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Weak sectors and weak ties? Labour dependence and asymmetric positioning in GVCs

Lorenzo Cresti[1,2] · Maria Enrica Virgillito[2]

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Abstract
Focusing on the labour requirements incorporated into GVCs, we develop a novel, non-conventional measure of learning capabilities, representing a proxy for the knowledge embodied in the division of labour within global production networks. In order to capture the division of labour and of embodied knowledge, we move from monetary flows of production, or value-added, to labour embodied in the I–O linkages. After constructing a new indicator, *Bilateral Net Labour Dependence*, we estimate its relationship with a measure of industry performance, namely labour productivity, seeking to challenge the established findings that generally report a positive effect of GVC participation for industry-level productivity. Our conjecture is that being in a weak position in terms of (net) labour provision results in an overall weakening of the capabilities of offshoring industries. We corroborate the conjecture with a panel analysis of 38 countries and 15 industries for the time period 2000–2019.

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✉ Lorenzo Cresti
lorenzo.cresti@cref.it

1 Enrico Fermi Research Center (CREF), Via Panisperna, 89a, 00184 Rome, RM, Italy

2 Institute of Economics, Sant'Anna School of Advanced Studies, Piazza Martiri Della Liberta' 33, 56127 Pisa, PI, Italy

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1 Introduction

Over the last three decades, advanced economies have witnessed a process whereby productive activities have increasingly been relocated abroad, often to developing and emerging countries. This phenomenon—which may be located within the broader global fragmentation of production and the rise of so-called Global Value Chains (GVCs) (Baldwin, 2013; Gereffi, 2014; Ponte et al., 2019) or Global Production Networks (GPNs) (Coe & Yeung, 2019; Henderson et al., 2002; Neilson et al., 2014)—has had a profound economic impact in terms of employment, incomes, innovation, and development of capabilities. Yet the possible detrimental outcomes for an economy due to increasing delocalization of inputs—often referred to as offshoring or global sourcing—have found only a limited place in the research agenda.

Scholars have largely focused on investigating the benefits of offshoring in terms of reducing costs and increasing efficiency, often with a firm-level perspective. Within the broader concept of *economic upgrading* (Humphrey & Schmitz, 2002), which refers to the possibility for firms, regions, or countries either to move into higher value-added stages or to make products better or more efficiently—eventually triggering spillovers for productivity and innovation—the literature has defined economic upgrading as the general economic gain from participating in GVCs (Gereffi, 2005; Giuliani et al., 2005; Kaplinsky & Morris, 2000; Marcato & Baltar, 2021; OECD, 2013; Pipkin & Fuentes, 2017). Recently, scholars in the GVC literature have also begun to address the *social* dimension of upgrading, which relates to the impact on employment, wages, working conditions, and workers' rights (Lee & Gereffi, 2015; Selwyn, 2013).

The ultimate scope of *upgrading* is to be able to appropriate higher-value-added activities via skills and know-how accumulation, process innovations and capital investments. Humphrey and Schmitz (2002) first identified four types of upgrading: *process* (adopting more efficient methods of production), *product* (producing new or more sophisticated commodities), *functional* (moving towards higher value-added activities or stages of production), and *chain* (shifting to more advanced production chains). Other channels are organizational, territorial, and structural upgrading (UNIDO, 2015); *entry into a GVC by a new actor* (Fernandez-Stark et al., 2014); and *end-marketing upgrading*. Describing different forms of upgrading, Marcato and Baltar (2021) point out that the end-market perspective, in particular, adopts a naive notion of upgrading rooted in the idea of greater space for the appropriation of products' value via GVC participation. A similar view is also shared by the so-called smile-curve climbing approach, according to which strategic participation in GVCs would imply moving away from assembly production stages, towards pre- (R&D, design) or post- (branding, marketing) production activities (Baldwin, 2013; Ye et al., 2015). According to the upgrading approach, participating in GVCs would eventually induce productivity enhancement. For instance, there is increasing evidence concerning the positive relationship between proxies of offshoring activity—i.e., measures of GVC participation from the backward linkages perspective—and performance (usually in terms of productivity) of sectors and countries (Amiti & Wei, 2009; Constantinescu et al., 2019; Kummritz, 2016; Winkler, 2010). The extant literature, however, tends to neglect that GVC benefits are hardly deterministic and, in order to acquire advantages from participation in GVCs, actors (firms, sectors, countries) require capabilities development and accumulation, and primarily the *ability to learn* in order to achieve economic upgrading and boost productivity (Dosi et al., 1995; Giuliani et al., 2005; Kaplinsky & Readman, 2001; Nathan & Sarkar, 2013).

