglomeration (Feldman & Kogler, 2010). This is particularly the case of industries wherein innovation processes heavily rely on tacit knowledge exchanges, making it crucial to exploit the geographical proximity between firms and business units carrying out different activities (Dankbaar, 2007; Castellani & Lavoratori, 2020; Fagerberg, 2022).

What these research lines suggest is that a wider array of activities can favour innovation capacity. Far from creating upgrading opportunities, strategies based on dismantling manufacturing activities to concentrate on higher value-adding functions at home might hinder the long-term competitiveness of economies.

Moreover, these lines of argument also support the view that functional diversification, by favouring innovation, may also affect the international performance of economies (see Castellani et al., 2022, for a review of the links between innovation and cross-border investment). Specifically, by enhancing innovation, functional diversification increases the capacity of economies to creatively react to supply chain interruptions, thus reducing the damage associated with sudden foreign market contractions. Moreover, functional diversification increases the capacity of domestic firms to absorb and utilize foreign inputs. Functional diversification may thus enable economies to better select foreign sources, reducing their reliance on foreign inputs. In our empirical exercise, we will consider the latter import-reducing effect while neglecting the former export-expansion effect.

The second building block of our interpretive framework refers to *risk management*. The idea is that functional diversification helps distribute the risk related to individual activities, thereby moderating the adverse effects of sector-specific shocks (Grabher & Stark, 1997; Boschma, 2014; Doran & Fingleton, 2018). In line with this view, the capacity of countries to diversify economic activities reflects the availability of a wider range of technological and organizational capabilities that are needed to absorb unprecedented shocks and to undertake new paths of development (Pendall et al., 2010; Pike et al., 2010; Martin, 2012).

While this line of argument is quite convincing per se, it requires reformulation consistent with a functional approach. Indeed, sectoral diversification may well be associated with a narrow variety of productive and knowledge capabilities. Should economies be active in a wide variety of sectors but specialized in a circumscribed range of functions, they will likely exhibit a limited capacity to tackle unforeseen changes. Hence, sectoral patterns of specialization are per se a poor predictor of domestic actors' capabilities to mobilize knowledge assets and resources to effectively recover from adverse GVC shocks. The competencies needed to carry out as diverse value chain functions as R&D activities, design, manufacturing and assembly

operations, logistics and supporting services are very different and do not entail the same opportunities in terms of learning effects, returns to scale and competencies (Gereffi, 2014; Timmer et al., 2019; Stöllinger, 2021; Coveri & Zanfei, 2023b).

It follows that functionally diversified economies are more likely to creatively respond to supply chain disruptions. In fact, they are more likely able to replace external resources with domestic ones. Moreover, they can combine a wider set of domestic competencies with alternative external inputs in case of sudden supply chain interruptions.

The implications of this line of reasoning are twofold. On one side of the coin, by increasing the capacity of economies to manage risky conditions, functional diversification might well induce them to maintain or even increase foreign input reliance. Under this circumstance, greater functional diversification would lower *risk aversion* and thus be positively associated with foreign input reliance. On the opposite side, by widening the range of domestic competencies available to respond to unpredicted changes, functional diversification might lower *the actual need for foreign inputs*. This entails greater self-sufficiency in case of supply chain disruptions. If this mechanism prevailed, functional diversification would turn out to be negatively associated with foreign input reliance. Our empirical analysis should help detect which effect will predominate, i.e., whether functional diversification will reduce risk aversion (hence increasing countries' and industries' exposure); or rather augment the self-sufficiency of economies (thereby decreasing their exposure in case of supply chain disruptions).

The third building block of our research line has to do with regional integration. This is, of course, a relevant aspect in the case of EU member countries. We have argued that functional diversification patterns may induce greater innovation capacity and, combined with risk aversion, can reduce the propensity of economies to rely on foreign suppliers. These mechanisms are also at play in the case of countries belonging to regionally integrated areas, but the functional diversification-foreign reliance nexus is likely more nuanced here.

One might, in principle, expect that the forces pushing in the direction of reducing foreign input reliance are stronger in the case of trade relations with partners *outside* the integrated area than *within* the same area. The EU is a relevant illustrative case in point. When facing disruptive events, EU member states should be more prone to undertake functional diversification strategies to reduce dependence on inputs from extra-EU trade partners than substituting other EU suppliers. This is for two reasons. First, standard trade creation and trade diversion mechanisms increase interdependence between member states (Viner, 1950; Frankel & Rose, 1998; Baldwin, 2006), thus moderating the negative effect of functional diversification. Second, members of integrated areas accumulate a history of cultural and institutional proximity, making them more easily reliable and trustworthy (Guiso et al., 2009), especially in a phase of mounting geopolitical tensions and trade wars.

However, while these integration mechanisms might soften the negative impact of functional diversification on foreign input reliance in the case of intra-EU trade relationships, some countervailing pressures could be exerted by internal disaggregating tensions within the Union, such as the emergence and take-over of nationalistic and populistic movements in some member states (Rodrik, 2018). This might induce sev-

eral countries to use functional (and sectoral) diversification as a weaponised strategy to reduce reliance also on other EU suppliers. Under such circumstances, one might observe a trend towards Strategic Autonomy with a much lower degree of Openness—and much less regionally coordinated action—than assumed in official EU documents (European Commission, 2020). Once again, assessing which effect prevails is largely an empirical question. The recent intensification of internal and global tensions might increase centrifugal forces, leading some countries to strengthen domestic activities to curb exposure also to other member states. In the case of the EU, this might have been the case of pathbreaking events like Brexit, which does not seem to have had any beneficial effects on intra-UE trade (Giammetti, 2020); and the emergence of diverging positions of member states concerning key policy issues such as migrations, resurging austerity measures and military matters (e.g., *vis-à-vis* the Russia-Ukraine and the Israeli-Palestinian conflicts). In a context of increasing departures from multilateralism, with the EU undertaking more confrontational postures in trade policy in recent years (Bauerle Danzman & Meunier, 2024; Mariotti, 2024), there is evidence of a higher propensity for EU member states to influence the decisions of national antitrust and the EU's regulatory authorities to condition the international movement of goods and capital to geopolitical objectives and national interest (Mariotti & Marzano, 2024).

The discussion above leads us to formulate the following research questions: *how does the functional diversification of EU economies affect their exposure to global supply chain interruptions? Is this effect different if the suppliers originate from inside or outside the EU?*

3 Data

Our analysis focuses on 17 manufacturing sectors belonging to 17 European economies over the period 2003–2018. Sector-wise, the focus on manufacturing industries is justified by their significantly higher trade intensity compared to services, making them more closely integrated into GVCs and, consequently, subject to greater foreign input reliance. Notably, the manufacturing sectors considered comply with the NACE Rev. 2 classification and are listed in Table 5 in the Appendix.

As for the time span, we have access to the fDi Markets database from 2003 to 2018, limiting the availability of the information used to construct our FDI-based indicator of functional diversification (illustrated in Sect. 3.2) to this period.

As for the sample selection, data limitations concerning the number of inward FDIs yearly targeting country-industry pairs prompt us to exclude EU countries that attracted an especially low number of inward FDIs over the period. In particular, we included all country-industry pairs that attracted at least 5 FDIs in at least one year of the period considered. This threshold is crucial to improve the reliability of our index of functional diversification in FDI, as this allows us to avoid computing the latter on a remarkably low number of inward investments. As a result, 9 EU countries were excluded from the sample, since they did not attract at least 5 FDI in any of the 17 manufacturing sectors under investigation. We also excluded Ireland and the Netherlands, as their especially favourable profit tax regime inevitably affects the inward

FDI patterns recorded by these countries, regardless of the structural determinants at play (Hines, 2010). We are therefore left with a country panel comprising the following 17 European economies: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Poland, Portugal, Romania, Slovakia, Spain, Sweden and the UK.

3.1 Europe's risk exposure in GVCs: unpacking the foreign input reliance

In this work, we measure the exposure of EU industries to supply chain disruptions by leveraging novel indicators on gross output flows in GVCs recently proposed by Baldwin and Freeman (2022) and Baldwin et al. (2022, 2023). In particular, we focus on the Foreign Input Reliance (FIR) indicator, which measures a country-industry's dependency on foreign-sourced manufacturing and service inputs for its domestic production, accounting for both direct and indirect upstream interconnections in GVCs. FIR thus provides a comprehensive measure of countries' and industries' exposure to external shocks, as it traces the (direct and indirect) acquisition of foreign inputs along the entire value chains economies are involved in.

FIR is computed by exploiting the 2023 release of the OECD Inter-Country Input-Output (ICIO) tables, providing data for 76 economies and 45 industries (conforming to the NACE Rev. 2 classification) from 1995 to 2020. The calculation of FIR employs the Leontief inverse matrix to quantify direct foreign inputs as well as multi-tiered indirect dependencies throughout the supply chain. Formally, FIR is identified as:

$$FIR_{r,j,s} = \sum_{i}^{I} a_{i,j}^{r,s} \quad \text{for all } r \neq s$$

where $a_{i,j}^{r,s}$ represents the elements of the Leontief inverse matrix, capturing the total (direct and indirect) foreign input requirements from sector i in country r to produce one unit of output by sector j in country s.

The deliberate inclusion of double counting, whereby intermediate inputs are accounted for each time they cross national borders, is in line with the idea that a GVC bottleneck in a specific location can disrupt the entire value chain, beyond the impact on the value-adding contribution from that location. This intentional counting of intermediate inputs implies that the FIR indicator accounts not only for the size of the exposure to an upstream partner in the value chain but also for the "distance" separating buyers from foreign suppliers, as it grows with the number of cross-border transactions taking place along the process that will eventually lead to final gross output (hence reflecting the "length" of the value chain). Overall, the FIR can be interpreted as the proportion of total domestic output exposed to foreign disruptions in GVCs. In other words, this metric indicates how exposed economies are to the risk associated with events that might disrupt trade flows, interrupting supply chains on the import side.[2]

[2] Freeman and Baldwin (2022) also introduced another indicator to account for downstream GVC dependencies, i.e., a country's direct and indirect reliance on foreign clients. In this paper, we are interested in

While the indicators on GVC dependencies introduced by Baldwin and Freeman (2022) do not per se inform on how such risk translates into actual damage, recent research has shown that greater GVC exposure is associated with larger domestic output reductions after a shock occurring in upstream (or downstream) industries (Schwellnus et al., 2023).[3] This by and large confirms that these indicators are reliable predictors of the impact of shocks to foreign suppliers (and buyers) on domestic production (especially in sectors with high geographic and industry concentration, hence featured by few supplying countries and few supplying firms within the industry).[4]

Notably, the FIR indicator can be disaggregated into a potentially infinite number of components, breaking down reliance on foreign inputs by sector, country of origin, or even individual suppliers. For the purpose of this analysis—focused on the risk exposure of European Union (EU) countries—we adopt a specific disaggregation that reflects the structure of the EU Single Market. Given the high level of economic integration within the EU (Giammetti et al., 2022), it is particularly insightful to decompose the FIR into two key components: the intra-EU FIR and the extra-EU FIR (hereafter intra- and extra-EU FIR, respectively).

The rationale for this specific disaggregation stems from the unique nature of the EU's highly integrated trade and production network. The EU Single Market has fostered seamless movement of goods, services, capital, and people across member states, creating a dense web of interdependence within the region. As a result, EU member states typically source a substantial portion of their foreign inputs from other EU countries. This can help mitigate some risks associated with external shocks, as intra-EU trade is buffered by regulatory alignment and cohesive economic policies. Indeed, the intra-EU FIR reflects the extent to which European economies are intertwined within their own regional network.

