Does functional diversification reduce the exposure to GVC disruptions? Evidence and implications for industrial policy

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ABSTRACT

This paper examines the links between the diversification of economies across value chain functions and their exposure to disruptions in global value chains (GVCs). We empirically test this nexus by combining new indicators of GVC exposure with an FDI-based measure of functional diversification for a wide range of countries and industries in 2003-2018. We show that greater functional diversification is on average associated with lower GVC exposure, both at the country and industry level. However, this negative relationship holds for Scale intensive and Suppliers dominated industries, while it is not confirmed for Science-based and Specialized suppliers industries. This seems consistent with the necessity for the most innovative industries to combine global sourcing of specific components and knowledge assets located abroad with functional diversification as a key competitive factor. Accordingly, industrial policies aimed at expanding the array of value chain functions to soften the potential adverse effects of GVC disruptions should be complemented with careful selection of global partners for sourcing key inputs.

Keywords:
global value chains; foreign direct investment; risk exposure; resilience; diversification.

JEL codes:
F12, F14, F23, F60, O14

1. Introduction

The international fragmentation of production has led to the geographical dispersion of value chain activities on a global scale for the realization of goods and services (Feenstra, 1998; Gereffi et al., 2005; Timmer et al., 2014). While this process has reshaped the international division of labour and opened industrialisation opportunities (UNCTAD, 2013), it has also led to greater inter-dependencies across world economies, increasingly exposing countries and regions to the risks of global interruptions in the access to critical intermediate inputs, components, as well as know-how (Gereffi, 2020; Schwellnus et al., 2023).

The increasing reliance on Chinese and Southeast Asian economies for an ever-widening range of components and materials has become a growing source of concern in advanced economies since the turn of the century, sparking a lively discussion on dependencies in global value chains (GVCs) and on the potential advantages associated with reshoring strategies (see, e.g., Panwar, 2010; Shih, 2014). Major disruptive events like the outbreak of the Covid-19 pandemic (Coveri et al., 2020; Giammetti et al., 2020; Strange, 2020; Gereffi et al., 2022), the Russian invasion of Ukraine (Mariotti, 2022; Sturm, 2022), the ongoing USA-China trade war (Gereffi et al., 2021; Fajgelbaum et al., 2023; Tung et al., 2023) and the rekindling of conflicts in the Middle East have definitively placed the evolving configuration and vulnerability of GVCs at the centre of academic and political debate (see, e.g., Javorcik, 2020; Miroudot, 2020; Pla-Barber et al., 2021).

Several recent studies have highlighted the dual role of GVCs in both transmitting economic shocks from specific regions where key suppliers are concentrated and mitigating supply shortages when domestic value chains are disrupted (Boehm et al., 2019; Bonadio et al., 2021; Carvalho et al., 2021; Espitia et al., 2021). Consistently, Borin et al. (2021) found that GVC integration reduces exposure to domestic shocks while increasing vulnerability to global shocks.[1]

In response to these challenges, there has been growing interest in policies aimed at increasing "strategic autonomy" in Europe and other regions. This strategy involves promoting self-reliance and control over key industries and technologies at the macro-regional level while selectively internationalizing through friend-shoring and regionalization of value chains (European Commission, 2022; Amighini et al., 2023). This policy approach emphasizes boosting production capacity in critical sectors and developing less risky, and more resilient supply chains (CSC, 2023; Giovannetti et al., 2023). What remains largely unexplored in extant literature is whether and how the level of specialisation or diversification of economies translates into a higher degree of "Open Strategic Autonomy" and hence into a lower exposure to GVC fragilities. This

[1] Borin et al. (2021) introduced new indicators based on international input-output tables aimed at measuring the exposure of countries and industries to GVC shocks, namely to the risks faced by countries and industries due to demand and supply bottlenecks in GVCs. In particular, they computed GVC measures based on the overall country-industries' output whose production is involved in global production networks, thereby providing a more comprehensive exposure to GVC disruptions than indicators based on export flows only.

paper aims to analyse this link conceptually and empirically. Our contribution in this respect is twofold.

First, we argue that the emergence and evolution of GVCs induces a deep reconsideration of the nature itself of diversification. Indeed, the issue at stake is not only, and not so much, the degree of diversification of economies at the product level. It is rather a matter of diversifying into *value chain functions* within individual industries (Kruse et al., 2023).

Second, we suggest that a higher functional diversification allows economies to expand their technological capabilities and enrich their productive matrix, thereby affecting their reliance on foreign inputs and moderating the exposure to risks of supply chain disruptions.

As we shall argue, there are important partially countervailing effects that functional diversification may have on GVC exposure. On the one hand, functionally diversified economies are likely to exhibit a higher capacity to innovatively respond to disruptive events, hence reducing the need for foreign inputs. On the other hand, they may be better at managing the risk associated with sudden changes in supply chains, hence enabling them to live up with, and benefit from, high foreign input reliance. These effects may be hard to disentangle, and an exploratory effort is needed.

We empirically address this issue by combining new indicators on the GVC exposure for a large array of countries and industries with high-quality data on Foreign Direct Investments (FDIs) reporting information on the value chain activities they are aimed to perform over the 2003-2018 period.

Our findings show that a greater functional diversification of economies is associated with lower levels of GVC exposure, suggesting that industrial policies aimed at expanding the array of value chain functions could soften the potential adverse effects of supply chain disruptions. Specifically, our results show that an increasing functional diversification of economies goes together with a lower reliance on gross flows of foreign inputs, arguably reducing their vulnerability to global shocks.

At the country level, our estimate results demonstrate a robust negative relationship between functional diversification in FDI and GVC exposure, as measured by the Foreign Input Reliance (FIR) indicator. This negative association remains significant across different model specifications, consistent with the idea that maintaining and expanding the capabilities for performing a broader set of value-adding activities may help reduce the overall foreign input reliance and creatively respond to GVC disruptions.

At the industry level, using Pavitt classes to group sectors according to their structure and innovation propensity, we observe that functional diversification shows a negative and statistically significant association with GVC exposure in Scale intensive (SI) and Suppliers dominated (SD) industries, which constitute the industrial base for many middle- as well as high-income countries. However, this negative relationship does not hold for Science-based (SB) and Specialized suppliers (SS) industries. The lack of significance in these sectors suggests that the benefits of functional diversification may

vary depending on the nature of the industry. For instance, SB sectors rely heavily on access to global knowledge sources and immaterial assets, which may not reduce the need for foreign inputs despite functional diversification. In the case of SS industries, which focus on capital goods and specialized equipment, a key competitive asset consists in the ability to creatively combine commodity-like components that can be accessed in international markets. Accordingly, FIR can hardly be reduced by additional capacities in R&D, logistics or marketing in these industries.

The remainder of this work is organized as follows. Section 2 discusses the conceptual framework of the analysis and puts forth the main research question we wish to address, concerning the links between functional diversification and GVC exposure. Section 3 describes the data used in this work, while Section 4 offers descriptive evidence on the main variables under investigation. Section 5 outlines our empirical strategy and Section 6 shows the results of the empirical analysis. The last section concludes by discussing some industrial policy implications.

2. Conceptual framework and research question

Our key argument is that the degree of diversification of economies is likely to affect the exposure to GVC disruptions. Before addressing this issue, it is necessary to anticipate how GVC exposure is defined in this paper. As illustrated in detail in section 3, we will concentrate on variants of one of the input-output based indicators proposed by Baldwin and Freeman (2022) and Baldwin et al. (2022, 2023) measuring the direct and indirect imported inputs as a share of gross output. As such, this indicator captures how exposed economies are to the risk associated with events that might disrupt trade flows, interrupting supply chains on the import side. It does not inform on how such risk translates into actual damage, how such risk is tackled by the examined economies nor how effective the response is if any. It nevertheless might be thought of as revealing of the intensity of such risk, and we are interested in assessing to what extent the diversification of economies affects their capacity to deal with it.

This line of arguments relies on two sets of reflections. First, we shall address the changing role of diversification and specialization of economies in a context of increasing international fragmentation of production. We shall argue that in such a world the specialization that matters concerns value-adding functions more than products and industries. Second, and most importantly, we will discuss whether and how the specialization or diversification in GVC functions is associated with the exposure of economies to changes in trade conditions that may suddenly interrupt GVCs. We will suggest that responding to these shocks implies a careful definition of the geographical boundaries of international production networks, substantial investments in strategic activities at the national and macro-regional levels, as well as selective global linkages to connect to key assets and knowledge sources whenever necessary (Coveri & Zanfei, 2023a).

2.1 From sectoral to functional diversification

Standard models have long relied on the argument that specialization is the key engine of gains from trade. However, the economic advantages of specialization are not as straightforward as they might appear at first glance.

On the one hand, some specialization patterns are more conducive to economic development than others. As pointed out by the pioneers of economic development – such as Rosenstein-Rodan (1943), Prebisch (1950), Singer (1950), Myrdal (1957), Hirschman (1958) and Kaldor (1967) – not all sectors share the same growth potential. Countries that manage to specialize in industries featured by larger learning effects and higher returns to scale are better placed to foster a sustained economic development path (Amsden, 1989; Dosi et al. 1990). In a nutshell, producing 'microchips' is not the same as producing 'potato chips': as has recently been shown by Dosi et al. (2021), the quality of specialization matters, especially for the long-term development prospects of economies.

On the other hand, gains from specialization of individuals co-exist with the benefits arising from diversification at more aggregated levels of analysis. This observation underlies a growing stream of literature adopting an "economic complexity" approach to economic development trajectories. From this perspective, productive diversification of countries (especially into products that are incrementally more complex) is a key driver for development (Hausmann et al., 2007; Hidalgo et al., 2007; Hidalgo & Hausmann, 2009).

Although the conceptual framework offered by the complexity approach proved promising, the emergence and evolution of GVCs induces a re-consideration of the specialization *versus* diversification argument. In fact, it appears that the issue at stake is not only nor primarily the degree of specialization – or diversification – of economies at the product level, rather a matter of specializing – or diversifying – into *functions* within individual industries.

Indeed, there are important conceptual and empirical issues to be tackled when bringing the analysis from products to functions (Coveri & Zanfei, 2023a). From a conceptual point of view, *it is at the functional rather than the product level that GVC participation and value appropriation can be appreciated*. By de-composing the exports of a given country (region or firm) into finer and finer product categories, one can derive no relevant information on what value-adding functions are being undertaken to bring those products to market. By disregarding the functional level of analysis, one is likely to miss a fundamental feature of the international fragmentation of production, i.e., the different economic value that is associated with distinct GVC activities within individual industries and product lines (Mudambi, 2008; Shin et al., 2012; Durand & Milberg 2020; Coveri & Zanfei, 2023b).