Measuring learning capabilities is all but an easy task, even more so when studying GVCs. The amount of labour incorporated into production activities is a good candidate for approaching this problem, however. Labour is the key input for production, as it embodies know-how and tacit knowledge so as to produce final artifacts. The ability to learn inside productive units occurs at the labour process level, and labour requirements, beyond being a sheer proxy of hours of work, represent the underlying knowledge incorporated into the final product. In addition, the production chain perspective expands the labour process in a given establishment/industry into a distribution of knowledge among nodes. The chain, therefore, implies losses/acquisitions of knowledge due to processes of off-shoring/in-shoring of labour. Whenever labour is offshored, the underlying productive capabilities are potentially lost. This is due to the changing geography of production, characterized by manufacturing activities being progressively lost in some geographical areas, and underlying capabilities reciprocally being gained by the workforce and associated organizations in the recipient country or region. For example, with reference to the relocation to Asia of the manufacturing of electronic chips, Nathan and Sarkar (2013, p. 5) argue that '[w]hile the supplier firm (and economy) acquires knowledge-intensive design capability, the lead firm may lose some of that capability.' And they quote Ernst as saying: 'To the degree that the flagship [the lead firm] has moved to *global sourcing*… this implies an *erosion* of the *collective knowledge* which used to be a characteristic feature of the flagship's home location. In some cases, that collective knowledge may have migrated for good to the suppliers' overseas cluster(s)' (Ernst, 2002, p. 17, quoted in Nathan & Sarkar, 2013). So far, the literature has addressed innovation-related kinds of embodiment, in terms of measurements of R&D embodied in I–O linkages (Cresti et al., 2023; Franco et al., 2011; Hauknes & Knell, 2009; Leoncini & Montresor, 2003; Marengo & Sterlacchini, 1990; Taalbi, 2020) or inter-sectoral knowledge diffusion (DeBresson, 1996; Foster-McGregor et al., 2017).

Focusing on the labour requirements incorporated into GVCs, in the following we develop a novel, non-conventional measure of learning capabilities, representing a proxy for the knowledge embodied in the division of labour within global production networks. In order to capture the division of labour and of embodied knowledge, we move from monetary flows, or value-added, to labour embodied in the I–O linkages. After constructing a new indicator, *Bilateral Net Labour Dependence* (hereafter BNLD), we estimate its relationship with a measure of industry performance, namely labour productivity, seeking to challenge the established findings that generally report a positive effect of GVC participation for sector-level productivity (Battiati et al., 2020; Constantinescu et al., 2019; Criscuolo & Timmis, 2017; Formai & Vergara Caffarelli, 2016; Jona-Lasinio & Meliciani, 2019; Pahl & Timmer, 2020; Taglioni & Winkler, 2016). Our conjecture is that being in a weak position in terms of (net) labour provision results in an overall weakening of the capabilities of the offshoring industries. We test this conjecture with a panel analysis on a dataset constructed by leveraging on the OECD ICIO Tables, OECD TiM and OECD STAN databases and including 38 countries, 15 manufacturing industries and the period from 2000 to 2019, in order to match data availability between the three sources and to avoid spurious results due to the COVID-19 crisis in 2020. Prior to that, we provide some descriptive evidence on the new measures we are proposing by exploiting a larger coverage of 61 countries. Tables 9, 10 and 11 in the appendices provide the complete list of industries and countries.

Our contribution lies at the intersection between dependency theory and the capability-based theory of economic development, and is situated within the literature documenting the side effects deriving from GVC participation. According to our results, increasing offshoring of labour inputs might worsen the macro-sectoral performances of countries, challenging the standard findings. In short, the novelties this paper offers are: first, contributing to the understanding of the productivity–GVC participation nexus by investigating the under-explored dimension of positioning in the international division of labour; second, empirically operationalizing the concept of collective knowledge embedded into the workforce and distributed along stages of production; third, shedding light on the possible detrimental outcomes, especially for mature economies, of the massive process of labour offshoring and the related weakening of industrial capabilities.

The paper is structured as follows: in Sect. 2 we critically review the state-of-the-art of the empirical literature on GVC participation—measured by Input–Output tables—and the relationship with labour productivity. In Sect. 3 we present our alternative theoretical background to frame (i) the notion of loss of knowledge embodiment in the offshoring process, and (ii) country/sector asymmetric positioning in the international division of labour. Section 4 describes the Input–Output methodology and the data we rely upon in order to compute the employment multipliers matrices, which represent the main source of information used to construct our indicator. In Sect. 5 we present descriptive statistics of BNLD in cross-section and time series to validate its properties. Section 6 performs a dynamic panel estimation, and Sect. 7 gives our concluding remarks and lays out future lines of research.