In contrast, the extra-EU FIR component measures reliance on inputs from non-EU countries, highlighting European countries' exposure to global supply chains outside the EU. While diversification of supply chains beyond the EU can bring costs, benefits and access to specialized inputs, it also exposes European economies to potentially higher external risks, such as geopolitical tensions, trade restrictions, or disruptions from global crises (Crowe & Rawdanowicz, 2023; Arriola et al., 2024).

By distinguishing between these two components, we can gain a more nuanced understanding of how exposed European countries are to disruptions both within and outside the EU. The total FIR for a country is the sum of its bilateral FIRs with all partners. To calculate extra-EU FIR, we sum up the bilateral FIRs with non-EU partners. The intra-EU FIR is then derived by subtracting the extra-EU FIR from the total FIR. This decomposition allows for an analysis of the extent to which European countries rely on inputs from global versus regional partners, helping to identify where vulnerabilities lie in the broader context of Europe's GVC integration.

the import-side exposure to GVC interruptions, which is why we focus on the FIR.

[3] In particular, Schwellnus et al. (2023) leveraged exogenous mobility shocks during the Covid-19 pandemic to estimate the supply chain transmission of foreign disruptions on domestic output.

[4] These findings are in line with previous work in the supply chain risk management and GVC literature (Mizgier et al., 2015; Gereffi, 2020; Gereffi et al., 2022), which have long recognized the risks due to the low geographical diversification of input supplies.

3.2 Building an indicator of functional diversification

In order to proxy the diversification of EU countries' manufacturing sectors across value chain functions, we exploit the wealth of information on cross-border investments offered by the fDi Markets database. This is a proprietary dataset, produced and maintained by fDi Intelligence (a specialist division of Financial Times Ltd), reporting high-quality data on all greenfield FDIs occurring across the globe from 2003 onwards. The database is one of the main data sources for UNCTAD's World Investment Report (specifically, fDi Markets is the only source on greenfield FDI used by UNCTAD—see, *inter alia*, UNCTAD, 2024) and has also recently been widely exploited by the International Monetary Fund (see, *inter alia*, Chap. 4 in IMF, 2023).

Specifically, fDi Markets includes, among other things, information on the country of origin and destination of FDI flows, the amount of capital invested in monetary terms, the two-digit sector to which the investment is directed, the date of each FDI project, and the business activity (i.e., value chain function) that each FDI is intended to perform in the host economy.[5]

As for the latter information, the fDi Markets database classifies cross-border investments into 17 value chain functions, spanning from headquarter activities, R&D and design, to production operations, up to logistics, marketing, sales and after-sales activities.[6] Accordingly, we follow the methodology adopted by Paglialunga et al. (2022) and leverage this distinctive information to compute an FDI-based measure of functional diversification.

In particular, for each country *c*, sector *j* and year *t*, and considering each value chain function *k*, our indicator of *functional diversification in FDI* (*FD*) is computed as follows:

$$FD_{c,j,t} = 1 - HHI^{K}_{c,j,t} = 1 - \left[\left(\sum\nolimits_{k=1}^{M} \left(\frac{FDI^{k}_{c,j,t}}{FDI_{c,\,j,t}} \right)^{2} - \frac{1}{M} \right) / \left(1 - \frac{1}{M} \right) \right] \quad (1)$$

where $HHI^{K}_{c,j,t}$ is the normalized Herfindahl–Hirschman index (HHI) based on value chain functions and the ratio in the round brackets is the share of FDIs in the *k*-th of the M functions over total FDIs received by country *c* in sector *j* in year *t*.[7] This measure of functional diversification will be used as the key regressor in the analysis of the drivers of industries' exposure to supply chain disruptions.

It is worth recognizing and discussing some shortcomings of our FDI-based indicator to further substantiate its usage. To start with, fDi Markets includes information on greenfield FDIs only, while mergers and acquisitions (M&As) are not accounted

[5] Further details on the fDi Markets database are provided, e.g., in Coveri and Zanfei (2023c).

[6] The complete list of business activities reported by the fDi Markets dataset, along with summary statistics on the monetary value of FDI inflows across these functions (for the whole country-industry sample considered in this work), is provided in Table 1 in the Appendix.

[7] The formula in squared brackets reported in Eq. (1) is the normalized version of the HHI, also known as the Berry-Herfindahl index (Berry, 1971).

for. However, data on brownfield FDIs are generally not available at the functional level, which explains why earlier works exploiting FDI data to retrieve information on the functional profile of countries and regions focused on greenfield foreign investments (e.g., Castellani & Pieri, 2013; Castellani et al., 2013; Crescenzi et al., 2014; Stöllinger, 2021; Casadei et al., 2023). It should also be noted that the distribution of greenfield investments primarily reflects the structural economic and occupational characteristics of targeted countries and industries, while M&As are more influenced by the features of target firms or financial motivations (Castellani et al., 2016). As a result, indicators based on greenfield FDI are likely to better capture the actual ability of industries to carry out different value-adding activities.

Secondly, our FDI-based indicator does reflect the functional involvement of industries in GVCs by measuring their capacity to attract cross-border investments across value chain activities. Nonetheless, this metric cannot exhaustively account for the whole functional diversification of economies, since it disregards the value-adding activities carried out by domestic actors. From this viewpoint, this indicator mainly traces the participation of industries to GVCs featured by a hierarchical type of governance (Gereffi et al., 2005). Still, multinational corporations are leading players in GVCs and play a sizeable role in shaping national capabilities and fostering knowledge flows among local businesses (Branstetter, 2006; Cadestin et al., 2019; World Bank, 2020). Consequently, we argue that comparing country-industry pairs based on the value chain functions addressed by FDI inflows does inform on the available technologies, skills and productive capacity industries are endowed with (Nachum et al., 2000; Waldkirch, 2011).

Overall, despite the aforementioned limitations reflecting information shortages on value chain activities carried out by economies in GVCs, our FDI-based measure should be considered as one of the very few available (and valuable) proxies for functional diversification.

4 Foreign input reliance and functional diversification in European manufacturing sectors: descriptive evidence

To contextualize the analysis of EU countries' GVC exposure, Fig. 1 shows FIR patterns across world macro-regions from 1995 to 2020. World FIR rose steadily until 2011, driven by the acceleration of production fragmentation, before declining slightly due to the economic uncertainties and policy responses following the Great Financial Crisis (Timmer et al., 2014; Baldwin, 2016; Antràs, 2020; Jaax et al., 2023).

Notable regional differences emerge in recent trends. China and the USA show sharp declines in FIR, reflecting efforts to boost domestic manufacturing and reduce external reliance. After a significant rise in FIR in the early 2000s, India has also experienced a reduction, aligning with other BRICS economies. In contrast, the EU27+UK has maintained higher and more stable FIR levels, highlighting its continued reliance on foreign inputs. Meanwhile, NAFTA countries display mixed patterns, with Canada and Mexico increasing their foreign reliance up to 2018. Most notably, the EU27+UK region exhibits by far the highest levels of FIR, underscoring the region's deeply integrated internal market and significant reliance on foreign inputs

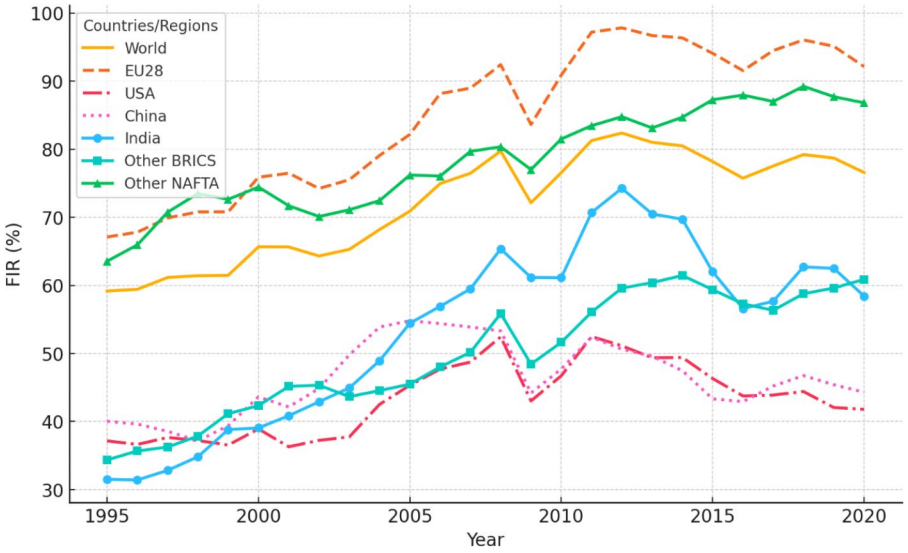

Fig. 1 Foreign Input Reliance of manufacturing sectors (%) by macro-region, 1995–2020. Source: authors' elaborations based on OECD ICIO data

for manufacturing production. Although it has stabilized since 2011, the EU's total FIR remains above 90%. The high level of FIR in the EU presents both opportunities and challenges. On the one hand, it reflects access to diverse and specialized inputs, fostering innovation and competitiveness. On the other hand, it increases the region's exposure to global supply chain disruptions, as evidenced during the COVID-19 pandemic (Javorcik, 2020; Schwellnus et al., 2023).

Overall, Fig. 1 highlights the heterogeneous patterns of FIR across macro-regions, with Europe standing out as the most reliant on foreign inputs. The remarkably high exposure of the EU to risks of potential trade disruptions provides strong motivation for the European Commission's decision to explicitly promote an "Open Strategic Autonomy" perspective. This approach aims to balance trade and economic openness with the mitigation of supply chain vulnerabilities and increased security concerns (European Commission, 2022; Amighini et al., 2023; Mariotti, 2024). The policy design focuses on expanding the range of suppliers to reduce reliance on single providers of critical materials; enhancing production capacities within the EU to reduce external dependencies in strategic industries; and prioritizing critical sectors such as semiconductors, pharmaceuticals, and green technologies to foster more sustainable and resilient supply chains.

However, as already stressed, reducing the external dependence of European economies is not easy in a context of high global interdependence and dispersed sources of knowledge and critical inputs. Moreover, the pursuit of a European economy that is "as open as possible and as autonomous as necessary" (Schmitz & Seidl, 2023) is particularly challenging and could be counterproductive if nationalistic pressures prevail, as these might undermine regional integration. To deepen the analysis of the EU countries' exposure to GVC disruptions, it is therefore worth disentangling the

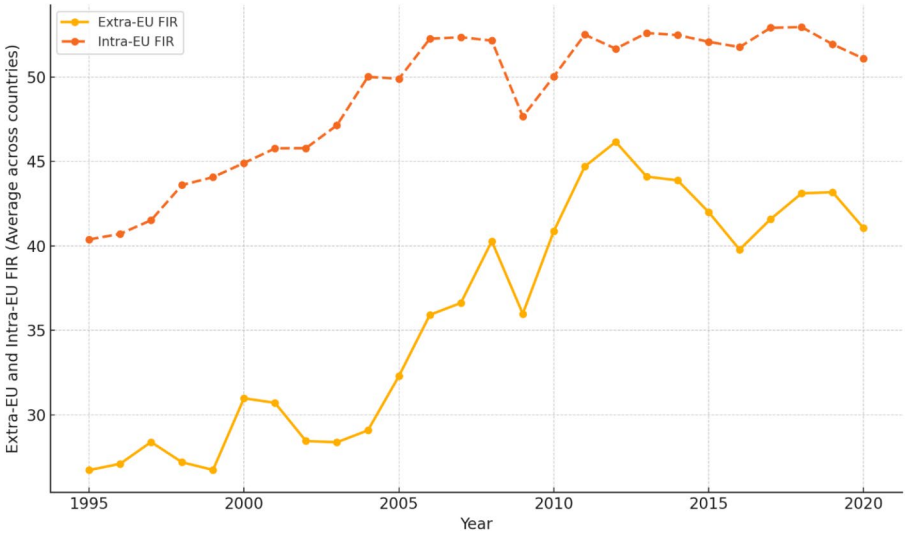

Fig. 2 Intra- and extra-EU FIR of European manufacturing sectors, average across selected EU countries, 1995–2020. Source: authors' elaborations based on OECD ICIO data

foreign input reliance of Europe into its different components, i.e., intra- and extra-EU FIR. This will be done in the next subsection.