From the empirical point of view, *research has long been at odds with the measurement of functions*. Let alone the approaches based on the detailed qualitative case studies concerning the GVC of specific products or industries (see, e.g., Dedrick et al., 2010), standard input-output based measures of the international fragmentation of production

(Johnson & Noguera, 2012; Koopman et al., 2014; Timmer et al., 2014) fail to capture what value-adding activities are being carried out in a given sector. In other words, one country may well be specialized in the export of a given set of goods that can be classified "upstream" in the value chain. However, no relevant information can be provided on the tasks undertaken in the production process, hence allowing little or no inference on its functional specialization and related value capture opportunities (de Vries et al., 2021).

Recent empirical research has more directly addressed the functional profile of economies. One strand of contributions, inaugurated by Timmer et al. (2019), provided a methodology to compute the 'functional specialization in trade' of economies based on the value added embodied in exports that is generated by (or accruing to) workers belonging to different occupational categories. By so doing, the authors are able to measure the amount of value added that can be traced back to workers performing specific tasks along the GVC of exported goods and services (see also Buckley et al., 2020). A different stream of research uses data on foreign direct investments (FDIs) occurring in different value chain activities (ranging from R&D to manufacturing operations, up to commercialization activities) to examine the geographic distribution of functions within "captive" GVCs controlled by large MNCs (Stöllinger, 2019; Zanfei et al. 2019). These authors introduced measures of 'functional specialization in FDI' by adopting a cross-sectional perspective at the country-industry level (Stöllinger, 2021) and a longitudinal perspective at both country and subnational region level (Coveri et al., 2022; Coveri & Zanfei, 2023b).

2.2 Functional diversification and exposure to GVC disruptions

How does functional specialization or diversification affect GVC exposure? On the one hand, specializing in low value-adding activities might undermine trade competitiveness. This might be the case also when countries are major producers and exporters in highly dynamic industries and products: an economy that only does assembly activities in no matters how many industries is not likely to capture large shares of value even if it is a major exporter of highly sophisticated goods. On the other hand, specializing "only" in a limited range of high value-adding activities (such as R&D and design functions) without any presence in lower-end activities (such as manufacturing or assembly) may not allow growth opportunities to be fully exploited. This low diversification (or hyper-specialization) risks reducing economies' ability to deal with events undermining trade relations.

There are several reasons to argue that greater functional diversification could be associated with a greater ability to deal with international markets and hence affect economies' exposure to trade disruptions.

A first set of channels through which functional diversification may affect the capacity of economies to respond to unexpected changes in trade flows is *innovation*. Diversified economies can be better placed to generate valuable knowledge and capabilities. This argument connects to a reflection on the importance of jointly carrying out manufacturing and other higher value-added activities, that dates back to Cohen and

Zysman (1987) and has been revived more recently by Pisano & Shih (2012) and Shih (2020). According to Pisano & Shih (2012), manufacturing offshoring strategies that have characterized advanced economies for decades may be rational at the micro level, i.e., if one adopts the point of view of the individual firm. However, such strategies can be detrimental at the macro level, i.e., for the economic system as a whole. In fact, they contribute to the steady erosion of what they call "industrial commons", which consist of "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). Moreover, specializing in an increasingly narrow set of core functions due to cost-reduction objectives has also hampered their capabilities to exploit external economies of agglomeration (Feldman & Kogler, 2010). This is especially true in industries where the innovation process largely relies on knowledge flows which are highly tacit, making the geographical proximity between lead firms and supply chain suppliers even more important to effectively transmit and exchange information and know-how (Dankbaar, 2007; Castellani & Lavoratori, 2020; Fagerberg, 2022).

These streams of literature converge in emphasizing that the long-term innovation capacity of economies could benefit from a wider array of activities, and provide sound arguments against the dismantling of manufacturing activities. In other words, delocalizing fabrication and assembly of goods abroad to concentrate on higher value-added functions at home does not necessarily entail upgrading: it is bound to reduce, rather than increase, the competitiveness and prosperity of economies.

To the extent that innovation is a key driver of internationalization (see Castellani et al. 2022 for a review), the lines of argument we have just recalled have implications for the analysis of the exposure of economies to trade disruptions. This for two main reasons. On the one hand, by increasing innovation capacity, functional diversification is likely to mitigate the potentially negative impacts of supply chain interruptions on the capacity to penetrate foreign markets. Hence economies exhibiting higher functional diversification may be expected to suffer less from foreign market shrinks determined by disruptive events (*outward internationalization mechanism*). On the other hand, higher innovation generated by functional diversification increases the absorptive capacity of domestic firms, improving their ability to search, and utilize, alternative supplies and suppliers. Hence functional diversification may determine a more effective selection of foreign sources, potentially reducing the economy's reliance on foreign inputs (*inward internationalization mechanism*). Given our focus on import-side exposure effects, we will take the latter mechanism into account in our empirical exercise and disregard the former.

A second channel through which functional diversification may affect the exposure to trade disruptions is *risk diversification*. This argument draws from an extensive economic literature on the role played by the (sectoral) diversification of economies, when dealing with economic fluctuations and instabilities. Especially in the field of economic geography, several contributions have highlighted that the development of a larger number of partially uncorrelated economic activities alleviates the negative

consequences which can derive from sector-specific shocks or other kinds of disruptive events that might affect selected productive technologies or occupational categories (Grabher & Stark, 1997; Boschma, 2015; Doran & Fingleton, 2018). Most importantly, countries' capacity to sustain a higher economic diversification would reflect the availability of a larger mix of technological and organizational capabilities, which in turn can be more easily and flexibly recombined to soften the consequences of adverse phenomena and to adapt to changing economic conditions (Neffke et al., 2011; Castaldi et al., 2015). Overall, a more diversified economic structure provides greater capacity to better absorb more severe shocks in the short term and larger "adaptability" in the long run by increasing the opportunities to develop new growth paths (Pendall et al., 2010; Pike et al., 2010; Martin, 2012; Tóth et al., 2022).

However, this line of argument needs to be qualified to account for a functional perspective. Economies exhibiting a high degree of sectoral diversification might at the same time be characterised by a narrow set of productive and knowledge capabilities if they are hyper-specialized in few selected value chain functions of products. In these cases, the capacity of places to deal with unforeseen changes is likely to be overestimated. In other words, looking at sectoral patterns of specialization is not enough to assess domestic actors' capabilities to absorb adverse shocks and to mobilize resources – in terms of assets, skills and knowledge – to rapidly recover. 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 et al., 2022; Coveri & Zanfei, 2023b). From this perspective, functionally diversified economies are likely to be more capable to creatively respond to adverse, unexpected phenomena for at least two reasons. First, they are better placed to find alternative domestic capacities that can replace external assets in case their supply is interrupted. Second, they can resort to more capabilities that can be recombined with other external inputs when changes in supply occur.

This line of argument may have potentially contradictory implications on the actual exposure of economies to disruptive events. On the one hand, by increasing their capacity to manage risky conditions, functional diversification might well reduce risk aversion and induce economies to maintain or even expand the size and range of foreign supplies, hence increasing foreign reliance and ultimately augmenting their actual exposure (*risk propensity effect*). On the other hand, by improving economies' abilities to respond to unpredicted changes, functional diversification might reduce the actual need for foreign inputs. There would then be no reason for economies to take a greater risk to purchase inputs abroad, as a higher self-reliance is possible. If this were the case, the link from functional diversification and input reliance would be negative (*risk aversion effect*). Assessing which effect will prevail is largely an empirical question. There might be a number of non-observable, time variant determinants, as well as remarkable country-specificities and cross-sectoral differences in the actual impact of functional diversification on risk-taking and on their actual dependence on foreign supplies.

Accordingly, the main research question we wish to address can be formulated as follows: *how does functional diversification of economies affect their exposure to GVC disruptions over time?*

3. Data

3.1 Measuring risk exposure in GVCs

Indicators on the exposure of economies to GVC disruptions are based on recent contributions by Baldwin and Freeman (2022) and Baldwin et al. (2022, 2023), who introduced novel gross output-based metrics, labelled Foreign Input Reliance (FIR) and Foreign Market Reliance (FMR), to gauge a nation's overall dependence on both directly and indirectly imported inputs from foreign suppliers (FIR) and exported output to foreign clients (FMR). The deliberate inclusion of double-counting, where intermediate inputs are tallied each time they cross national borders, aligns with the notion that a GVC bottleneck in a specific location can disrupt the entire value chain, beyond affecting solely the value-added contribution from that location. This intentional counting of intermediate inputs implies that the indicators account for the length of the upstream (FIR) and downstream (FMR) value chain a country-industry is engaged in. It follows that these indicators consider both the size of exposure to a partner in the value chain and the distance to this partner, representing the length of the value chain. Overall, FIR and FMR can be interpreted as the proportion of total domestic output exposed to foreign disruptions in GVCs, accounting for both upstream and downstream risks.

The indicators on GVC dependencies introduced by Baldwin and Freeman (2022) have been recently employed by Schwellnus et al. (2023) to investigate whether a higher exposure of industries to GVC risks is associated with larger reductions in domestic output after that a shock occurs in upstream or downstream industries. In particular, they used exogenous mobility shocks during the Covid-19 pandemic to estimate the transmission of foreign disruptions on domestic output through global supply chains, finding that the new indicators of exposure to GVC risk developed by Baldwin and Freeman (2022) are accurate predictors of the impact of shocks to foreign suppliers and buyers on domestic production (especially in industries with few supplying countries, i.e., showing high geographic concentration, and few supplying firms within the industry, i.e., reporting high industry concentration).[2]

In this work, we compute the FIR indicator – hence the "import-side" of GVC exposure – by exploiting the 2023 release of the OECD Inter-Country Input-Output (ICIO) tables, providing data for 76 economies and 45 industries for the period 1995-2020.