2 The gains from GVC participation: state-of-the-art and what is left aside

Although using alternative quantitative measures of economic upgrading (see Marcato & Baltar, 2021; Milberg & Winkler, 2011), the stream of research adopting input–output tables to compute the gains from participation in GVCs has largely focused on effects upon productivity, as a proxy for the performance of countries and industries. In general, positive effects have been documented (Battiati et al., 2020; Constantinescu et al., 2019; Criscuolo & Timmis, 2017; Formai & Vergara Caffarelli, 2016; Jona-Lasinio & Meliciani, 2019; Pahl & Timmer, 2020; Taglioni & Winkler, 2016). Participation in GVCs can take the 'seller' perspective in the form of *forward* linkages (i.e., domestic value-added embodied in foreign exports) or the 'buyer' perspective in the form of *backward* linkages (i.e., foreign value-added embodied in domestic exports). The rationale for productivity benefits stems from the fact that backward activities allow interaction from domestic and foreign capabilities and access to new advanced technologies, while forward activities increase exposure to new ideas, products, and technologies, thus fostering production upgrading and thereby facilitating gains from specialization (Battiati et al., 2020).

More in detail, the backward indicator, computed by applying the trade-in-value-added approach to international input–output tables, measures the extent to which a country's or sector's exports are dependent on imported inputs, highlighting the value-added dimension. It resembles the vertical specialization measures (Hummels et al., 2001) and it has been widely used to assess the positive link with productivity (see in particular Amiti & Wei, 2009; Winkler, 2010; Kummritz, 2016; Constantinescu et al., 2019). In a nutshell, offshoring segments of the production process results in productivity benefits because of technology transfer and knowledge spillovers: learning-by-exporting, learning-by-supplying, training by lead firms, imitation, and reverse engineering are all mechanisms according to which knowledge transfers may occur. In this respect, the *forward linkages* type of participation driven by lead firms allows the generation of positive outcomes for learning and the development potential of supplier firms and territories, particularly in the context of developing economies (De Marchi & Alford, 2022; Gereffi, 2018).

The theoretical explanation behind gains from GVC participation resembles the one deriving from FDI, which argues for positive productivity spillovers towards industries that supply multinationals (Javorcik, 2015). In addition, other *static* and *dynamic* positive effects are laid out: the former entail increasing access to better-quality or more diverse inputs (also called *supply effect*) and at lower cost (also called *price effect*), the latter refer to the reallocation of factors towards more efficient tasks (thus outsourcing activities less efficiently performed in-house). Taglioni and Winkler (2016, p. 29) stress the role of what they call the *labour turnover effect*, namely the fact that 'knowledge embodied in the workforce of participating firms (MNCs or their local suppliers) moves to other local firms', hence providing for the upgrading of their productive capabilities. However, the authors also stress that true benefits arise only if the absorptive capacity of domestic actors is built up through investments intended to upgrade technical capacity. The benefits from GVC participation have been acknowledged to be not deterministic but rather dependent on the strategic interests of lead firms, the absorptive capacity of a given industrial system and its technological endowment, and the institutional context therein, also highlighting the risk of hyper-specialization and the asymmetric relations that obtain between countries located in different hierarchical positions or between multinational and local firms (Bandick, 2020; Barrientos et al., 2016; Coveri & Zanfei, 2023b; Fridell & Walker, 2019; Kaplinsky & Readman, 2001; Morrison et al., 2008; Nathan & Sarkar, 2013; OECD, 2013; Pietrobelli & Rabellotti, 2011; Selwyn, 2015; Shepherd, 2015; UNIDO, 2015).

Having acknowledged the state of the art, we must now note that a series of criticisms applies to this literature. First of all, the fallacy of composition (Mayer, 2002) arises as a historical issue in international trade when considering the negative effects of export-led models for developing countries. While the motivations put forward for the benefits of participating in GVCs appear more appropriate for a firm-level perspective, the majority of studies adopt a sectoral or country unit of analysis due to data availability (input–output tables are mainly available at 2-digit sectoral level of aggregation). At such a broad level of aggregation, the process of offshoring segments of productive activities could entail negative effects, producing coordination failures (Rodrik, 1996). For instance, the firm-level choice of shutting down factories is not necessarily connected with the strategic relocation of less-efficient tasks at the entire industry level; however, firm-level offshoring decisions, considered to be strategic, may led to negative spillovers at the industry level.

Second, the undervaluation of the role of positioning in the chain. While for multinational companies the gains are more credible, the possibilities of moving towards higher-value-added activities – outsourcing labour-intensive tasks – and increasing value capture and learning opportunities are not equally accessible for non-multinational firms. Aggregating at the industry level, the effects might be different.