4.1 European manufacturing industry's reliance on foreign inputs

Figure 2 illustrates the evolution of the intra- and extra-EU FIR components of the European manufacturing sectors, averaged across all EU countries included in our sample.[8] The divergence between intra-EU and extra-EU FIR is noteworthy. The intra-EU FIR, which captures EU countries' reliance on inputs sourced from other EU countries, has remained relatively stable since 2004, suggesting that regional integration within the EU has maintained its importance. However, the significant rise in extra-EU FIR, especially since the mid-2000s and up to 2012, points to a growing reliance on global inputs from outside the EU, likely driven by cost advantages and the expanding role of emerging economies in global production (Feenstra, 1998; Gereffi et al., 2005). After 2012, extra-EU FIR stabilized around values slightly above 40%, at a much smaller distance from intra-EU FIR levels than in the 1990s.

The shrinking gap between intra-EU and extra-EU FIR in 1995–2011 (followed by more stable levels of both FIR components) suggests a structural shift in the geographical sources of inputs for European manufacturing. While regional value chains

[8] It is worth noting that that the FIR is not substantially affected by the size of the economies since, for each country, this indicator gauges the amount of directly and indirectly foreign-sourced inputs relative to domestic gross output. Accordingly, the FIR measures the "intensity" of foreign input reliance, allowing us to draw some consistent insights from the assessment of the average FIR across European countries. Moreover, since the country-industry sample considered does not change over time, the evolution of the series shown in Fig. 2 can be appreciated consistently.

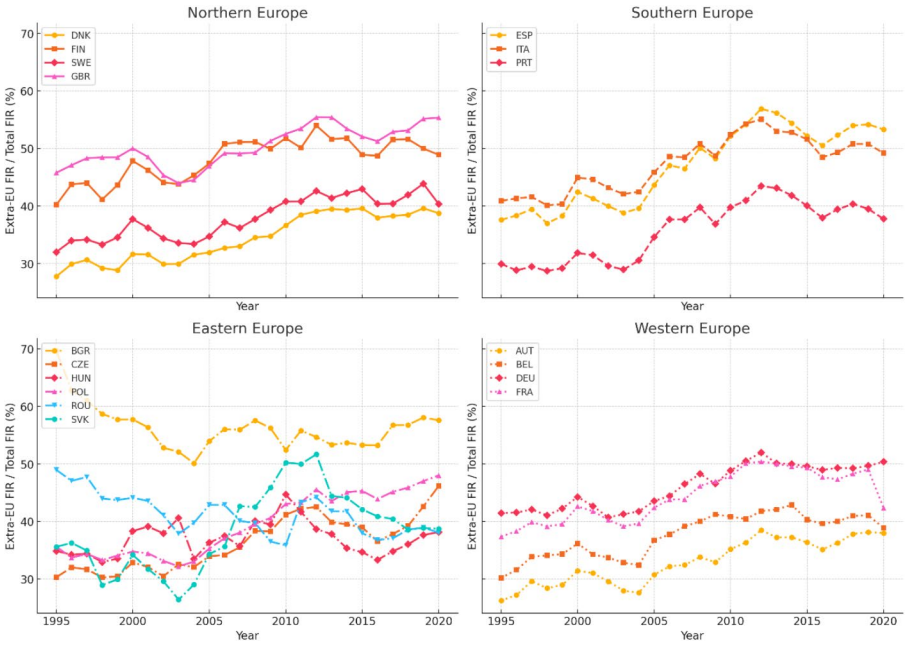

Fig. 3 Extra-EU share (%) of total FIR for selected EU countries' manufacturing sectors, 1995–2020. Source: authors' elaborations based on OECD ICIO data

within the EU remain robust, European countries have increasingly sourced inputs from non-EU suppliers, particularly from emerging economies such as China and Southeast Asia (Giammetti et al., 2022; Timmer et al., 2016). This shift has significant implications for the resilience of European manufacturing, as reliance on global suppliers increases exposure to external shocks and disruptions, as highlighted by recent events like the COVID-19 pandemic (Bonadio et al., 2021; Coveri et al., 2020; Gereffi, 2020; Giammetti et al., 2020).

Figure 3 shows the extra-EU share (%) of total FIR at the country level, grouping economies into four major European regions: Northern Europe, Southern Europe, Eastern Europe, and Western Europe.[9]

In Northern Europe, a marked increase in extra-EU FIR has been observed over the last two decades. This reflects a broader trend to diversify supply sources beyond the EU, underscoring this region's integration into broader global production networks (Timmer et al., 2016). Extra-EU FIR has also increased significantly in Southern Europe, especially in Italy, which has expanded its sourcing networks to include non-EU suppliers. This shift likely reflects the need for access to more specialized or cost-effective inputs from outside the EU, particularly in sectors like textiles and automotive components (Grossman & Helpman, 2002). Western European countries, including major economies like Germany, France, and Belgium, also show high levels of extra-EU FIR. Germany's rise in extra-EU FIR reflects its position as a key player in global manufacturing industries, such as automotive and machinery, which

[9] Countries are grouped according to the United Nations Geoscheme for Europe.

Fig. 4 Extra-EU share (%) of total FIR of European manufacturing sectors, average across selected EU countries, 1995–2020. Source: authors' elaborations based on OECD ICIO data

have long and increasingly relied on inputs from Asia, especially China (Sturgeon et al., 2008).

Finally, Eastern European countries exhibit higher heterogeneity in both FIR levels and evolution over time. Bulgaria historically maintains a very high level of extra-EU input reliance, while other countries such as Poland and Slovakia have significantly and rather steadily increased their extra-EU FIR, particularly post-2010. This increase suggests growing participation in global production networks beyond Europe, driven by industries like automotive and electronics, where global sourcing is essential for maintaining competitiveness (Gereffi et al., 2022).

Figure 4 provides a sectoral breakdown of the extra-EU share (%) of total FIR across different manufacturing industries, averaged across EU countries.[10] The figure reveals a general increase in extra-EU shares of total FIR, although with significant differences in the levels and dynamics over time across macro-sectors. In primary and basic manufacturing sectors, such as wood (D16) and basic metals (D24), the extra-EU FIR share has increased, reflecting a growing reliance on non-EU inputs due to the search for competitively priced commodities (Koopman et al., 2014). In intermediate goods manufacturing, e.g. chemicals (D20) and rubber and plastics (D22), as well as in heavy manufacturing industries, e.g. motor vehicles (D29), the

[10] The classification of industries adopted aims to illustrate the varying reliance on foreign inputs for both upstream and downstream sectors, also accounting for their technological intensity (Timmer et al., 2013). See Table 1 in the Appendix for the complete list of manufacturing sectors considered.

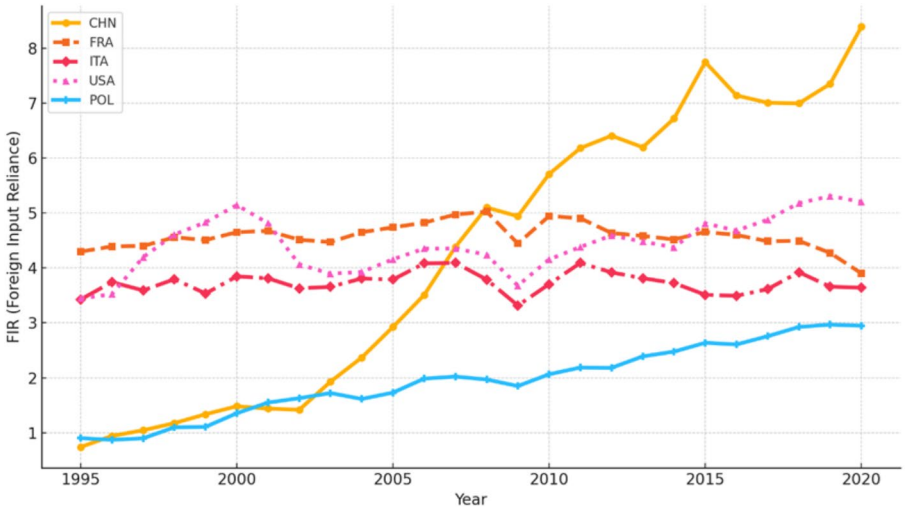

Fig. 5 Top foreign suppliers to Germany's automotive sector (D29), 1995–2020. Source: authors' elaborations based on OECD ICIO data

trends are even more pronounced, with the extra-EU FIR share rising sharply. These sectors are especially susceptible to global supply chain dynamics, given their reliance on high-tech components often sourced from Asian economies (Antràs & Chor, 2013). Knowledge-intensive sectors, such as pharmaceuticals (D21) and electronics (D26), exhibit similar patterns, with rising extra-EU FIR shares. This reflects the increasing importance of global inputs for innovation-driven industries, where firms often rely on cutting-edge technologies and specialized components from outside Europe (Mudambi, 2008).

Due to its prominence in the European industrial landscape, the automotive sector (D29) is of particular interest. The German automotive industry, which is deeply integrated into GVCs, shows indeed a sharp rise in dependence on non-EU suppliers, especially China (Fig. 5). This trend is consistent with broader shifts in the global automotive industry, where firms increasingly rely on specialized components from global suppliers, particularly in the electronics and battery sectors (Sturgeon & Van Biesebroeck, 2011). The significant increase in extra-EU FIR in Germany's automotive industry illustrates the deepening integration of global production networks and the increasing importance of Chinese suppliers in the global automotive supply chain.

The descriptive evidence presented in this section highlights several key trends. First, while European countries remain strongly integrated in terms of trade in intermediate inputs—with some EU suppliers playing a growing role, as shown in the case of Poland among the suppliers of the German Automotive industry—, they are increasingly reliant on inputs from outside the EU (Giammetti et al., 2022), especially in knowledge-intensive and high-tech sectors. Second, the rise in extra-EU FIR underlines the growing importance of global suppliers (especially Chinese ones) in European production networks, reflecting the benefits and risks associated with deeper integration into GVCs (Gereffi et al., 2005; Johnson & Noguera, 2012).