[2] These results confirm previous research in the supply chain risk management literature (Babich, 2007; Mizgier, 2015, Schmitt, 2015; Namdar, 2018; Moosavi, 2022) and GVC studies (Sturgeon, Van Biesebroeck, & Gereffi, 2008; Buckley & Strange, 2015; Sun & Grimes, 2018; Arriola, 2020; Baldwin, 2020; UNCTAD, 2020; Gereffi, 2020; Gereffi, 2022), which have long recognized the risks associated with a lack of geographical diversification in sourcing strategies.

3.2 Measuring functional diversification

We combine trade-based indicators on GVC exposure with a measure on the functional diversification of economies, that we build by leveraging the richness of information on cross-border investments provided by the fDi Markets database. The latter is a proprietary data source maintained by the Financial Times, covering all greenfield FDIs from 2003 onwards and reporting, *inter alia*, information on the destination country-industry of each FDI together with the business function undertaken in the host economy.[3]

To compute our measure of functional diversification, we follow Paglialunga et al. (2022) and focus on information concerning the value chain functions each inward FDI is aimed to perform. The fDi Markets database classifies cross-border investments in several functions, ranging from headquarter activities, R&D and design, to production operations, up to logistics, marketing and further post-production activities. Accordingly, we use the above classification of FDIs to compute an index of *functional diversification in FDI* (FD) based on the normalized Herfindahl–Hirschman index (HHI). For each country *c* and year *t*, and considering each GVC function *k*, the FD index is computed as follows:

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

where $HHI^{K}_{c,t}$ is the normalized HHI based on GVC functions and the ratio in the round brackets represents the share of FDIs related to the *k*-th of the M functions over the total inward FDIs for country *c* in year *t*.[4] This measure of functional diversification will be used as focal explanatory variable in the analysis of the determinants of the economies' exposure to GVC disruptions.

As we shall explain more in detail in section 5, we will first explore the association between functional diversification in FDI and GVC exposure at the country level. Next, we will deepen the analysis by scaling down the empirical investigation at the macro-industry level by aggregating sectors according to the revised Pavitt taxonomy (Pavitt, 1984; Bogliacino & Pianta, 2010).

4. Descriptive evidence

This section lays the groundwork for our empirical analysis by detailing the trends in risk exposure within GVCs and examining functional diversification across both countries and industries.

[3] Further details on the fDi Markets database are provided in Coveri & Zanfei (2023c).

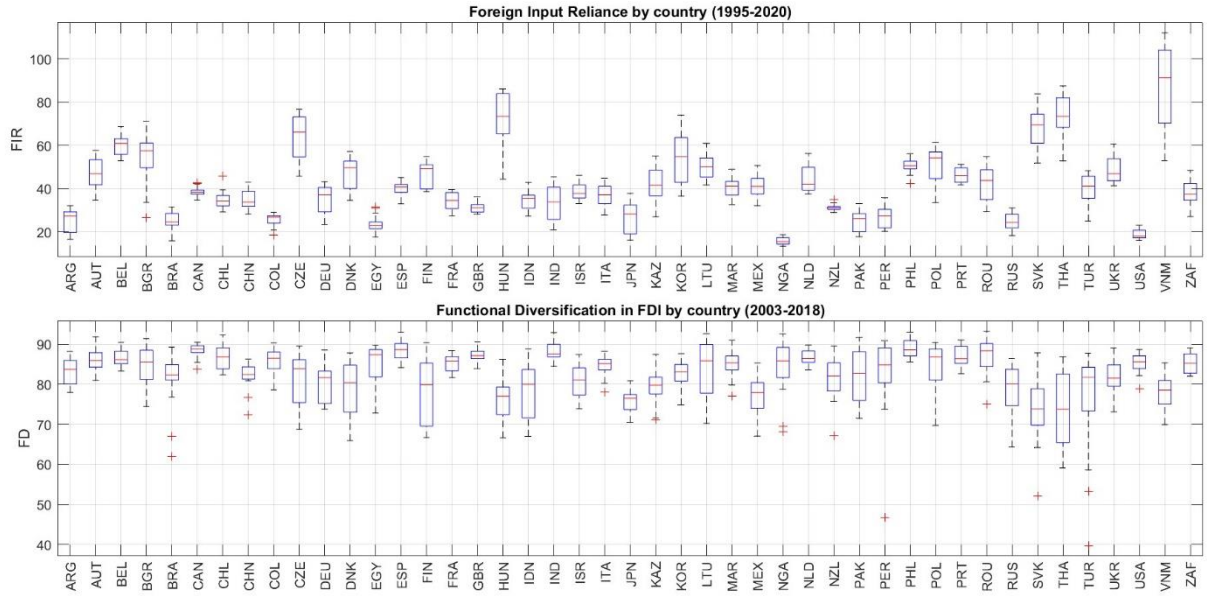
[4] The formula in squared brackets reported in equation (1) is the normalized version of the HHI, also known as Berry-Herfindahl index (Berry, 1971).

4.1 Country-level evidence

The box plots in Figure 1 depict Foreign Input Reliance (FIR) and Functional Diversification (FD), providing a nuanced perspective on the global economic landscape and revealing the intricate balance between economic size and supply chain structures. FIR data reveals that smaller economies such as Vietnam, Thailand, Slovakia, and Hungary have higher FIR, indicating a greater reliance on foreign inputs to sustain industries and meet domestic demand. These countries have high medians and wide interquartile ranges, reflecting both dependence and variability. Conversely, large economies such as the United States, Japan, and Brazil have lower FIRs, suggesting stronger domestic supply chains or distinct industrial compositions. However, there are exceptions among large economies, such as Germany, India, and China, which have moderate to high FIRs, reflecting sectors that are deeply integrated into global supply chains or industries that rely on imported components.

The FD analysis in Figure 1 shows advanced economies like Canada, France, the UK, and the USA maintaining high and stable FD levels, indicating diversified economic activities in FDI. Emerging economies such as Brazil, China, and Poland exhibit moderate and variable FD, reflecting ongoing efforts at economic diversification. Notably, countries with high FIR, like Hungary, Slovakia, Vietnam, and Thailand tend to show lower FD, aligning with the hypothesis of a negative relationship between these indicators. Furthermore, the contrast between stable FD in advanced economies and fluctuating FIR in emerging economies underscores the importance of functional diversification in bolstering economic resilience. Countries with balanced and high FD are better positioned to absorb global shocks, whereas those with high FIR face greater economic risks.

Figure 1. Foreign Input Reliance and Functional Diversification in FDI by country

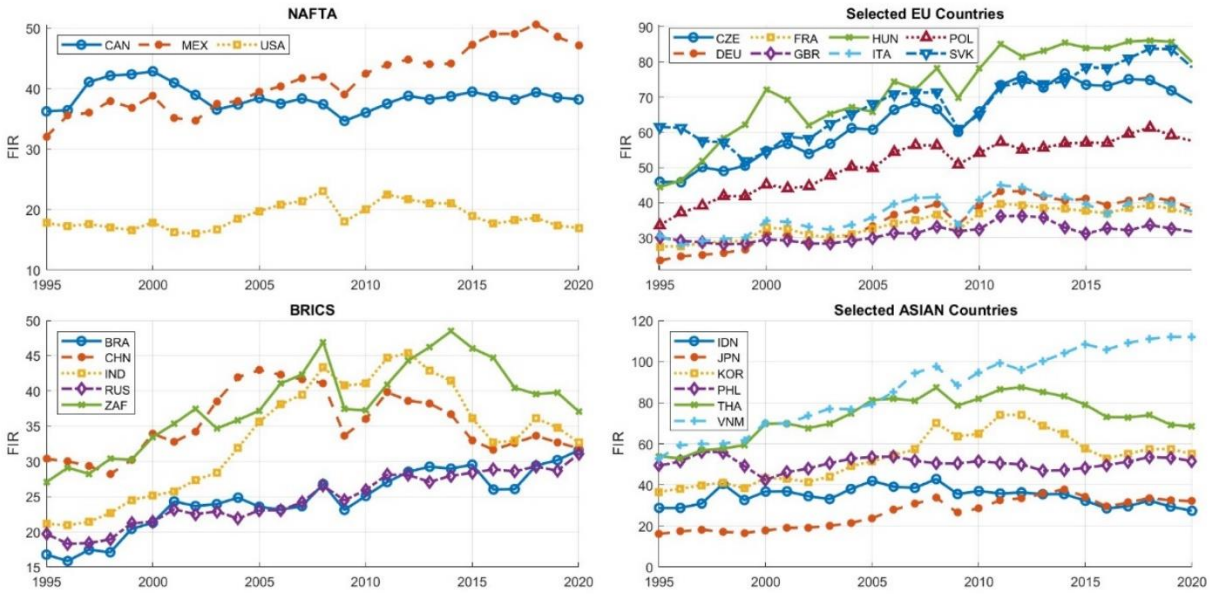


Source: authors' elaborations based on OECD ICIO and fDi Markets data.

There are important similarities and differences in terms of FIR and FD patterns over time both across and within macro-regions.

As far as FIR is concerned, suffice here to highlight four main features (Fig. 2). First, all countries experienced *a long-term increase in FIR* since the beginning of the observation period (1995), with the partial exception of North America whose foreign input reliance has been rather stable over time. Second, *the average level of FIR reached by most European and Asian countries is on average much higher than that of BRICS and NAFTA members*, reflecting the larger size of the latter economies as well as their historically lower trade openness. Third, *the 2008-2009 financial crisis triggered a dramatic drop in FIR in all countries* around the world, underscoring the global economic downturn's disruptive impact on international trade and supply chains. Fourth, *post-crisis recovery patterns vary significantly within all macro-regions*. While some countries have soon undertaken a new steady path of trade opening (as in the case of Eastern European economies, a few Asian countries and Mexico), other major players like Cina, India and South Africa have started decreasing their foreign input reliance, signaling a substantial re-orientation in trade-policy over the past decade.

Figure 2. Foreign Input Reliance by selected countries in absolute values, 1995-2020

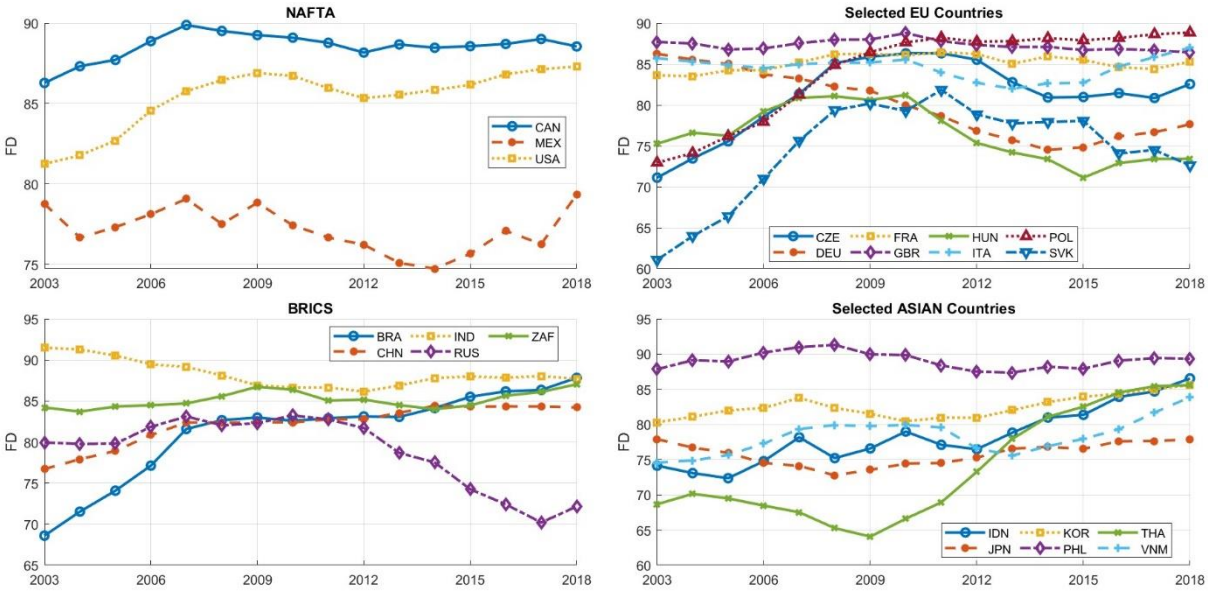


Source: authors' elaborations based on OECD ICIO data.

When considering FD patterns over time (Fig. 3), one can also observe a remarkable heterogeneity. On the one side, *advanced economies* with mature industrial bases – such as Canada, France, the UK, and the USA – *exhibit high and stable FD*. On the other side, *Eastern European countries* in the European Union (EU) show increasing FD, highlighting the benefits of regional integration and participation in broader value chains. Moreover, *a number of emerging economies have considerably invested in diversifying their functional activities as part of substantial upgrading efforts*. This is particularly the case of Asian countries, such as China, but also Korea, Thailand, Philippines and Vietnam, although with some variability over time. India makes a

partial exception with a relatively high but slightly declining functional diversification pattern. Among other emerging economies, Brazil and Mexico have also reached relatively high levels of FD, although their diversification patterns appear to be less stable. Lastly, a key player in geopolitics such as *Russia exhibits a lower, fluctuating, and decreasing FD, reflecting its specialization* in natural resource-based industries influenced by commodity price changes and global demand instability.

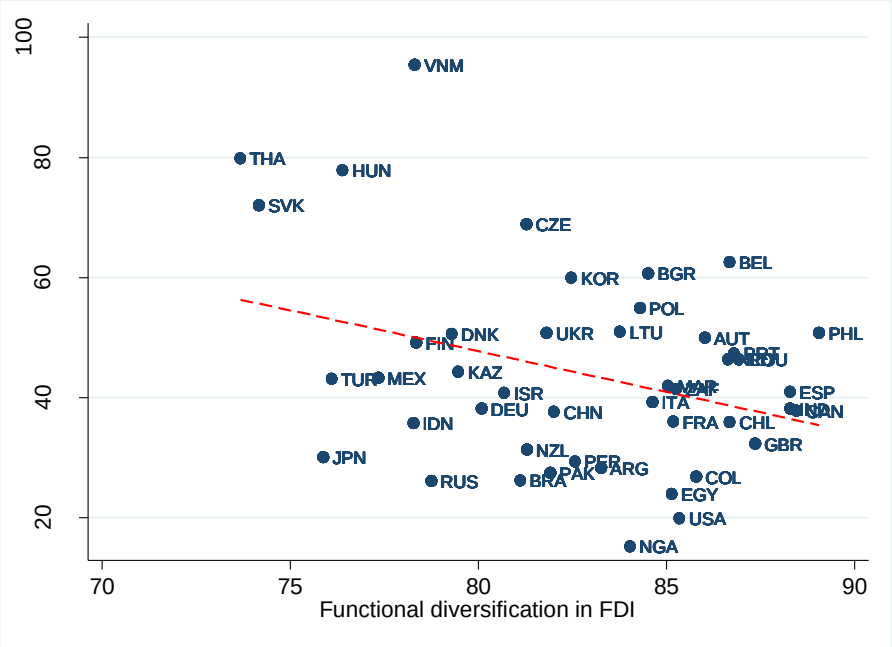
Figure 3. 5-year moving average of Functional diversification (FD) in FDI, selected economies, 2003-2018



Source: authors' elaborations based on fDi Markets data.

Figure 4 illustrates the association between functional diversification in FDI and FIR at the country level. The descriptive evidence is consistent with the line of argument developed in section 2, suggesting that enhancing functional diversification may mitigate the exposure to disruptions in GVCs. This motivates further exploration of the functional diversification-GVC exposure nexus in Section 5 of this paper.

Figure 4. The association between Functional diversification in FDI and the FIR indicator, average values over the period 2003-2018



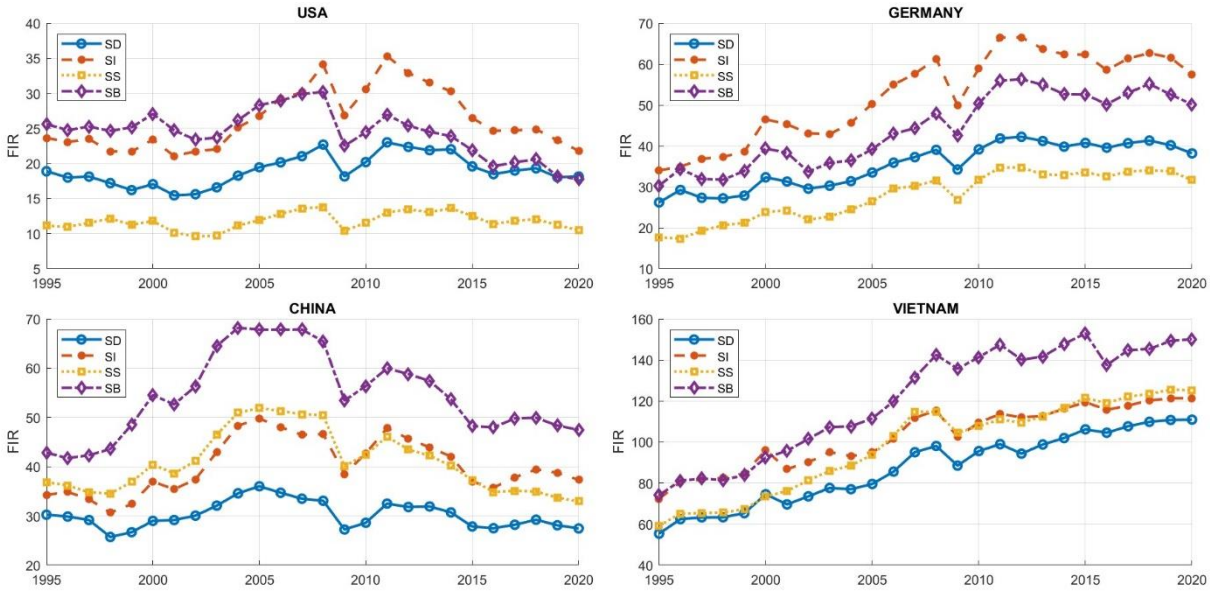
Source: authors' elaborations based on OECD ICIO and fDi Markets data.

4.2 Industry-level evidence using Pavitt classes

Figures 5 and 6 offer a comprehensive view of FIR and FD across selected countries – USA, Germany, China, and Vietnam – broken down by macro sectors categorized according to the Pavitt taxonomy (Science Based (SB), Scale Intensive (SI), Supplier Dominated (SD), and Specialized Suppliers (SS)). These trends elucidate these countries' economic strategies and sector-specific dependencies over time.

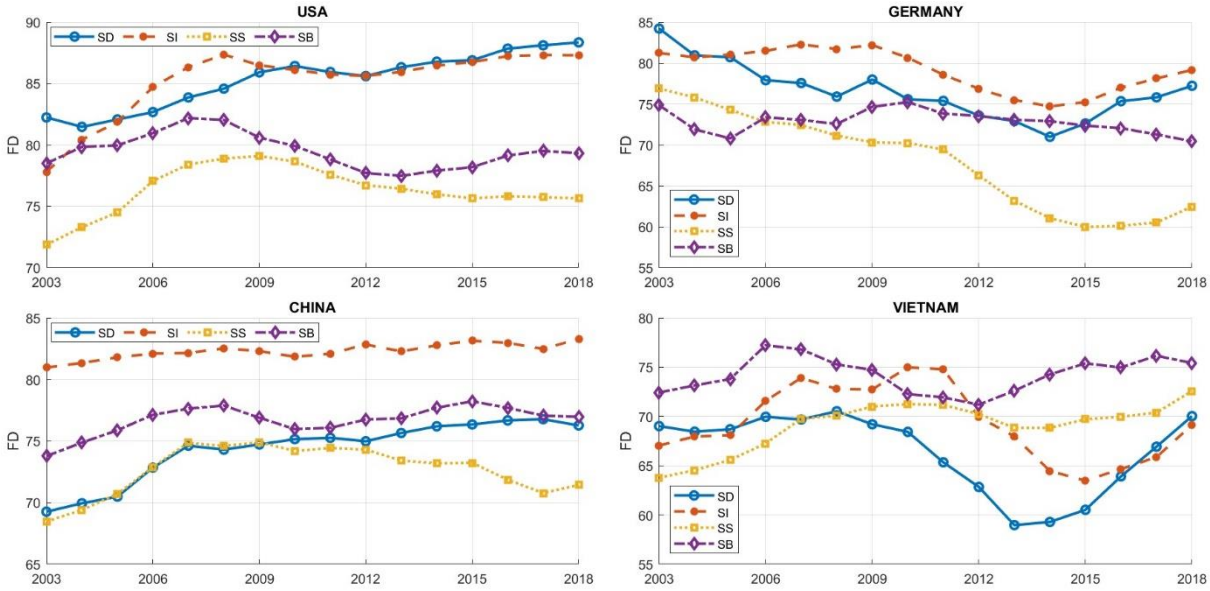
The analysis of FIR trends reveals distinct patterns across the examined country-industry pairs. In the USA, there is a notable decline in FIR for most sectors post-2008 financial crisis, indicating a strategic move towards self-reliance. However, the Scale intensive industry remains an exception, maintaining consistently high FIR, which underscores the complexity and global integration of industries such as aerospace and automotive. Germany shows a substantial increase in FIR across all sectors until around 2010, after which the trend stabilizes. The highest FIR is observed in the SI sector, reflecting the country's deep integration into global supply chains, particularly in industries like automotive. China exhibits a significant reduction in FIR, especially post-2005, highlighting a strategic shift towards self-reliance. This is likely driven by substantial investments in domestic R&D and policies aimed at reducing dependency on foreign technologies. Vietnam displays high and increasing FIR across all sectors, with a marked upward trend in the SI and SB sectors, reflecting its role as a key player in global manufacturing and its reliance on foreign inputs to sustain industrial growth.