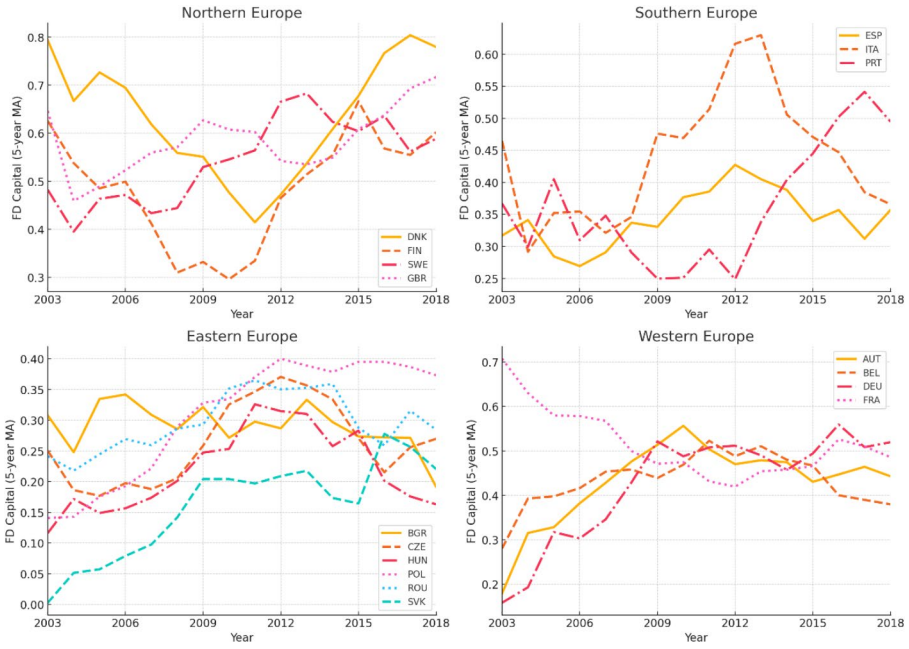

Fig. 6 5-year moving average of Functional diversification in FDI (*FD*) for selected EU countries' manufacturing sectors, 2003–2018. Source: authors' elaborations based on fDi Markets data

The increasing reliance on non-EU inputs has important implications for economic resilience. While intra-EU integration does not seem to have decreased in absolute terms and represents a potential stabilizing factor in European countries' production networks, the growing dependence on extra-EU inputs exposes European industries to external risks, particularly in times of GVC disruptions (Bonadio et al., 2021; Arriola et al., 2024). As global supply chains continue to evolve, European firms may face challenges in balancing the benefits of global sourcing with the need to reduce vulnerability to external shocks. As shown in the following sections, functional diversification may play a critical role in mitigating these risks.

4.2 Exploring the association between functional diversification in FDI and foreign input reliance of EU industries

This section analyzes the evolution of Functional Diversification in FDI (*FD*) and the association between the latter and the distinct components of FIR indicator—i.e., total, intra- and extra-EU FIR—for the manufacturing sectors of the European economies included in our sample over the 2003–2018 period.

Consistently with the descriptive statistics reported in the previous section, Fig. 6 shows the dynamics of *FD* by grouping the European countries under investigation into four classes—i.e., Northern, Southern, Eastern and Western Europe—and taking a 5-year moving average to capture countries' *FD* long-term trends while smoothing out short-term fluctuations.

The analysis of *FD* across European manufacturing industries highlights significant regional differences. Northern Europe, led by the UK and more recently by Denmark, shows high levels of FDI diversification across a range of manufacturing functions, positioning it as a key hub for diverse global manufacturing investments. Slightly lower levels of *FD* can be observed for Western European countries, with Germany exhibiting a remarkable increase in functional diversification levels, while France experienced a long-term decline in *FD*. Other countries with less sizeable manufacturing industries—like Belgium and Austria—have reduced their functional diversification after the crisis. Southern Europe exhibits an intermediate functional diversification—between the levels attained by Nordic and Western countries—, with Portugal significantly rising its *FD* post-2012, while Italy and Spain continue to face challenges in maintaining sustained diversification in their manufacturing sectors. Eastern Europe, especially Poland and Hungary, is well-integrated into global manufacturing value chains, attracting diversified FDI across various manufacturing industries. Overall, EU countries appear to have followed very heterogeneous patterns of *FD*, which might reveal a lack of convergence and coordination in the effort to strengthen the industrial basis of the region.

We conclude this section by providing descriptive evidence on the relationship between functional diversification and reliance on foreign inputs for the EU economies. In particular, Fig. 7 illustrates such a relationship by looking at average values over the period under investigation and distinguishes the *FD* vs. total FIR (panel A) from the *FD* vs. extra-UE FIR (panel B) and the *FD* vs. intra-UE FIR relationship (panel C). The negative association emerges rather clearly in all panels, although it results more scattered in the case of intra-UE than extra-EU FIR. This negative relationship supports the line of argument we developed in Sect. 2, according to which greater functional diversification may represent an effective strategy to mitigate the exposure to GVC disruptions. This is consistent with the idea that countries reporting higher functional diversification can, on the one hand, reduce the need for foreign inputs that can more easily produced domestically; and, on the other hand, be more selective in accessing foreign input sources whenever these are useful or necessary.

It is also worth stressing that, although increasing *FD* could represent a strategic tool to achieve more manageable levels of foreign input reliance, there can be a wide variety of combinations in the *FD*-FIR space. To illustrate this, Fig. 7 can be leveraged to identify how EU countries are positioned in an ideal path leading to a "Strategic Autonomy" that is "Open" enough to benefit from world trade integration. This is done in Fig. 8, which highlights the positioning of EU countries according to their *FD* and total FIR values compared to the EU median values. This enables us to assign countries to four distinct quadrants, corresponding to four different combinations of *FD*-FIR values. In this way, we can characterise the profiles of different countries in terms of the variety of value-adding functions they are active in, which roughly gauges their degree of "autonomy", and their GVC exposure. The idea is that countries may differ significantly in their capacity to respond to disruptive events according to their mix of diversification across functions and foreign reliance.

In particular, Fig. 8 shows that most of the core European countries (e.g., France, Germany and Sweden), as well as Italy, are placed in the bottom-right quadrant—labelled 'Robust autonomy'—as they report *FD* values above the EU median cou-

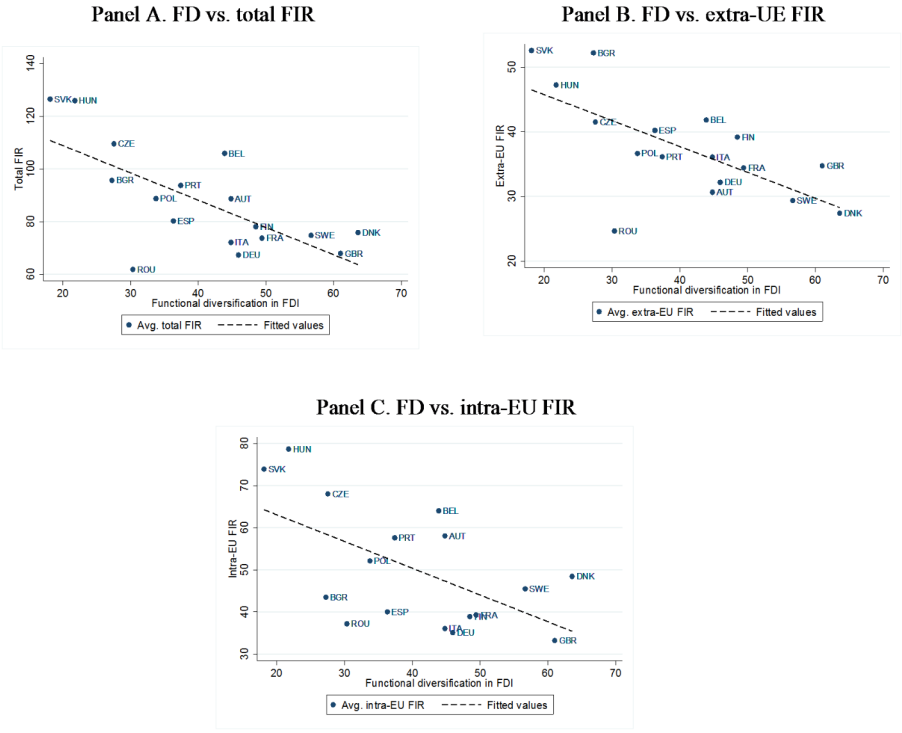

Fig. 7 Association between Functional diversification in FDI (*FD*) and total FIR (panel A), *FD* and extra-UE FIR (panel B), and *FD* and intra-UE FIR (panel C) for selected EU countries' manufacturing sectors, avg. values over the period 2003–2018.
Source: author's elaboration based on OECD ICIO and fDi Markets data.

pled with total FIR values below the EU median. Austria and Belgium are instead positioned in what we may call the 'Low-risk exposure' quadrant, characterized by relatively high values of total FIR combined with relatively high values of functional diversification. Countries in the "Robust autonomy" and "Low-risk exposure" quadrants occupy relatively advantageous positions in the ideal risk-reduction path while maintaining a non-negligible foreign dependence. Conversely, Romania can be characterized as a case of 'Weak autonomy', with relatively low values of both *FD* and total FIR. Note that Spain is on the borderline between the 'Weak Autonomy' category and another rather worrisome profile that we label 'Risky exposure', including a relatively large number of EU countries with higher-than-median values of total FIR and lower-than-median values of *FD*. This set consists mainly of Central and Eastern European countries, in particular Slovakia and Hungary, as well as Portugal.

Three main insights can be drawn from this empirical exploration. First, the negative association between *FD* and EU countries' reliance on foreign inputs holds when considering total FIR as well as extra-EU and intra-EU FIR. Second, such a negative relationship appears to be stronger (more scattered) when looking at the nexus between *FD* and the extra-EU (intra-EU) FIR, suggesting that greater *FD* may play a particularly strong role in enabling EU countries to reduce their reliance on

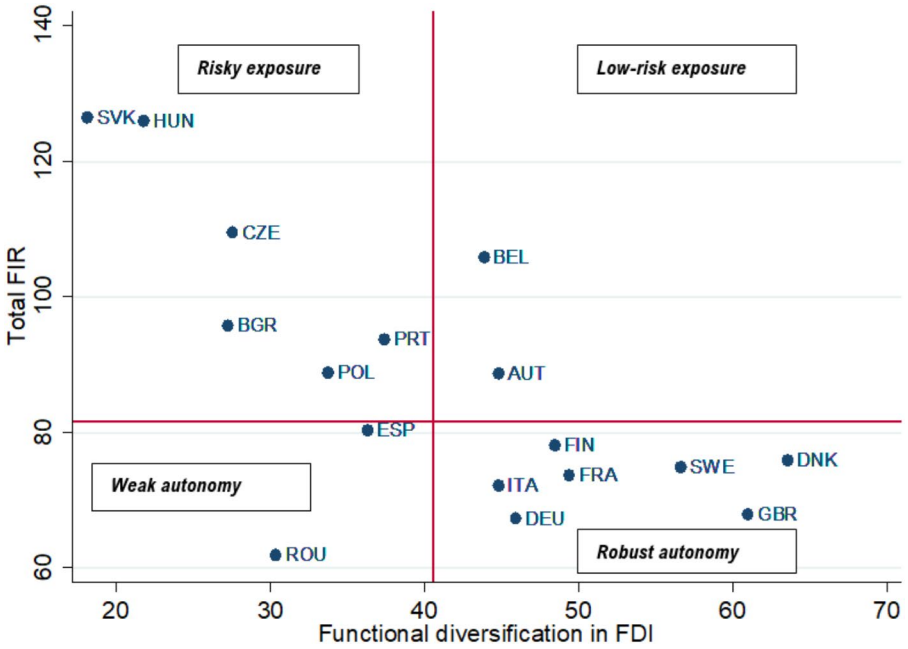

Fig. 8 Positioning of EU countries in the *FD vs. FIR* space, average values over the period 2003–2018. Source: author's elaboration based on OECD ICIO and fDi Markets data. Note: the horizontal bold line shows the median value of total FIR, while the vertical bold line shows the median value of functional diversification in FDI.

potentially risky suppliers located outside Europe. Third, economies belonging to the European core countries appear to be better positioned in the race towards Open Strategic Autonomy. In fact, core EU countries generally exhibit what we have identified as a 'Robust autonomy' profile, marked by relatively high values of *FD* and relatively low values of foreign input reliance. Notably, although total FIR is below the EU median in these cases, the actual level of reliance on foreign inputs is still quite high and never falls below 30% (i.e., foreign supplies account for about one third of the gross output even in the case of countries that have managed to reduce their exposure most successfully). Core EU countries appear to combine the advantages of a stronger and more diversified industrial base with the benefits of foreign exposure that is "low enough" to reduce disruption risks and "high enough" to enable them to occupy key positions in GVCs. Conversely, more peripheral countries like Central and Eastern European economies, together with Spain and Portugal, are generally found in the 'Risky exposure' class, featuring relatively low values of *FD* and relatively high values of foreign input reliance. These countries are likely to be more vulnerable to GVC disruptions, as they massively rely on foreign production inputs while retaining the capabilities to perform a relatively narrow array of value-adding activities within the global production networks they are engaged in.