Figure 5. Foreign Input Reliance by selected countries and Pavitt classes, 1995-2020



Source: authors' elaborations based on OECD ICIO data.

Figure 6. 5-year moving average of Functional diversification in FDI by selected countries and Pavitt classes, 2003-2018



Source: authors' elaborations based on fDi Markets data.

When it comes to FD, a remarkable heterogeneity can also be observed across country-industry pairs. The USA maintain a high and stable FD over time. In this scenario of long-term stability, a slow but rather steady increase in functional diversification can be observed for Scale intensive and Suppliers dominated industries in this country. Germany, while displaying high FD, shows a slight decline, suggesting potential vulnerabilities despite its diversified industrial base. This is especially the case in

Specialized suppliers industries wherein functional diversification appears to have decreased considerably over time, signaling a reorganization of the German GVCs in some key sectors such as machine tools with a reduction in domestic fabrication capacity, partially compensated by greater efforts in post-production. China exhibits moderate increase in FD in all sectors except SS industries, reflecting ongoing efforts to diversify its economy amidst its transition from an export-driven to a consumption-driven growth model. Vietnam shows more volatile FD patterns, indicative of its dynamic but less diversified economic structure. However, it exhibits a relatively more stable and slowly increasing diversification patterns in Science-based industries, revealing an effort to move beyond its established strengths in traditional industries and enter different value-adding activities in some key sectors such as electronic components, optical and medical apparatuses.

Figure 7 shows the association between FD and the FIR indicator by country-Pavitt pairs. The Suppliers dominated industry exhibits a noticeable negative correlation between FIR and FD. Vietnam stands out with high FIR, indicating significant reliance on foreign inputs, while its FD remains relatively low. Conversely, advanced economies like the USA, Japan, and Germany exhibit lower FIR and higher FD, suggesting a more balanced and diversified approach to their economic activities. This sector, dominated by traditional industries and services, underscores the critical role of diversification in enhancing economic resilience and reducing dependency on external inputs.

A negative relationship between FIR and FD is also clearly observed in the Scale intensive industry. Countries such as Hungary, the Czech Republic, and Vietnam are characterized by high FIR and lower FD, highlighting their integration into global value chains, particularly in industries like automotive. On the other hand, advanced economies, including the USA, Japan, and several Western European countries, exhibit low FIR and higher FD, reflecting their diversified and resilient industrial structures. This trend emphasizes the importance of scale and scope in manufacturing and the benefits of maintaining a diversified economic base to mitigate over-reliance on foreign inputs.

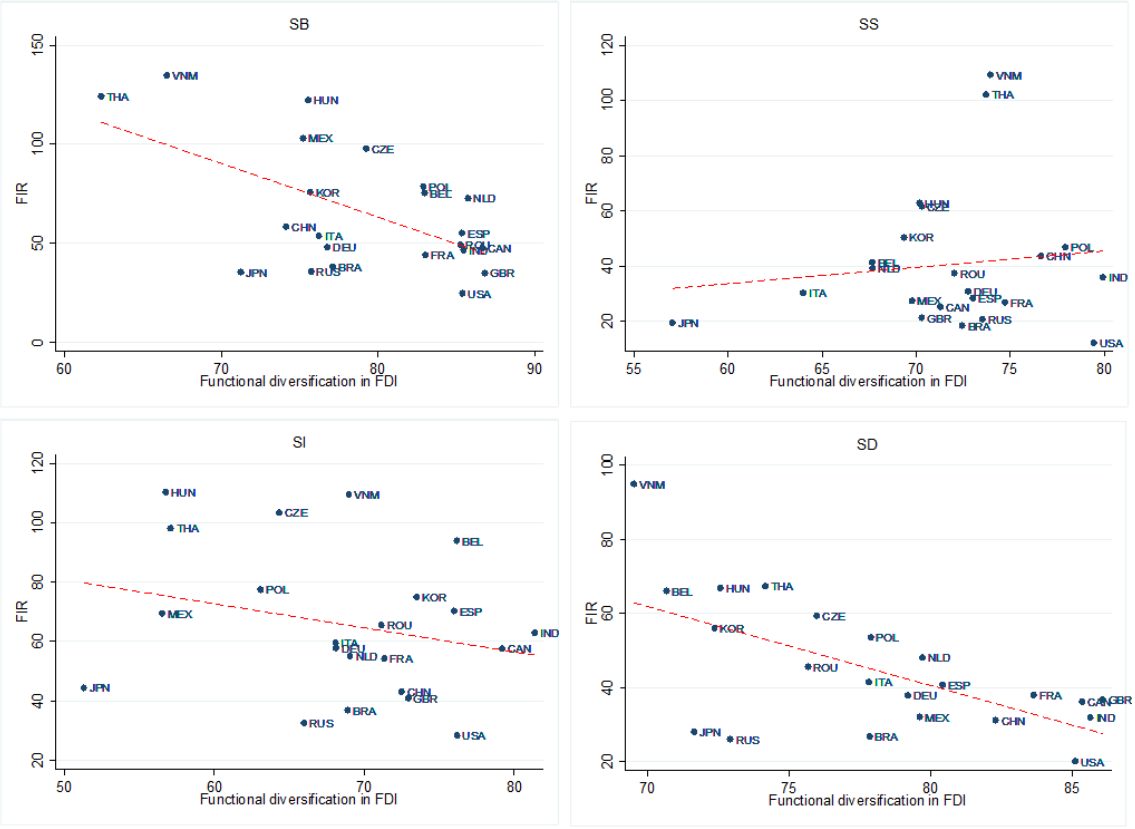
The picture is only apparently similar and straightforward in the case of industries wherein technology and intangibles play a greater role. In the Science-based sector, a negative relationship between FIR and FD is evident, but this association is apparently driven by countries which are not major players in these industries. In fact, the negative correlation seems to be mainly due to countries such as Thailand, Vietnam, Hungary, and Mexico, which display high FIR and relatively low (albeit growing) FD, indicating a heavy reliance on foreign inputs and a lack of diversification within this sector. The scatterplot is more blurred when it comes to more advanced economies. Indeed, the USA, Japan, and several Western European countries exhibit much lower FIR and higher FD, reflecting robust domestic capabilities and diversified industrial bases. However, in the context of largely globalized industries as SB sectors are, observing this correlation at the country level might be misleading and is more likely to signal the challenges faced by smaller and emerging economies in reducing their dependency on strategic foreign inputs while striving to diversify their industrial activities. More in-

depth analyses and multi-variate techniques are needed to better the actual links between functional diversification and foreign input reliance in this set of industries.

The Specialized suppliers sector sheds further light on the complexities of the FD-FIR nexus, which is characterized by a slightly positive trend in the case of these industries. Vietnam and Thailand again show high FIR, but this time coupled with varying levels of FD. In contrast, countries like the USA, Japan, and several European nations demonstrate both low FIR and relatively high FD, suggesting mature and diversified economies that manage to maintain a balance between domestic production and foreign input reliance. The less distinct relationship in this sector may indicate unique challenges and opportunities for countries engaged in specialized supply activities, where adaptive innovation and niche markets play significant roles.

Overall, the figures highlight the varying degrees of FIR and FD across different macro sectors and countries, reinforcing the notion that higher FIR often correlates with lower FD and vice versa. This relationship is particularly evident in the SI and SD sectors. This is especially true for advanced economies, which tend to exhibit lower reliance on foreign inputs and higher functional diversification, although some emerging countries are also undertaking the effort of expanding the range of value-adding activities and reduce their exposure to trade instabilities. The negative correlation observed for SB needs closer observation and the less clear association in the case of SS sectors suggest that specific industrial characteristics and market dynamics can influence the FIR-FD relationship differently. While these insights are consistent with the idea that strategic investments in domestic capabilities and industrial diversification are important to mitigate the risks associated with global supply chain disruptions, the FD-FIR nexus needs to be explored more closely using more appropriate econometric techniques.

Figure 7. The association between Functional diversification in FDI and the FIR indicator by country-Pavitt pairs, average values over the period 2003-2018



Source: authors' elaborations based on OECD ICIO and fDi Markets data.

5. Empirical strategy

In this section we further explore the extent to which diversification in terms of value chain activities is associated with the reliance of economies on foreign partners. In particular, we explore the association between functional diversification of countries and industries and their risk exposure to GVC disruptions by means of panel methodologies, which allow us to also control for a number of other potential drivers of economies' vulnerability to GVC-disrupting events.

To this aim, we compute the functional diversification in FDI at both country and industry levels. In the latter case, data limitations concerning the number of inward FDIs yearly targeting country-industry pairs prompt us to aggregate sectors in macro-industries. We opted for aggregating sectors according to the revised Pavitt taxonomy (Pavitt, 1984; Bogliacino & Pianta, 2010), which classifies both manufacturing and service industries in four classes, namely Science-based (SB), Scale and information intensive (SI), Specialized suppliers (SS) and Suppliers dominated (SD). This classification allows us to explore the heterogeneity in the association between FD and FIR according to the innovation propensity of industries, which is especially important from an industrial policy perspective. Moreover, by classifying industries according to market structure and the nature, sources and appropriability of innovation, the Pavitt

taxonomy provides more insight into the technological and organizational characteristics and market potential of industries than classifications based only on R&D intensity (Galindo-Rueda & Verger, 2016).

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

$$FIR_{c,t} = \beta_0 + \beta_1(FD_{c,t}) + \beta_2(total\ inward\ FDI)_{c,t} + \beta_3 X_{c,t} + \gamma_c + \delta_t + \varepsilon_{c,t} \qquad (2)$$

where $FIR_{c,t}$ is the Foreign Input Reliance index and represents our measure of risk exposure in GVCs for country *c*, at time *t*. $FD_{C,t}$ stands for our FDI-based measure of functional diversification, $total\ inward\ FDI$ captures the overall number of cross-border investments received by country *c* at time *t*, while the term $X_{c,t}$ includes an array of time-varying control variables at country level. The terms γ_c and δ_t stand for country and time fixed effects, accounting respectively for unobserved time-invariant country-specific characteristics (e.g., geographical location) and year-specific events that may have an impact on both dependent and explanatory variables. Finally, β_0 stands for the intercept and $\varepsilon_{c,t}$ is the error term.

Control variables account for country size (population and GDP in constant 2017 international PPP dollars), level of economic development (GDP per capita), industrial structure (manufacturing value added as percentage share of GDP), technological change (R&D expenditure and gross fixed capital formation as percentage shares of GDP), trade openness (sum of exports and imports as a percentage share of GDP), and the KOF financial globalization index (*de facto*), the latter capturing short-term portfolio investments along with other stocks of financial assets and liabilities. Data on all these variables are retrieved from the World Bank's World Development Indicators (WDI) database, except for data on the financial globalization index which are drawn from the KOF Swiss Economic Institute database of the ETH Zurich (Dreher, 2006; Gygli et al., 2019).

As a robustness check, we also control for further indicators measuring international trade and capital flows, namely the KOF trade globalization index (*de facto*), gauging the trade openness along with the trade partner diversity of economies; and four variables quantifying the "depth" and "breadth" of both trade and capital flows.[5] Additional controls include upstreamness and downstreamness indicators, measuring countries' positioning along GVCs (Antràs et al., 2012; Fally, 2012). In particular, these distance-oriented indicators gauge the absolute value of the (average) number of production steps that "separate" a country's output from final demand (upstreamness) and primary inputs (downstreamness), i.e. from the two ends of global chains of

[5] Indicators on "depth" measure the size of international trade and capital flows relative to domestic activity, while variables on "breadth" captures how closely each country's distribution of international flows across its partner countries matches the global distribution of partners for those flows. Accordingly, breadth captures whether a country's international flows are spread out globally or more narrowly focused. Data on these indicators are drawn from Altman and Bastian (2024), to which we refer for further details.

production. Notably, controlling for these variables gives us the opportunity to at least partially "isolate" the component of the FIR that depends on the length of GVCs in which countries are involved (Antràs & Chor, 2013).[6]

Lastly, adopting the same methodology used for computing the functional diversification in FDI, we calculate an index of *sectoral diversification in FDI* based on the industry each FDI has targeted. The inclusion of this control variable allows us to compare the role played by the functional and the sectoral diversification of economies in affecting the GVC exposure of countries. From a formal point of view, for each country *c* and year *t*, the index is computed as follows:

$$Sectoral\ diversification\ in\ FDI_{c,t} = 1 - HHI^{J}_{c,t} = 1 - \left[\left(\sum_{j=1}^{N}\left(\frac{FDI^{j}_{c,t}}{FDI_{c,t}}\right)^{2} - \frac{1}{N}\right)\Big/\left(1 - \frac{1}{N}\right)\right] \qquad (3)$$

where $HHI^{J}_{c,t}$ is the normalized HHI based on the one-digit NACE Rev. 2 sectoral classification, with the ratio in the round brackets representing the share of FDIs related to the *j*-th of the *N* sectors over the total inward FDIs for country *c* in year *t.*

The estimated regression equation for the model at the country-Pavitt level is as follows:

$$FIR_{c,j,t} = \beta_0 + \beta_1\left(FD_{c,j,t}\right) + \beta_2(total\ inward\ FDI)_{c,j,t} + \beta_3 \ln(gross\ output)_{c,j,t} + \gamma_{c,j} + \delta_{j,t} + \varepsilon_{c,j,t} \qquad (4)$$

where $FIR_{c,j,t}$ is the Foreign Input Reliance index for country *c*, Pavitt class *j* at time *t*. $FD_{C,j,t}$ measures the functional diversification in FDI at the country-Pavitt level, while the natural logarithm of gross output is introduced to account for the industry size. Notably, the terms $\gamma_{c,j}$ and $\delta_{j,t}$ stand for country-industry and industry-time fixed effects, accounting respectively for unobserved time-invariant specific characteristics of country-industries and unobserved time-varying factors affecting all industries belonging to a given Pavitt class over the period. These set of fixed effects is crucial in allowing us to control for a large number of unobserved factors that may have an impact on both dependent and explanatory variables, hence softening endogeneity concerns due to omitted variable bias.

We have access to fDi Markets data from 2003 to 2018, which is thus the time span covered by our empirical investigation. As for the country sample, the country-level analysis is conducted on 45 countries out of the 76 economies included in the ICIO tables provided by the OECD. In particular, we selected all countries that attracted at least 15 FDIs *each* year, *all* years.[7] This selection procedure is needed to increase the

[6] For consistency with the FIR indicator, these variables are based on OECD ICIO data and are drawn from the dataset recently compiled by Mancini et al. (2024). A discussion on the pros and cons of these indicators can be found in de Vries et al. (2021) and Coveri et al. (2024).

[7] Five countries were excluded from the analysis because being tax havens (Hong Kong, Ireland, Singapore and Switzerland) (Hines, 2010) or because data on several control variables (e.g., GDP, population, etc.) were not available (Taiwan).

reliability of our FDI-based functional diversification indicator, as it avoids computing the latter for countries which received few FDIs over the period. The sample on which the country-Pavitt level analysis is conducted includes 22 countries (out of the 45 countries included in the country level analysis), i.e. all economies that attracted more than 5 FDIs in *each* Pavitt class *each* year, *all* years. Once again, adopting this selection criterion is crucial to increase the reliability of our measure of functional diversification of countries and industries.[8] Following this procedure, we ended up with two relatively large and strongly balanced panel datasets at the country and country-Pavitt level, comprising 720 and 1408 observations, respectively.[9]

Descriptive statistics for all the variables considered in our empirical models are reported in Table A.2 in the Appendix.

6. Results

6.1 Country-level estimates

Table 1 provides the empirical results deriving from the estimation of the fixed effects model at the country level with the FIR as dependent variable, as reported by equation (2). We start from a parsimonious specification and introduce step by step a number of control variables in order to assess the robustness of our findings. Notably, the coefficient of functional diversification in FDI is negative and significant across all the estimated specifications. As for the other variables, the coefficient of total inward FDIs always reports a negative but not statistically significant coefficient, except in columns 9 and 10 where it turns out significant.[10] While the coefficient of the GDP per capita is not significant (column 2), the negative and significant coefficients of the population size and absolute value of the GDP of economies are in line with the descriptive evidence provided above, confirming that larger countries are typically less reliant on foreign inputs for production (columns 3 and 4). Moreover, when we account for both these variables simultaneously (columns 5 to 10), the coefficient of population remains significant while that of GDP does not, signalling that the former better captures the negative association between countries' size and FIR.

[8] In selecting these thresholds, we had to balance the reliability of our indicator of functional diversification of economies with the need to include as many countries as possible in the sample (to avoid shrinking the number of observations). As for the reliability of the indicator, it is worth noting that – following this procedure – the average number of inward FDIs received by economies included in the country-level sample is relatively high and equal to 217 per year, while the median value is 111 per year; the corresponding magnitudes for country-industry pairs included in the country-Pavitt level sample are 87 and 52, respectively. Nonetheless, we also selected higher thresholds (e.g., including countries which received at least 20 or 30 FDIs each year, all years) and performed our empirical analysis on restricted country samples as a robustness check. The results are qualitatively unchanged and are available upon request.

[9] The full list of economies included in the country and country-Pavitt level analyses is reported by Table A.1 in the Appendix.

[10] Estimate results in columns 9 and 10 are based on a lower number of observations because data on manufacturing value added (% of GDP) are not available for Bulgaria, and data on R&D expenditure (% of GDP) of some countries are not available in a few years of our time span.

In column 6 we include trade openness as a control variable to account for the overall involvement of countries in international flows of exported and imported goods and services. As expected, this regressor shows a positive and strongly significant association with countries' reliance on foreign inputs (trade openness also seems to capture the role played by country size better than GDP and population, which are found to be not significant when this regressor is included). The next two columns of Table 2 report estimate results when controlling for our proxy of sectoral diversification in FDI, the financial globalization index and GFCF (% of GDP), both without and together with trade openness (see columns 7 and 8, respectively). The variable concerning financial globalization (GFCF) turns out (not) significant in the specification shown in column 7 as well as in subsequent ones (columns 8 to 10), suggesting that countries with more liberalized capital accounts tend also to show a higher reliance on foreign inputs.

Most importantly, the coefficient of our FDI-based indicator of sectoral diversification in FDI turns out negative and statistically significant in column 7 only, while it is not in columns 8 to 10. This result allows us to distinguish the role played by functional from sectoral diversification and suggests that, while one might argue that diversification across industries could help reducing GVC exposure in some circumstances, it is functional diversification that matters. As already discussed in section 2, a country could be widely diversified across sectors while being highly specialized in few value-adding functions within sectors, which can lead to over-reliance (and increased exposure to GVC disruptions) on foreign partners for an ever-widening range of inputs. As for columns 9 and 10, these reports estimate results for model specifications controlling also manufacturing value added and R&D expenditure as percentage shares of GDP. While all previous results are confirmed, the coefficient related to manufacturing value added (proxying the industrial structure of the economies) is found to be positive and significant in column 9 only (which could be consistent with the typically higher levels of international fragmentation of production of manufacturing industries compared to primary and service sectors); while R&D expenditure reports a negative but not significant coefficient in both specifications.

As a robustness check, we also estimated the model specification by including all explanatory variables with a one-year lag. Although this technique does not suffice to identify strictly causal relationships, it proves useful in reducing reverse causality and mitigating endogeneity problems, thereby increasing the reliability of our empirical analysis. These results are reported in Table 3 in the Appendix and confirm our previous findings. In particular, the coefficient of functional diversification in FDI is found to be negative and significant in all specifications except column 4, while sectoral diversification is negative but never statistically significant.