5 Empirical strategy to test the *FD*-FIR association in EU industries

In this section, we test the association between functional diversification and the risk exposure to GVC disruptions of European manufacturing industries by relying on panel methodologies.

As explained in more detail below, the structure of our panel leads us to employ a Least Square Dummy Variable (LSDV) estimator that allows us to jointly control for a large number of factors which might affect the country-industry pairs' exposure to GVC disruptions, thus providing us with the opportunity to better test for the role played by functional diversification.

Formally, the empirical analysis is carried out by estimating the following regression equation:

$$\begin{aligned} FIR^{g}_{c,j,t} = \beta_0 + \beta_1 \left(functional\ div.\ in\ FDI_{c,j,t}\right) + \beta_2 ln\left(total\ inward\ FDI_{c,j,t}\right) \\ + \beta_3 ln(gross\ output_{c,j,t}) + \theta_c + \vartheta_j + \mu_t + \gamma_{j,t} + \delta_{c,t} + \varepsilon_{c,j,t} \end{aligned} \quad (2)$$

where $FIR^{g}_{c,j,t}$ is the Foreign Input Reliance index for g = {total; intra-EU; extra-EU}, representing our measure of risk exposure in GVCs for country c, sector j at time t; while $Functional\ div.\ in\ FDI_{c,j,t}$ stands for our FDI-based measure of functional diversification.

$Total\ inward\ FDI_{c,j,t}$ captures the whole amount of incoming FDIs in terms of capital invested, controlling therefore for the overall FDI attractiveness of sectors. Notably, including this explanatory variable also allows us to soften potential endogeneity issues that might stem from omitted variable bias. In fact, greater FDI inflows are likely to be associated with larger foreign dependency because of FDI-induced trade integration among economies (e.g., due to greater imports of intermediates by subsidiaries from headquarters; see, *inter ali*a, Adarov & Stehrer, 2021). By controlling for total inward FDIs, we largely mitigate this potential source of endogeneity.

Moreover, we control for the $gross\ output_{c,j,t}$ in order to take into account the industry size.

The terms θ_c, ϑ_j and μ_t stand for country, industry and time fixed effects, accounting respectively for unobserved time-invariant country-specific characteristics (e.g., geographical location), unobserved time-invariant industry-specific characteristics (e.g., knowledge intensity, as well as relatively more upstream or downstream positioning along global production chains), and year-specific events that may have an impact on both dependent and explanatory variables. Notably, we also control for industry-time ($\gamma_{j,t}$) and country-time ($\delta_{c,t}$) fixed effects, accounting respectively for all unobserved time-varying factors affecting specific industries (e.g., the sudden impact of the Covid-19 pandemic on microchip production, which affects all automotive industries) and specific countries (e.g., business cycle, labour productivity trends, or changes to the tax system) over the period. These sets of fixed effects are therefore crucial in allowing us to control for a very large number of unobserved factors that are likely to impact on both dependent and explanatory variables, hence softening endogeneity concerns due to omitted variable bias. Finally, β_0 stands for the intercept and $\epsilon_{c,j,t}$ is the error term.

Although the empirical strategy described above should significantly mitigate endogeneity problems, the latter still cannot be completely neglected. As a robustness check, we will therefore estimate the model specification by including all explanatory variables with a two-year lag, with the aim of further softening reverse causality concerns. Along with the estimate findings, the empirical results from this robustness check will also be discussed in the next section and fully reported in the Appendix.

As previously mentioned, our empirical analysis is carried out on a sample including 17 NACE Rev. 2 manufacturing sectors belonging to 17 European economies over the 2003–2018 period (the latter being the time span in which we have access to fDi Markets data). Notably, the country-industry selection procedure illustrated in Sect. 3 leads us to work with an *unbalanced panel dataset* including 1553 observations. This is the result of our effort to strike a balance between our willingness to include a number of observations as large as possible in our empirical analysis and the need to ensure the reliability of our FDI-based index of functional diversification.[11]

It is worth noting that the unbalanced nature of our panel data also explains the choice of using an LSDV estimator in place of a 'within' estimator (like the Fixed effects). In fact, several country-industry pairs are not observed in all years of the period considered, and some are only observed in one, two or three years over the entire time span. Accordingly, employing a 'within' estimator designed to focus on the evolution of country-industry pairs over time and 'cleaning up' the entire cross-sectional data variation is most likely not the most suitable estimator to capture the variability in our data. Therefore, we opted for the adoption of an LSDV estimator, taking care to 'saturate' the model by including dummy variables capturing *all other dimensions of variation* in our data.

Summary statistics for all variables considered in our empirical model are shown in Table 1.

6 Estimate results

This section shows the empirical results deriving from the estimation of the regression model reported by Eq. (2). As for the structure of the estimate tables, columns 1, 3 and 5 always report the most parsimonious specifications, including only functional diversification in FDI and total inward FDI flows as regressors; while columns 2, 4 and 6 also include the gross output of sectors as an additional explanatory variable. Most importantly, while columns (1) and (2) include time, industry, and country fixed effects, columns (3) and (4) also include industry-time fixed effects. Finally, the model is fully saturated in columns (5) and (6) with the inclusion of both industry-time and country-time fixed effects.

Table 2 provides the estimate results of the LSDV model with total FIR as dependent variable. We find a negative and significant coefficient for functional diversifica-

[11] As for the reliability of the indicator, it is worth noting that– following this procedure– the average number of inward FDIs received by country-industry pairs is equal to 14 per year, while the median value is 10 per year. The corresponding magnitudes at the country level for the 17 economies included in our sample are 95 and 56, respectively.

Table 1 Summary statistics

	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables					
Total FIR (%)	1553	83.2	29.8	21.4	204.822
Intra-EU FIR (%)	1553	47.9	20.7	9.5	140.4
Extra-EU FIR (%)	1553	35.3	15.5	7.0	140.3
Key regressor					
Functional diversification in FDI	1553	34.3	25.0	0	87.48
Control variables					
Total inward FDIs (USD million)	1553	400.8	520.0	1	6018.2
Ln(total inward FDIs)	1553	5.4	1.1	0	8.7
Gross output (USD million)	1553	46422.2	62237.4	125.761	491658.4
Ln(gross output)	1553	10.0	1.3	4.834	13.1

Source: authors' elaboration

Note: Functional diversification in FDI was multiplied by 100 in order to improve the readability of the estimate coefficients. Control variables in absolute terms (without logarithmic transformation) are reported for transparency and illustrative purposes only

Table 2 LSDV model for total FIR

	(1)	(2)	(3)	(4)	(5)	(6)
	Total FIR	*Total FIR*	*Total FIR*	*Total FIR*	*Total FIR*	*Total FIR*
Functional div. in FDI	−0.08***	−0.07***	−0.08***	−0.08***	−0.07***	−0.08***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Ln(total inward FDI)	0.46	0.15	0.45	0.14	−0.04	−0.38
	(0.41)	(0.42)	(0.48)	(0.50)	(0.54)	(0.56)
Ln(gross output)		2.85***		2.74***		2.48**
		(0.93)		(1.01)		(1.23)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	*No*	*No*	Yes	Yes	Yes	Yes
Country-Time FE	*No*	*No*	*No*	*No*	Yes	Yes
Observations	1,553	1,553	1,553	1,553	1,553	1,553
R-squared	0.78	0.78	0.80	0.80	0.83	0.83

Source: authors' elaboration

Note: the dependent variable is the total Foreign Input Reliance (FIR) indicator. A constant is included but not reported. Robust standard errors clustered at country-industry level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

tion in FDI across all the estimated specifications, meaning that greater functional diversification of manufacturing sectors is associated with lower exposure to GVC disruptions as proxied by foreign input reliance. Conversely, the coefficient of total inward FDIs never turns out to be significant, while the coefficient of gross output is always found to be positive and significant.

In Table 3, the estimate results of the LSDV model with the extra-EU FIR as dependent variable are shown. Once again, the coefficient of functional diversification in FDI is negative and significant across all the estimated specifications, meaning that greater functional diversification is also associated with lower values of manufacturing sectors' reliance on production inputs from outside EU27+UK. The variable capturing total inward FDIs always reports a negative but not significant coefficient, except in column 6 where it turns out both negative and significant. Finally, the coefficient of gross output is consistent with previous findings, resulting always positive and significant.

Lastly, Table 4 shows the estimate results of the LSDV model with the intra-EU FIR as dependent variable. Notably, our FDI-based functional diversification index confirms a negative and significant coefficient in all specifications, suggesting that higher diversification across value chain functions by European manufacturing sectors is also associated with lower dependence on inputs from other EU countries. Interestingly enough, the variable measuring total incoming FDIs always reports a positive coefficient, which also turns out to be significant in four out of six specifications. This may be in line with the fact that the bulk of FDI flows targeting EU27+UK countries come from other European economies, and this is likely also associated with deeper trade integration among EU countries. Finally, gross output now always reports a negative coefficient, which also results significant in the last

Table 3 LSDV model for extra-EU FIR

	(1)	(2)	(3)	(4)	(5)	(6)
	Extra-EU FIR	*Extra-EU FIR*	*Extra-EU FIR*	*Extra-EU FIR*	*Extra-EU FIR*	*Extra-EU FIR*
Functional div. in FDI	−0.03**	−0.03**	−0.03**	−0.03**	−0.04*	−0.04**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Ln(total inward FDI)	−0.02	−0.34	−0.02	−0.38	−0.39	−0.91**
	(0.26)	(0.28)	(0.32)	(0.34)	(0.38)	(0.40)
Ln(gross output)		2.99***		3.22***		3.85***
		(0.76)		(0.82)		(0.96)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	*No*	*No*	Yes	Yes	Yes	Yes
Country-Time FE	*No*	*No*	*No*	*No*	Yes	Yes
Observations	1,553	1,553	1,553	1,553	1,553	1,553
R-squared	0.58	0.59	0.61	0.61	0.66	0.67

Source: authors' elaboration

Note: the dependent variable is the extra-EU Foreign Input Reliance (FIR) indicator (i.e., net of intra-EU exposure). A constant is included but not reported. Robust standard errors clustered at country-industry level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4 LSDV model for intra-EU FIR

	(1)	(2)	(3)	(4)	(5)	(6)
	Intra-EU FIR	*Intra-EU FIR*	*Intra-EU FIR*	*Intra-EU FIR*	*Intra-EU FIR*	*Intra-EU FIR*
Functional div. in FDI	−0.04***	−0.04***	−0.05***	−0.05***	−0.04***	−0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Ln(total inward FDI)	0.48*	0.49*	0.47	0.53*	0.35	0.54*
	(0.25)	(0.26)	(0.29)	(0.30)	(0.30)	(0.31)
Ln(gross output)		−0.14		−0.49		−1.37**
		(0.48)		(0.50)		(0.54)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	*No*	*No*	Yes	Yes	Yes	Yes
Country-Time FE	*No*	*No*	*No*	*No*	Yes	Yes
Observations	1,553	1,553	1,553	1,553	1,553	1,553
R-squared	0.85	0.85	0.87	0.87	0.90	0.90

Source: authors' elaboration

Note: the dependent variable is the intra-EU Foreign Input Reliance (FIR) indicator (i.e., net of extra-EU exposure). A constant is included but not reported. Robust standard errors clustered at country-industry level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

model specification (column 6). Combining these findings with those emerging from Table 3 suggests that larger European manufacturing industries rely more on production inputs from extra-EU economies, while smaller ones' sourcing strategies tend to depend more on other European industries.