As a further robustness check, Table A.4 shows results from model specifications including additional control variables on the involvement of economies in trade and capital flows. Also in this case, all our previous findings are confirmed, reassuring us about the robustness of our results. In particular, the coefficient of functional diversification in FDI always reports a negative significant coefficient, while the

different proxies of trade openness (i.e., the KOF trade globalization index and the trade depth indicator) emerge positive and significant (columns 1 to 3). Other variables capturing if a country's trade and capital flows are relatively more spread globally or narrowly focused, as well as capital depth, do not report significant coefficients (columns 3 to 5). Lastly, when accounting for the upstreamness and downstreamness of countries, we find that the former shows a negative and significant coefficient, while the latter a positive and significant one (column 6). Given that FIR captures the "import-side" of GVC exposure and increases as value chains lengthen, this result is perfectly consistent with our expectations. In fact, countries located more upstream along production chains are mainly suppliers of intermediate inputs (thereby featuring lower reliance on foreign productions), while the opposite is true for economies located more downstream along value chains (as they typically rely more on global sourcing of intermediate goods and services). It is also worth reminding that these indicators assume higher values the longer value chains are, allowing us to control for the length of GVCs. Accordingly, results in column 6 suggest that functional diversification of FDI is negatively and significantly associated with the "size" of foreign input reliance.

6.2 Industry-level estimates using Pavitt classes

Table 2 provides the estimate results of an empirical model whereby the unit of observation is scaled down from the country to the country-Pavitt level, as reported by equation (4). This analysis allows us to explore whether the functional diversification within Pavitt's industry classes is associated with a lower exposure of the latter to GVC-disrupting events.

Columns 1 to 3 show estimate results stemming from specifications which account for country-Pavitt and time fixed-effects, while in columns 4 to 6 we also control for unobserved time-varying factors affecting Pavitt industries. Our FDI-based indicator of functional diversification reports a negative and statistically significant coefficient in all specifications, confirming that greater diversification in terms of value-adding activities is negatively associated with GVC exposure even at the level of Pavitt industries. Once again, total inward FDIs always reports a non-significant although positive coefficient, while gross ouput (proxying industry size) turns out, as expected, positive and significant.

As a robustness check, we replicated the estimation of these model specifications of the model by introducing all regressors with a one-year lag to soften reverse causality and endogeneity issues. Once again, results are broadly confirmed and reported in Table A.5 in the Appendix.

Finally, and most importantly, we performed separate estimates by Pavitt class with the aim to explore the heterogeneity in the FD-FIR nexus across Pavitt industries. Results are reported in Table 3. Notably, we find that coefficients of functional diversification are negative and significant for SI and SD industries (columns 5-6 and 7-8, respectively), while they are not for SB and SI industry categories (columns 1-2 and 3-4, respectively). The result obtained SI and SD industries is largely consistent with the general pattern observed at the country level and discussed in section 6.1. It is not

surprising that these industries "drive" the general results, since it is these macro-sectors that constitute the bulk of the industrial base of emerging countries as well as most high-income economies.

As for the most innovative industries, i.e. SB and SS industries, our results highlight the need of a closer industry-by-industry examination as well as a more detailed analysis of economic and institutional features of countries and macro-regions under observation. While this is a matter for future research, we may dare suggesting here two possible general explanations underlying the results obtained for these two macro-sectors.

First, SB sectors are by definition characterised by a greater role of science and technology as major sources of innovation and economic performance. While functional diversification is necessary for the generation and exploitation of innovation in these industries, the key competitive challenge is to gain access to knowledge sources and key components wherever available. Hence, there is no guarantee that a higher functional diversification reduces the need for foreign inputs in these industries. Conversely, SD and SI industries require resources, components and knowledge inputs that can more easily reproduced domestically – or at least at the macro-regional level – through greater diversification efforts.

Second, SS industries are by and large producers of capital goods specialised in the creative assembling of commodity-like components and in the adaptation of equipment to industrial user needs. A large fraction of innovative activities in these industries occurs at the plant level and does not necessarily require institutionalised R&D nor high investment in logistics or in marketing activities. Consequently, expanding the range of functions by enhancing domestic capacities to carry out these activities would not end up reducing FIR in the case of these industries.

Table 1. Fixed effects model at the country level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable:	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*
Functional diversification in FDI	-0.084**	-0.070*	-0.065*	-0.103***	-0.092***	-0.082***	-0.063*	-0.071*	-0.071*	-0.096***
	(0.037)	(0.035)	(0.034)	(0.032)	(0.031)	(0.027)	(0.036)	(0.037)	(0.038)	(0.035)
ln(total inward FDI)	-1.264	-1.343	-1.083	-0.172	-0.245	-0.393	-0.031	-0.451	-1.153*	-1.415***
	(1.065)	(0.998)	(0.914)	(0.959)	(0.894)	(0.826)	(0.830)	(0.657)	(0.593)	(0.452)
ln(GDP per capita)		-4.785								
		(5.890)								
ln(GDP)			-8.245*		-3.605	-1.790	-3.128	-2.331	-7.873*	-3.475
			(4.893)		(5.910)	(3.224)	(6.151)	(3.685)	(4.218)	(3.574)
ln(population)				-31.805***	-27.375***	3.017	-17.687**	6.490	-23.002***	-4.304
				(7.616)	(8.832)	(6.891)	(7.746)	(7.035)	(7.687)	(5.291)
Trade (% of GDP)						0.266***		0.246***		0.215***
						(0.054)		(0.057)		(0.062)
Sectoral diversification in FDI							-0.067*	-0.027	-0.048	-0.014
							(0.035)	(0.028)	(0.036)	(0.029)
KOF Financial Glob. index							0.277***	0.151**	0.164***	0.096*
							(0.079)	(0.065)	(0.050)	(0.048)
GFCF over GDP (%)							-0.070	0.053	0.201	0.180
							(0.208)	(0.166)	(0.189)	(0.219)
Manufacturing v.a. (% of GDP)									0.746***	0.215
									(0.266)	(0.332)
R&D exp. (% of GDP)									-1.048	-2.333
									(1.402)	(1.399)
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	720	720	720	720	720	720	720	720	614	614
R-squared	0.386	0.393	0.415	0.445	0.449	0.652	0.514	0.669	0.611	0.698
Number of countries	45	45	45	45	45	45	45	45	44	44

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

Table 2. Fixed effects model at the country-Pavitt level

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*
Functional diversification in FDI	-0.069**	-0.068**	-0.068**	-0.067**	-0.066**	-0.065**
	(0.030)	(0.030)	(0.029)	(0.027)	(0.027)	(0.027)
ln(total inward FDI)		0.431	0.329		1.089	0.981
		(0.798)	(0.797)		(0.811)	(0.807)
ln(gross output)			0.226***			0.218***
			(0.064)			(0.060)
Country-Pavitt FE	YES	YES	YES	YES	YES	YES
Pavitt-Time FE	-	-	-	YES	YES	YES
Time FE	YES	YES	YES	-	-	-
Observations	1,408	1,408	1,408	1,408	1,408	1,408
R-squared	0.401	0.402	0.406	0.447	0.451	0.455
Number of country-Pavitt	88	88	88	88	88	88

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

Table 3. Fixed effects model at the country-Pavitt level distinguishing by Pavitt class

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*
Pavitt class:	*Science Based*		*Specialized Suppliers*		*Scale Intensive*		*Suppliers Dominated*	
Functional div. in FDI	-0.068	-0.054	0.021	0.008	-0.140**	-0.137**	-0.085*	-0.083*
	(0.068)	(0.069)	(0.029)	(0.030)	(0.060)	(0.063)	(0.043)	(0.043)
ln(total inward FDI)		2.934		1.414		-0.223		-0.200
		(2.281)		(1.323)		(1.967)		(1.108)
ln(gross output)		0.144		0.260**		0.209		0.212**
		(0.146)		(0.095)		(0.147)		(0.086)
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	352	352	352	352	352	352	352	352
R-squared	0.405	0.421	0.275	0.297	0.555	0.558	0.494	0.499
Number of countries	22	22	22	22	22	22	22	22

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

7. Industrial policy implications and conclusions

This work contributes to the analysis of factors that can mitigate the exposure of economies to global supply chain disruptions. By examining the relationship between functional diversification in FDIs and GVC exposure, we provide new insights into how economies could reduce their vulnerability to global disruptions. The findings carried significant implications for industrial policy, particularly in the context of increasing geopolitical tensions and global uncertainties.

Our empirical analysis underscores that countries and industries diversifying their value chain activities in terms of inward FDIs have reduced GVC exposure. Overall, functional diversification is indeed negatively associated with the need for economies to resort to foreign inputs, with the observed negative relationship resulting robust across different model specifications. Moreover, when disaggregating our sample according to Pavitt industries, we find that such negative association holds for sectors featured by a relatively lower innovation propensity, i.e. Scale intensive and Suppliers dominated industries. In this case, the lower gains from trade are arguably more than compensated by greater advantages deriving from the creative use of domestic capabilities and lower exposure to potential foreign shocks. It thus appears that broadening value chain functions enables economies to cultivate broader technological capabilities and a more robust productive matrix. Beyond merely reducing dependency on specific foreign suppliers, functional diversification equips industries to better adapt to and recover from disruptions in supply chains.

The key policy implication we derive from our analysis is not to merely reduce foreign reliance, but to reshape GVCs to prioritize suppliers based on their value creation and reliability. Strengthening national and regional capacities to perform crucial activities is pivotal. This dual strategy of GVC restructuring and enhancing domestic functional and industrial diversification can bolster economic resilience against disruptive events and facilitate innovative responses. Our research line thus supports industrial policies enhancing domestic capabilities and economic diversification in a context of global interdependencies (Rodrik, 2008; Hauge, 2020). Accordingly, it is suggested that governments should undertake targeted and long-term commitments to expand the array of value chain functions that economies are able to perform, while selecting partners involved in GVCs.

However, national and – in the case of integrated areas – supranational governments should incentivize firms to diversify their value chain activities domestically and especially at the macro-regional level. This can be achieved through targeted incentives for investments across various stages of production, from R&D to logistics and marketing. Investing in technology and innovation is indeed especially crucial to enabling functional diversification and expanding domestic production capabilities (Gereffi et al., 2021; Tung et al., 2023).