As a robustness check, we also estimated the model specification by including all explanatory variables with a two-year lag. Although this technique does not suffice to identify strictly causal relationships, it proves helpful in softening reverse causality and mitigating endogeneity problems, thereby increasing the reliability of our empirical analysis. These results are reported in Tables 7, 8 and 9 in the Appendix and broadly confirm our previous findings. In particular, the coefficient of functional diversification in FDI is found to be negative and significant in all specifications. The results for the other explanatory variables are qualitatively unchanged.

Our results are broadly consistent with the interpretive framework proposed in Sect. 2. In fact, the observed negative association supports the idea that more functionally diversified economies exhibit greater capacity to innovate and mobilise domestic resources that can be used to substitute foreign sources of critical inputs, whenever these are too costly, too risky or simply unavailable. While our findings confirm that these mechanisms can help explain the negative relationship between *FD* and extra-EU FIR, which is all the more relevant in times of growing geopolitical tensions, the fact that more functionally diversified countries also generally show lower intra-UE FIR is even more interesting. We interpret this result as evidence that trade creation opportunities that typically characterise integrated regions like the EU could be undermined by nationalistic domestic policies aimed at increasing resilience by individual member states.

7 Conclusions: towards open strategic autonomy??

This paper has explored the intricate relationship between functional diversification and foreign input reliance of manufacturing sectors in selected EU countries. We have shown that greater functional diversification is generally associated with lower reliance on foreign inputs. This result highlights that investing in a wider variety of value-adding activities can be a valid strategy to mitigate the risks due to the exposure of the economies to GVC disruptions. More precisely, our findings underline the importance of functional diversification as a key policy tool to mitigate dependence on non-EU suppliers in an era of mounting geopolitical tensions.

However, greater functional diversification may also favour a reduction in *intra-EU* foreign input reliance, thus contributing to undermine the EU trade integration. Our results shed a novel light on this worrisome perspective. First, we have shown that while EU countries still rely heavily on other EU suppliers (as an intended result of a long-term integration process), they have been sourcing inputs from extra-EU countries at a much faster pace in recent decades. Second, we have illustrated that functional diversification patterns of EU member states are largely diverging, far from revealing EU-wide concerted coordination efforts. Third, we found that functional diversification is as negatively associated with extra-EU input reliance as with intra-EU input reliance. These results reveal that functional diversification strategies independently undertaken by individual member states could weaken economic integration, which has been a hallmark of the EU's project. Intra-EU trade ties have historically acted as a buffer against external shocks, facilitating economic stability and fostering long-term interdependence among member states (Giovannetti et al., 2023). A decline in intra-EU foreign input reliance could erode these ties, undermining the mechanisms that have supported EU-wide resilience.

Our findings also suggest that the path towards a European economy that is "as open as possible and as autonomous as necessary" (Schmitz & Seidl, 2023) crucially requires a joint effort to meet the challenges of an increasingly weaponized competition between geopolitical blocks. From this perspective, we have shown that core EU countries are better positioned than peripheral economies in combining a more diversified industrial basis with an economic openness that is "high enough" to play a non-marginal role in GVCs, and "low enough" to soften the risks associated with GVC disruptions. "High enough" means wide access to the most valuable sources of knowledge and critical inputs wherever these are located. "Low enough" means greater selection of partners and shorter supply chains wherever possible.

Finding a proper balance of foreign reliance and de-risking requires a coordinated industrial policy that promotes functional diversification across the EU, ensuring that countries do not pursue national strategies that could weaken regional integration. Accordingly, Open Strategic Autonomy only makes sense if it is accompanied by

bold fiscal and industrial policies that coordinate diversification efforts at the European level, fostering greater economic and structural convergence among member states (Fontana & Vannuccini, 2024).

While this work has highlighted the potential benefits of functional diversification strategies to reduce dependence on non-EU countries, we acknowledge that the European production network exhibits significant heterogeneity and asymmetries. Several contributions have indeed documented the structural divides between core and peripheral EU economies, which have led to an uneven distribution of the benefits deriving from the EU integration process and participation in European GVCs (e.g., Stöllinger, 2016; Bontadini et al., 2022, 2024, Guarascio et al., 2024). Reducing dependence on extra-EU suppliers could unintendedly exacerbate these core-periphery imbalances, increasing the reliance of peripheral economies on core EU countries. To mitigate this risk, complementary policies are necessary to reduce asymmetries within the EU and ensure that diversification efforts benefit all member states. Such policies could include targeted investments in infrastructure, innovation and industrial capacity in less developed regions, as well as measures to foster equitable integration in the Single Market. Addressing these disparities is critical to ensuring that deeper intra-EU linkages contribute to resilience, cohesion, and inclusivity within the European economic framework.

The imperative of EU-wide convergence is especially important because European countries vary in their levels of functional diversification and foreign input reliance. For instance, countries with relatively low diversification and relatively high FIR should be supported to increase functional diversification and selectively reduce their dependence on potentially risky suppliers. Economies that are already highly diversified can afford a higher FIR without incurring serious risks and could even strengthen their position by achieving a more effective balance between these two dimensions.

Overall, this study underscores the dual role of functional diversification, both as a buffer against external risks and as a potential threat to intra-EU cohesion if not managed appropriately. Europe's resilience depends on its ability to balance diversification across value chain functions with global and regional integration. In this respect, coordinated industrial and cohesion policy initiatives are essential to secure Europe's role in a rapidly evolving global economy.

Despite the robustness of our findings, several limitations and avenues for future research warrant attention. First, while this study highlights the importance of functional diversification in reducing FIR, it does not explicitly analyze how diversification interacts with countries' occupational structures and their evolution. Future research could investigate whether diversification, as measured here, does reflect a concurrent shift towards upstream, high value-adding occupations such as R&D or managerial activities. Exploring these trends would contribute to clarifying the complex relationship and likely co-evolution between increasing involvement in

more knowledge-intensive activities (and occupations) and wider diversification opportunities.

Second, future research could further explore the intricate relationship between specialization and diversification, as well as deepen the analysis of the trade-off between them when it comes to spurring economic development while enhancing resilience. Although we have argued in favour of functional diversification as a strategy to reduce exposure to GVC disruptions, there is ample room here for specific case studies which could highlight how countries may pursue their own balance and follow specific patterns of GVC integration over time. For instance, countries belonging to the Central and Eastern periphery of Europe have been largely specializing in fabrication functions as a way to foster their participation in production networks (e.g., Pavlínek, 2022; Coveri et al., 2024a, b). While this strategy allowed them to benefit from greater industrialization opportunities, we have shown that this has also exposed their economies to higher risks in case of supply chain disruptions. Quite symmetrically, one might observe that increased specialization in high value-adding activities offers comparable or even greater benefits than diversification across fabrication-related functions at the lower end of the value chain.

Third, while our study provides some evidence of sectoral heterogeneity in the relationship between functional diversification and FIR, future research could deepen the analysis of sectoral specificities to better tailor policy interventions. For instance, selected sectors may exhibit a stronger negative association between functional diversification and FIR, while others, particularly those heavily reliant on highly specialized components and knowledge inputs, may benefit from more targeted industrial policy strategies. Overall, a more in-depth exploration of these sectoral dynamics would improve our understanding of how functional diversification operates across different industries.

Addressing these limitations would not only strengthen the robustness of the current findings but also provide a more nuanced understanding of the interplay between functional diversification, specialization, and GVC resilience. Future studies leveraging functional and sectoral information complemented with granular occupational data could shed further light on these dynamics, contributing to the formulation of more targeted industrial and trade policies.

Appendix

See Tables 5, 6, 7, 8 and 9.

Table 5 List of manufacturing industries

NACE Rev. 2 code	Industry description
D10T12	Food products, beverages and tobacco
D13T15	Textiles, textile products, leather and footwear
D16	Wood and products of wood and cork
D17T18	Paper products and printing
D19	Coke and refined petroleum products
D20	Chemical and chemical products
D21	Pharmaceuticals, medicinal chemical and botanical products
D22	Rubber and plastics products
D23	Other non-metallic mineral products
D24	Basic metals
D25	Fabricated metal products
D26	Computer, electronic and optical equipment
D27	Electrical equipment
D28	Machinery and equipment, nec
D29	Motor vehicles, trailers and semi-trailers
C30	Other transport equipment
D31T33	Manufacturing nec; repair and installation of machinery and equipment

Source: authors' elaboration

Table 6 Summary statistics on the monetary value (USD million) of FDI inflows across the business activities included in the fDi markets database

Value chain function (fDi Markets business activity)	Obs.	Mean	Std. Dev.	Min	Max
Manufacturing	1553	305,2	463,8	0	5862,2
Logistics, Distribution & Transportation	1553	22,9	84,8	0	1540,3
Design, Development & Testing	1553	19,2	53,6	0	722,8
Headquarters	1553	12,0	36,5	0	672,8
Research & Development	1553	11,9	67,9	0	1850
Sales, Marketing & Support	1553	8,7	14,8	0	154
Extraction	1553	5,7	122,9	0	4300
Maintenance & Servicing	1553	3,6	18,2	0	359,1
ICT & Internet Infrastructure	1553	2,4	30,9	0	853,6
Electricity	1553	2,2	26,0	0	488,1
Education & Training	1553	2,1	31,5	0	1204
Recycling	1553	2,1	16,1	0	481,9
Shared Services Centre	1553	1,6	15,5	0	500
Technical Support Centre	1553	0,5	4,8	0	112,6
Customer Contact Centre	1553	0,4	2,3	0	60,2
Business Services	1553	0,3	2,2	0	39,1
Construction	1553	0,2	7,7	0	302,4
Total inward FDIs	1553	400,8	520,0	1	6018,2

Source: authors' elaboration based on fDi Markets data

Table 7 LSDV model for total FIR with two-year lagged *(t-2)* explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)
	Total FIR	*Total FIR*	*Total FIR*	*Total FIR*	*Total FIR*	*Total FIR*
Functional div. in FDI *(t-2)*	−0.08***	−0.08***	−0.08***	−0.08***	−0.10***	−0.10***
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Ln(total inward FDI) *(t-2)*	0.68	0.51	0.50	0.31	0.14	0.08
	(0.50)	(0.52)	(0.60)	(0.62)	(0.73)	(0.75)
Ln(gross output) *(t-2)*		1.94		1.94		0.45
		(1.23)		(1.35)		(1.71)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	*No*	*No*	Yes	Yes	Yes	Yes
Country-Time FE	*No*	*No*	*No*	*No*	Yes	Yes
Observations	1,033	1,033	1,033	1,033	1,033	1,033
R-squared	0.80	0.80	0.82	0.82	0.85	0.85

Source: authors' elaboration

Note: the dependent variable is the total Foreign Input Reliance (FIR) indicator. A constant is included but not reported. Robust standard errors clustered at country-industry level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8 LSDV model for the extra-EU FIR with two-year lagged *(t-2)* explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)
	Extra-EU FIR	*Extra-EU FIR*	*Extra-EU FIR*	*Extra-EU FIR*	*Extra-EU FIR*	*Extra-EU FIR*
Functional div. in FDI *(t-2)*	−0.04**	−0.04**	−0.04**	−0.05**	−0.06**	−0.07**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Ln(total inward FDI) *(t-2)*	−0.05	−0.38	−0.26	−0.63	−0.45	−0.98*
	(0.36)	(0.38)	(0.45)	(0.48)	(0.56)	(0.58)
Ln(gross output) *(t-2)*		3.68***		3.95***		4.00***
		(1.03)		(1.11)		(1.31)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	*No*	*No*	Yes	Yes	Yes	Yes
Country-Time FE	*No*	*No*	*No*	*No*	Yes	Yes
Observations	1,033	1,033	1,033	1,033	1,033	1,033
R-squared	0.57	0.58	0.60	0.61	0.67	0.68

Source: authors' elaboration

Note: the dependent variable is the extra-EU Foreign Input Reliance (FIR) indicator (i.e., net of intra-EU exposure). A constant is included but not reported. Robust standard errors clustered at country-industry level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9 LSDV model for intra-EU FIR with two-year lagged *(t-2)* explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)
	Intra-EU FIR	*Intra-EU FIR*	*Intra-EU FIR*	*Intra-EU FIR*	*Intra-EU FIR*	*Intra-EU FIR*
Functional div. in FDI *(t-2)*	−0.04***	−0.04***	−0.04***	−0.04**	−0.04***	−0.04**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Ln(total inward FDI) *(t-2)*	0.74**	0.89***	0.76**	0.95***	0.59	1.06***
	(0.29)	(0.30)	(0.34)	(0.36)	(0.38)	(0.39)
Ln(gross output) *(t-2)*		−1.74**		−2.01***		−3.55***
		(0.68)		(0.72)		(0.77)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Time FE	*No*	*No*	Yes	Yes	Yes	Yes
Country-Time FE	*No*	*No*	*No*	*No*	Yes	Yes
Observations	1,033	1,033	1,033	1,033	1,033	1,033
R-squared	0.88	0.88	0.90	0.90	0.92	0.92

Source: authors' elaboration

Note: the dependent variable is the intra-EU Foreign Input Reliance (FIR) indicator (i.e., net of extra-EU exposure). A constant is included but not reported. Robust standard errors clustered at country-industry level in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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References

Adarov, A., & Stehrer, R. (2021). Implications of foreign direct investment, capital formation and its structure for global value chains. *The World Economy*, *44*(11), 3246–3299.

Agénor, P. R. (2017). Caught in the middle?? The economics of middle?-Income traps. *Journal of Economic Surveys*, *31*(3), 771–791.

Amighini, A., Maurer, A., Garnizova, E., et al. (2023). *Global value chains: Potential synergies between external trade policy and internal economic initiatives to address the strategic dependencies of the EU*. European Union.

Amsden, A. (1989). *Asia's next giant: South Korea and late industrialization*. Oxford University Press.

Antràs, P. (2020). Conceptual aspects of global value chains. *The World Bank Economic Review*, *34*(3), 551–574.

Antràs, P., & Chor, D. (2013). Organizing the global value chain. *Econometrica*, *81*(6), 2127–2204. https://doi.org/10.3982/ECTA10813

Arriola, C., Cai, M., Kowalski, P., Miroudot, S., & van Tongeren, F. (2024). Towards demystifying trade dependencies: At what point do trade linkages become a concern?? *OECD Trade Policy Paper*, no. 280.

Baldwin, R. (2006). Globalisation: The great Unbundling(s). *Economic Council of Finland*, *20*(3), 5–47.

Baldwin, R. (2016). *The great convergence: Information technology and the new globalization*. Harvard University Press.

Baldwin, R., & Freeman, R. (2022). Risks and global supply chains: What we know and what we need to know. *Annual Review of Economics*, *14*(1), 153–180.

Baldwin, R., & Ito, T. (2021). The smile curve: Evolving sources of value added in manufacturing. *Canadian Journal of Economics*, *54*(4), 1842–1880.

Baldwin, R., Freeman, R., & Theodorakopoulos, A. (2022). Horses for Courses: Measuring Foreign Supply Chain Exposure, NBER Working Paper No. 30525.

Baldwin, R., Freeman, R., & Theodorakopoulos, A. (2023). Hidden Exposure; Measuring US Supply Chain Reliance, *Brookings Papers on Economic Activity*, September.

Bauerle Danzman, S., & Meunier, S. (2024). The EU's geoeconomic turn: From policy laggard to institutional innovator. *Journal of Common Market Studies*, *62*, 1097–1115.

Bernard, A. B., & Fort, T. C. (2015). Factoryless goods producing firms. *American Economic Review*, *105*(5), 518–523.

Berry, C. H. (1971). Corporate growth and diversification. *Journal of Law & Economics*, *14*(2), 371–383.

Bonadio, B., Huo, Z., Levchenko, A. A., & Pandalai-Nayar, N. (2021). Global supply chains in the pandemic. *Journal of International Economics*, *133*, 103534.

Bontadini, F., Evangelista, R., Meliciani, V., & Savona, M. (2022). Patterns of integration in global value chains and the changing structure of employment in Europe. *Industrial and Corporate Change*, *31*(3), 811–837.

Bontadini, F., Evangelista, R., Meliciani, V., & Savona, M. (2024). Technology, global value chains and functional specialization in Europe. *Research Policy*, *53*(2), 104908.

Borin, A., Mancini, M., & Taglioni, D. (2021). Measuring Exposure to Risk in Global Value Chains. World Bank Policy Research Working Paper, No. 9785.

Boschma, R. (2014). Towards an evolutionary perspective on regional resilience. *Regional Studies*, *49*(5), 733–751.

Branstetter, L. (2006). Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the united States. *Journal of International Economics*, *68*(2), 325–344.

Buckley, P. J., Strange, R., Timmer, M. P., & de Vries, G. J. (2020). Catching-up in the global factory: Analysis and policy implications. *Journal of International Business Policy*, *3*, 79–106.

Cadestin, C., De Backer, K., Miroudot, S., Moussiegt, L., Rigo, D., & Ye, M. (2019). Multinational enterprises in domestic value chains. *OECD Science Technology and Industry Policy Papers*, 63, March. OECD Publishing.

Carvalho, V. M., Nirei, M., Saito, Y. U., & Tahbaz-Salehi, A. (2021). Supply chain disruptions: Evidence from the great East Japan earthquake. *Quarterly Journal of Economics*, *136*(2), 1255–1321.

Casadei, P., Comotti, S., Crescenzi, R., & Iammarino, S. (2023). *Where global value chains go local: EU regions, global value chain creation and local upgrading*. Publications Office of the European Union.

Castellani, D., & Lavoratori, K. (2020). The lab and the plant: Offshore R&D and co-location with production activities. *Journal of International Business Studies*, *51*, 121–137.

Castellani, D., & Pieri, F. (2013). R&D offshoring and the productivity growth of European regions. *Research Policy*, *42*(9), 1581–1594.

Castellani, D., Jimenez, A., & Zanfei, A. (2013). How remote are R&D labs? Distance factors and international innovative activities. *Journal of International Business Studies*, *44*(7), 649–675.

Castellani, D., Meliciani, V., & Mirra, L. (2016). The determinants of inward foreign direct investment in business services across European regions. *Regional Studies*, *50*(4), 671–691.

Castellani, A., Perri, A., Scalera, V., & Zanfei, A. (Eds.). (2022). *Cross-border innovation in a changing world. Players, places, policies*. Oxford University Press.

Coveri, A., & Zanfei, A. (2023a). The virtues and limits of specialization in global value chains: Analysis and policy implications. *Journal of Industrial and Business Economics*, *50*(1), 73–90.

Coveri, A., & Zanfei, A. (2023b). Functional division of labour and value capture in global value chains: A new empirical assessment based on FDI data. *Review of International Political Economy*, *30*(5), 1984–2011.

Coveri, A., & Zanfei, A. (2023c). Who wins the race for knowledge-based competitiveness? Comparing European and North American FDI patterns. *The Journal of Technology Transfer*, *48*(1), 292–330.
Coveri, A., Cozza, C., Nascia, L., & Zanfei, A. (2020). Supply chain contagion and the role of industrial policy. *Journal of Industrial and Business Economics*, *47*(3), 467–482.
Coveri, A., Giammetti, R., & Zanfei, A. (2024a). Does functional diversification reduce the exposure to GVC disruptions? Evidence and implications for industrial policy. Paper presented at the Paper Development Workshop on Industrial policy and global value chains in an era of disruptions of the Journal of International Business Policy, 4 March 2024.
Coveri, A., Paglialunga, E., & Zanfei, A. (2024b). Functional specialization and upgrading in European regions: new insights from FDI data. Working Papers Series in Economics, Mathematics and Statistics, no. 2024/01, University of Urbino.
Crescenzi, R., Pietrobelli, C., & Rabellotti, R. (2014). Innovation drivers, value chains and the geography of multinational corporations in Europe. *Journal of Economic Geography*, *14*(6), 1053–1086.
Crowe, D., & Rawdanowicz, L. (2023). Risks and opportunities of reshaping global value chains. *OECD Economics Department Working Papers*, no. 1762.
Dankbaar, B. (2007). Global sourcing and innovation: The consequences of losing both organizational and geographical proximity. *European Planning Studies*, *15*(2), 271–288.
de Vries, G., Jiang, A., Lemmers, O., & Wei, S-J. (2021). Firm productivity and functional specialisation. *World Economy*, *44*, 1232–1260.
Dedrick, J., Kraemer, K. L., & Linden, G. (2010). Who profits from innovation in global value chains? A study of the iPod and notebook PCs. *Industrial and Corporate Change*, *19*, 81–116.
Doran, J., & Fingleton, B. (2018). US metropolitan area resilience: Insights from dynamic Spatial panel Estimation. *Environment and Planning A: Economy and Space*, *50*(1), 111–132.
Dosi, G., Pavitt, K., & Soete, L. (1990). *The economics of technical change and international trade*. New York University.
Durand, C., & Milberg, W. (2020). Intellectual monopoly in global value chains. *Review of International Political Economy*, *27*(2), 404–429.
Espitia, A., Mattoo, A., Rocha, N., Ruta, M., & Winkler, D. (2022). Pandemic trade: COVID-19, remote work and global value chains. *World Economy*, *45*(2), 561–589.
European Commission (2022). *EU Strategic Dependencies and Capacity: Second Stage of In-Depth Reviews*. Commission Staff Working Document, February. Available at: https://ec.europa.eu/docsroom/documents/48878
European Commission (2020). Europe's moment: Repair and prepare for the next generation. *COM(2020) 456 final*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A456%3AFIN. Accessed 15 June 2024.
Fagerberg, J. (2022). Mobilizing innovation for the global green shift: The case for demand-oriented innovation policy. In D. Castellani, A. Perri, V. G. Scalera, & A. Zanfei (Eds.), *Cross-Border innovation in a changing world: Players, places, and policies* (pp. 272–291). Oxford University Press.
Feenstra, R. (1998). Integration of trade and disintegration of production in the global economy. *Journal of Economic Perspectives*, *12*(4), 31–50.
Feldman, M. P., & Kogler, D. F. (2010). Stylized facts in the geography of innovation. *Handbook of the Economics of Innovation*, *1*, 381–410.
Felipe, J. (2012). Tracking the Middle-Income Trap: What is It, Who is in It, and Why? ADB Economics Working Paper Series No. 306. Asian Development Bank.
Fontana, O., & Vannuccini, S. (2024). How to institutionalise European industrial policy (for strategic autonomy and the green Transition). *Journal of Industry Competition and Trade*, *24*(20), 1–30.
Francois, J., & Hoekman, B. (2010). Services trade and policy. *Journal of Economic Literature*, *48*(3), 642–692.
Frankel, J., & Rose, A. (1998). The endogeneity of the optimum currency area criteria. *The Economic Journal*, *108*(449), 1009–1025.
Gereffi, G. (2014). Global value chains in a post-Washington consensus world. *Review of International Political Economy*, *21*(1), 9–37.
Gereffi, G. (2020). What does the COVID-19 pandemic teach Us about global value chains?? The case of medical supplies. *Journal of International Business Policy*, *3*(3), 287–301.
Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy*, *12*(1), 78–104.