Moreover, policy interventions need to be tailored to the specific characteristics and needs of different industries. For instance, Science-based industries may benefit from policies that facilitate access to global knowledge networks, whereas Scale intensive

sectors may require investments in strengthening domestic supply chain capabilities. By adopting sector-specific policies, countries can thus optimize the benefits of functional diversification across their economic sectors (Boehm et al., 2019; Bonadio et al., 2021). Therefore, reducing foreign input reliance is not an objective to be pursued in these industries, at least not as a general rule and not at the level of individual countries; while functional diversification ought to be pursued to increase the capacity of nations and regions to innovate and creatively react to trade disruptions.

Building robust supply chains especially at the macro-regional level is another critical strategy. Governments should support local and regional suppliers, foster collaboration among domestic firms, and invest in infrastructure that enhances the efficiency of production and distribution networks. From this viewpoint, a partial regionalization of value chains might create more stable and less risky supply networks in some circumstances, thereby reducing exposure to global disruptions (Espitia et al., 2021; Pla-Barber et al., 2021). Nevertheless, policies should keep into account the need for the most innovative industries to source key components and knowledge assets located abroad and engage in international collaborations with selected partners. From this perspective, reducing overall involvement in global networks is not *per se* a rule of thumb.

In this context, long-term commitments and strategic investments are paramount. Governments should undertake sustained efforts to expand the array of value chain functions performed domestically. This strategic approach not only strengthens national economic foundations but also reduces vulnerability to external shocks by diversifying sourcing and production capabilities. Recent policy initiatives emphasizing the consolidation of domestic capabilities underscore the importance of such long-term investments in securing economic resilience (Tung et al., 2023).

Public procurement could also emerge as a powerful lever for industrial policy to be deployed. By aligning procurement practices with broader industrial policy objectives, governments can steer technological advancements and bolster production capacity within strategic sectors. This strategic use of public procurement could not only foster innovation but also mitigate the vulnerability to global disruptions, thereby promoting sustainable economic growth and resilience (Pananond et al., 2020; Pla-Barber et al., 2021).

As a general conclusion, the evidence we provide highlights the need for both a strategic re-orientation of international trade relations and a stronger commitment of countries and macro-regions towards large-scale investments aimed at fostering the development of local capabilities across the business activities of key value chains.

Despite the robustness of our findings, limitations exist. The complex nature of GVCs and the varying impact of functional diversification across different sectors and regions suggest that further research is needed. Future studies could explore the long-term effects of functional diversification on economic resilience and the specific policy measures that can best support this process. Additionally, given the dynamic nature of GVCs, ongoing research should monitor evolving global trade patterns and technological advancements' implications for functional diversification and GVC

exposure (Mariotti, 2022; Sturm, 2022). Moreover, while emphasizing the importance of functional diversification, our study acknowledges the intricate complexities of global trade relationships and factors influencing GVC resilience (Fajgelbaum et al., 2023; Miroudot, 2020). Accordingly, future research could leverage more granular data to explore further dimensions shaping the interplay between FDIs, functional diversification, and GVC exposure.

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Appendix

Tab. A.1 List of countries

Country level analysis		Country-Pavitt level analysis	
Europe	*South America*	*Europe*	*South America*
Austria	Argentina		
Belgium	Brazil	Belgium	Brazil
Bulgaria	Chile		
Czech Republic	Colombia	Czech Republic	
Denmark	Peru		
Finland			
France	*Asia*	France	*Asia*
Germany	China	Germany	China
Hungary	India	Hungary	India
Italy	Indonesia	Italy	
Lithuania	Japan		Japan
Netherlands	Kazakhstan	Netherlands	
Poland	New zealand	Poland	
Portugal	Pakistan		
Romania	Philippines	Romania	
Slovakia	Russia		Russia
Spain	South Korea	Spain	South Korea
UK	Thailand	UK	Thailand
Ukraine	Vietnam		Vietnam
USMCA (former NAFTA)	*Africa and Middle-East*	*USMCA (former NAFTA)*	
Canada	Egypt	Canada	
Mexico	Israel	Mexico	
USA	Morocco	USA	
	Nigeria		
	South africa		
	Turkey		

Source: authors' elaboration.

Tab. A.2 Descriptive statistics

	N	Mean	Std. Dev.	min	max
Country level analysis					
Dependent variable					
FIR	720	44.151	17.051	13.345	111.007
Key regressor					
Functional diversification in FDI	720	82.64	6.677	39.822	93.188
Control variables					
ln(total inward FDI)	720	4.797	1.024	2.708	7.458
ln(GDP per capita)	720	9.931	0.774	7.963	11.028
ln(GDP)	720	27.455	1.206	24.833	30.686
ln(population)	720	17.509	1.398	14.841	21.055
Trade (% of GDP)	720	76.341	39.221	20.723	208.307
Sectoral diversification in FDI	720	75.574	9.944	30.81	93.11
KOF Financial Glob. index	720	66.262	17.204	28.307	96.955
GFCF (% of GDP)	720	22.671	5.272	12.446	44.519
Manufacturing v.a. (% of GDP)	703	16.087	5.088	6.553	32.452
R&D exp. (% of GDP)	631	1.394	1.06	0.055	4.797
KOF Trade Glob. index	720	52.585	18.016	18.676	87.188
Trade depth (DHL score)	720	47.475	9.587	34.452	78.735
Trade breadth (DHL score)	720	60.562	6.166	45.463	74.864
Capital depth (DHL score)	720	49.393	2.65	45.163	62.802
Capital breadth (DHL score)	720	55.566	5.104	45.404	66.731
Upstreamness	720	2.1	0.289	1.593	3.962
Downstreamness	720	2.092	0.258	1.62	3.786
Country-Pavitt level analysis					
Dependent variable					
FIR	1408	54.382	28.117	9.703	153.026
Key regressor					
Functional diversification in FDI	1408	74.291	10.213	24.004	92.832
Control variables					
ln(total inward FDI)	1408	4.061	0.871	1.946	6.5
ln(gross output)	1408	10.916	1.965	4.473	15.977

Source: authors' elaboration.

Table A.3 Fixed effects model at the country level with lagged (y-1) explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*
L.functional diversif. in FDI	-0.068*	-0.067*	-0.063**	-0.057	-0.064*	-0.070*	-0.092**
	(0.040)	(0.038)	(0.031)	(0.036)	(0.036)	(0.039)	(0.038)
L.ln(total inward FDI)	-1.397	-0.452	-0.605	0.056	-0.269	-1.107*	-1.339***
	(1.020)	(0.817)	(0.747)	(0.779)	(0.661)	(0.579)	(0.472)
L.ln(GDP)		-4.776	-2.970	-3.091	-2.118	-7.038	-3.222
		(5.806)	(3.933)	(5.973)	(4.319)	(4.342)	(3.925)
L.ln(population)		-24.137**	1.322	-16.009*	2.714	-23.111***	-8.384
		(10.025)	(8.986)	(8.708)	(8.449)	(7.449)	(5.535)
L.trade (% of GDP)			0.209***		0.181***		0.166**
			(0.060)		(0.056)		(0.062)
L.sectoral diversif. in FDI				-0.046	-0.018	-0.028	-0.003
				(0.033)	(0.026)	(0.033)	(0.028)
L.KOF Financial Glob. index				0.231***	0.139**	0.137***	0.082*
				(0.062)	(0.060)	(0.039)	(0.042)
L.GFCF (% of GDP)				-0.237	-0.152	0.070	0.052
				(0.193)	(0.163)	(0.188)	(0.212)
L.manufact. v.a. (% of GDP)						0.676***	0.273
						(0.236)	(0.300)
L.R&D exp. (% of GDP)						-2.226	-3.399**
						(1.484)	(1.358)
Country FE	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES
Observations	675	675	675	675	675	575	575
R-squared	0.325	0.387	0.520	0.451	0.541	0.543	0.600
Number of countries	45	45	45	45	45	44	44

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

Table A.4 Fixed effects model at the country level with further controls on trade and capital flows

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*
Functional diversif. in FDI	-0.082***	-0.076**	-0.083***	-0.088**	-0.072**	-0.064*
	(0.027)	(0.031)	(0.029)	(0.033)	(0.030)	(0.033)
ln(total inward FDI)	-0.393	-0.855	-0.664	-0.598	-0.672	0.059
	(0.826)	(0.815)	(0.704)	(0.867)	(0.760)	(0.694)
ln(GDP)	-1.790	0.635	0.341	-1.827	1.677	-6.718
	(3.224)	(5.354)	(4.742)	(6.486)	(5.159)	(4.880)
ln(population)	3.017	-16.926*	-4.194	-29.187***	-4.096	-37.873***
	(6.891)	(8.772)	(6.981)	(8.615)	(7.522)	(7.311)
Trade (% of GDP)	0.266***					
	(0.054)					
KOF Trade Glob. index		0.245**				
		(0.112)				
Trade depth			1.029***		1.043***	
			(0.210)		(0.210)	
Trade breadth			0.339		0.370	
			(0.222)		(0.243)	
Capital depth				0.288	-0.036	
				(0.319)	(0.263)	
Capital breadth				-0.380	-0.474	
				(0.356)	(0.387)	
Upstreamness						-17.816***
						(3.938)
Downstreamness						29.393***
						(6.440)
Country FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Observations	720	720	720	720	720	720
R-squared	0.652	0.487	0.592	0.459	0.600	0.635
Number of countries	45	45	45	45	45	45

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

Table A.5 Fixed effects model at the country-Pavitt level with lagged (y-1) explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*	*FIR*
L.functional diversification in FDI	-0.070**	-0.070**	-0.070**	-0.070**	-0.069**	-0.070**
	(0.034)	(0.034)	(0.033)	(0.030)	(0.030)	(0.029)
L.ln(total inward FDI)		0.312	0.218		0.878	0.779
		(0.780)	(0.786)		(0.800)	(0.804)
L.ln(gross output)			0.214***			0.209***
			(0.062)			(0.059)
Country-Pavitt FE	YES	YES	YES	YES	YES	YES
Pavitt-Time FE	-	-	-	YES	YES	YES
Time FE	YES	YES	YES	-	-	-
Observations	1,320	1,320	1,320	1,320	1,320	1,320
R-squared	0.345	0.346	0.350	0.393	0.396	0.400
Number of country-Pavitt	88	88	88	88	88	88

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