Gereffi, G., Pananond, P., & Pedersen, T. (2022). Resilience decoded: The role of firms, global value chains, and the state in COVID-19 medical supplies. *California Management Review*, *64*(2), 46–70.
Giammetti, R. (2020). Tariffs, domestic import substitution And trade diversion in input-output production networks: An exercise on brexit. *Economic Systems Research*, *32*(3), 318–350.
Giammetti, R., Papi, L., Teobaldelli, D., & Ticchi, D. (2020). The Italian value chain in The pandemic: The input–output impact of Covid-19 lockdown. *Journal of Industrial and Business Economics*, *47*(3), 483–497.
Giammetti, R., Papi, L., Teobaldelli, D., & Ticchi, D. (2022). The network effect of deglobalisation on European regions. *Cambridge Journal of Regions Economy and Society*, *15*(2), 207–235.
Giovannetti, G., Marvasi, E., & Ricchiuti, G. (2023). The future of global value chains and international trade: An EU perspective. *Italian Economic Journal*, *9*(3), 851–867.
Grabher, G., & Stark, D. (1997). Organizing diversity: Evolutionary theory, network analysis and postsocialism. *Regional Studies*, *31*(5), 533–544.
Grossman, G. M., & Helpman, E. (2002). *Special interest politics*. MIT Press.
Guarascio, D., Reljic, J., Cucignatto, G., Simonazzi, A., & Celi, G. (2024). Between scylla and Charybdis: Long-term drivers of EU structural vulnerability. *Review of Keynesian Economics*, *13*(1), 112–140.
Guiso, L., Sapienza, P., & Zingales, L. (2009). Cultural biases in economic exchange?? *Quarterly Journal of Economics*, *124*(3), 1095–1131.
Hausmann, R. (2013). The Specialization Myth. Project Syndicate, 30 December. Available at: https://www.project-syndicate.org/commentary/ricardo-hausmann-warns-that-advising-cities--states--and-countries-to-focus-on-theireconomies--comparative-advantage-is-both-wrong-and-dangerous. Accessed 15 Jan 2025
Hausmann, R., & Rodrik, D. (2003). Economic development as self-discovery. *Journal of Development Economics*, *72*(2), 603–633.
Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of Economic Growth*, *12*, 1–25.
Hidalgo, C. A., & Hausmann, R. (2009). The Building blocks of economic complexity. *Pnas*, *106*, 10570–10575.
Hidalgo, C. A., Klinger, B., Barabási, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science*, *317*(5837), 482–487.
Hines, J. R. (2010). Treasure Islands. *Journal of Economic Perspectives*, *24*(4), 103–126.
Hirschman, A. O. (1958). *Strategy of economic development*. Yale University Press.
Imbs, J., & Wacziarg, R. (2003). Stages of diversification. *American Economic Review*, *93*(1), 63–86.
International Monetary Fund. (2023). *World economic outlook, April 2023: A Rocky recovery*. International Monetary Fund.
Jaax, A., Miroudot, S., & van Lieshout, E. (2023). Deglobalisation? The reorganisation of GVCs in a changing world. *OECD Trade Policy Paper*, no. 272.
Javorcik, B. (2020). Global supply chains will not be the same in the post-COVID-19 world. In R. Baldwin, & S. J. Evenett (Eds.), *COVID-19 and trade policy: Why turning inward won't work* (pp. 111–116). CEPR. VoxEU.org eBook.
Johnson, R. C., & Noguera, G. (2012). Accounting for intermediates: Production sharing and trade in Value-Added. *Journal of International Economics*, *86*(2), 224–236.
Kaldor, N. (1967). *Strategic factors in economic development*. Cornell University Press.
Koopman, R., Wang, Z., & Wei, S. J. (2014). Tracing Value-Added and double counting in gross exports. *American Economic Review*, *104*(2), 459–494.
Lee, J., & Gereffi, G. (2021). Innovation, upgrading, and governance in cross-sectoral global value chains: The case of smartphones. *Industrial and Corporate Change*, *30*(1), 215–231.
Mariotti, S. (2024). Open strategic autonomy as an industrial policy compass for the EU competitiveness and growth: The good, the bad, or the ugly? *Journal of Industrial and Business Economics*. https://doi.org/10.1007/s40812-024-00327-y
Mariotti, S., & Marzano, R. (2024). Janus-like antitrust policy: How to make the pro-FDI orientation prevail. In P. Gugler, & A. T. Tavares-Lehmann (Eds.), *Handbook of international business policy* (pp. 125–141). Edward Elgar Publishing.
Martin, R. (2012). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography*, *12*(1), 1–32.

Mizgier, K. J., Wagner, S. M., & Jüttner, M. P. (2015). Disentangling diversification in supply chain networks. *International Journal of Production Economics*, *162*, 115–124.
Mudambi, R. (2008). Location, control and innovation in Knowledge-Intensive industries. *Journal of Economic Geography*, *8*(5), 699–725.
Myrdal, G. (1957). *Economic theory and underdeveloped regions*. Gerald Duckworth.
Nachum, L., Dunning, J. H., & Jones, G. G. (2000). UK FDI and the comparative advantage of the UK. *World Economy*, *23*, 701–720.
Paglialunga, E., Coveri, A., & Zanfei, A. (2022). Climate change and within-country inequality: New evidence from a global perspective. *World Development*, *159*, 106030.
Pavlínek, P. (2022). Relative positions of countries in the core-periphery structure of the European automotive industry. *European Urban and Regional Studies*, *29*(1), 59–84.
Pendall, R., Foster, K. A., & Cowell, M. (2010). Resilience and regions: Building Understanding of the metaphor. *Cambridge Journal of Regions Economy and Society*, *3*(1), 71–84.
Pike, A., Dawley, S., & Tomaney, J. (2010). Resilience, adaptation and adaptability. *Cambridge Journal of Regions Economy and Society*, *3*(1), 59–70.
Pisano, G. P., & Shih, W. C. (2012). *Producing prosperity: Why America needs a manufacturing renaissance*. Harvard Business.
Prebisch, R. (1950). *The economic development of Latin America and its principal problems*. United Nations Department of Economic Affairs.
Rodrik, D. (2016). Premature deindustrialization. *Journal of Economic Growth*, *21*(1), 1–33.
Rodrik, D. (2018). Populism and the economics of globalization. *Journal of International Business Policy*, *1*(1), 12–33.
Rosenstein-Rodan, P. (1943). Problems of industrialisation of Eastern and South-Eastern Europe. *Economic Journal*, *53*(210–211), 202–211.
Rowthorn, R., & Wells, J. R. (1987). *De-industrialization and foreign trade*. Cambridge University Press.
Schmitz, L., & Seidl, T. (2023). As open as possible, as autonomous as necessary: Understanding the rise of open strategic autonomy in EU trade policy. *Journal of Common Market Studies*, *61*, 834–852.
Schwellnus, C., Haramboure, A., Samek, L., Pechansky, R. C., & Cadestin, C. (2023). *Global value chain dependencies under the magnifying glass* (Vol. 142No.). OECD Science, Technology and Industry Policy Papers.
Shin, N., Kraemer, K. L., & Dedrick, J. (2012). Value capture in the global electronics industry: Empirical evidence for the smiling curve concept. *Industry and Innovation*, *19*(2), 89–107.
Singer, H. W. (1950). The distribution of gains between investing and borrowing countries. *American Economic Review*, *40*(2), 473–485.
Stöllinger, R. (2016). Structural change and global value chains in the EU. *Empirica*, *43*, 801–829.
Stöllinger, R. (2019). Testing the Smile Curve: Functional Specialisation in GVCs and Value Creation. wiiw Working Paper, No. 163
Stöllinger, R. (2021). Testing the smile curve: Functional specialisation and value creation in GVCs. *Structural Change and Economic Dynamics*, *56*, 93–116.
Sturgeon, T., & Van Biesebroeck, J. (2011). Global value chains in the automotive industry: An enhanced role for developing countries?? *International Journal of Technological Learning Innovation and Development*, *4*(1/2/3), 181–205.
Sturgeon, T. J., Van Biesebroeck, J., & Gereffi, G. (2008). Value chains, networks and clusters: Reframing the global automotive industry. *Journal of Economic Geography*, *8*(3), 297–321.
Timmer, M. P., Los, B., Stehrer, R., & de Vries, G. J. (2013). Fragmentation, incomes, and jobs: An analysis of European competitiveness. *Economic Policy*, *28*(76), 613–661.
Timmer, M. P., Erumban, A. A., Los, B., Stehrer, R., & de Vries, G. J. (2014). Slicing up global value chains. *Journal of Economic Perspectives*, *28*, 99–118.
Timmer, M. P., Los, B., Stehrer, R., & de Vries, G. J. (2016). *An Anatomy of the Global Trade Slowdown based on the World Input-Output Tables. GGDC Research Memorandum, No. 162*. Groningen Growth and Development Centre, University of Groningen.
Timmer, M. P., Miroudot, S., & de Vries, G. J. (2019). Functional specialisation in trade. *Journal of Economic Geography*, *19*(1), 1–30.
UNCTAD. (2024). *Global economic fracturing and shifting investment patterns. A diagnostic of 10 FDI trends and their development implications*. United Nations.

Viner, J. (1950). *The Customs Union Issue*. Oxford University Press.
Waldkirch, A. (2011). Comparative advantage FDI? A host country perspective. *Review of World Economics*, *147*(3), 485–505.
World Bank. (2020). *World Development Report 2020. Trading for Development in the Age of Global Value Chains*. World Bank.
World Bank. (2024). *World Development Report 2024: The Middle-Income Trap*. World Bank.
Zanfei, A., Coveri, A., & Pianta, P. (2019). FDI patterns and global value chains in the digital economy. Working Papers Series in Economics, Mathematics and Statistics, no. 3, University of Urbino.