Third, asymmetries arise not only among outsourcing firms but also among outsourcing and outsourced firms, sectors, and countries. Indeed, power relations, unequal exchange, and asymmetric positioning, for instance between global lead firms and their fragmented supplier base, or directly between countries and sectors (Alford & Phillips, 2018; Blazek, 2016; Ponte & Ewert, 2009; Selwyn & Leyden, 2022), are still largely neglected by leading policy reports, such as the World Bank's 2020 World Development Report (World Development Report, 2020). Broadly speaking, the benefits pointed out in the literature again fall under the heading of comparative advantage trade theory (Dosi & Tranchero, 2021; Dosi et al., 2022), claiming *mutual gains* for suppliers and headquarter firms thanks to specialization in complementary activities. Therefore, GVCs represent yet another opportunity for cost minimization. In line with the predictions of neoclassical trade theory, countries should exploit their comparative advantages, given their factor endowments, not only in different sectors but also in different stages of production within sectors (Grossman & Rossi-Hansberg, 2008; World Development Report, 2020). As highlighted by Selwyn and Leyden (2022, p. 168), the World Bank's report 'sees the world from the *perspective of capital*. It heralds lead and supplier firms as representing dynamic and innovative actors while workers are portrayed as "comparative advantage factors of production" to be deployed by developing countries to attract foreign direct investment'. The dimension of learning and production capabilities is left out from the mainstream analysis of the benefits from GVCs.

Fifth, to our knowledge, this stream of research has mainly focused on the productive dimensions of GVC participation, measured in monetary value of production or in Trade in Value-Added (TiVA) statistics, even though some scholars have started addressing the jobs fragmentation dimension related to GVCs, shedding new light on what could be called the new international division of labour and the relation between offshoring and labour demand (Baldwin & Lopez-Gonzalez, 2015; Bontadini et al., 2022; Cresti & Virgillito, 2022; Fana & Villani, 2022; Foster-McGregor et al., 2016; Garbellini & Wirkierman, 2014; Pahl et al., 2019; Wirkierman, 2022).

3 Countries and industries in the international division of labour: an alternative conceptual framework

3.1 Division of labour, division of (embodied) knowledge

To characterize the notion of embodied knowledge in the labour requirements along GVCs, we build upon two well-known streams of research. First of all, the Pasinettian structuralist tradition (Andreoni & Scazzieri, 2014; Cardinale & Scazzieri, 2020; Landesmann & Scazzieri, 1996; Pasinetti, 1981; Scazzieri, 1990, 2014) which emphasizes the role of industrial interdependencies, i.e., productive linkages between economic branches. This approach has stimulated researchers to investigate the evolution of productive structures in a way that overcomes the traditional boundaries of industries as defined in standard classifications. Indeed, production processes do not take place in isolated productive units but rather in sequential stages of activities, progressively entailing several factories, and the workers therein, belonging to various sectors and countries. With the upsurge of globalization, such interdependencies have become increasingly global and now constitute international supply chains whose weights (the contribution of each country-industry) are constantly changing in size, reflecting the changing importance of branches and economies. This disproportionate dynamics is at the core of the international division of labour that has led manufacturing activity—and now also services (Baldwin & Freeman, 2022)—to be spatially and vertically fragmented. This process has been driven by delocalizations, implemented largely by multinational corporations through outsourcing and offshoring practices. In this work we focus on the latter, as it entails shifting production and labour abroad.

Second, our theoretical background builds upon the evolutionary studies of sectoral patterns of innovation (Breschi & Malerba, 1997; Dosi, 1982; Pavitt, 1984). Indeed, sectors have different learning patterns and innovation sources: every chain is therefore composed of heterogeneous branches in terms of technological content. Moreover, according to the evolutionary tradition and the capability-based theory of the firm, problem-solving knowledge and the ‘recipes’ underlying technological change are to a significant extent embodied in the organizational routines and problem-solving capabilities developed by workers. Cimoli et al. (2009) pointed out that the process of accumulation of knowledge and capabilities is at the core of virtuous structural transformations. Although economic theory and empirical research have largely focused on machine-embodiment, knowledge—in its multifaceted nature—is also embodied in the workforce, with substantial heterogeneity deriving from ‘where’ labour is employed (e.g., sector-specific technological regimes but also stage/department-specific). It goes without saying that embodied knowledge can also be increased through learning by using (or by doing) (Andreoni, 2014; Dosi & Nelson, 2010; Rosenberg, 1982). Considering labour as a generic productive factor, and thus neglecting its (cumulative) knowledge content and the *socially embedded* dimension of capabilities (Andreoni et al., 2021; Barrientos et al., 2011), results in missing an element that is crucial for understanding the sources of economic upgrading/downgrading. This insight is of particular importance given the unit of analysis of our interest, that is country-industry at a high level of aggregation (2-digit). As discussed in the previous section, at this level of investigation, the concept of offshoring of labour cannot simply be related to the strategic motivations for relocating production abroad or to pure technical progress making the sector more capital-intensive. On the contrary, a reduced workforce in a sector in favour of labour inputs coming from abroad is often related to entire factories closing, thus losing employment and productive capacity, with the associated social costs. Indeed, the workforce employed in a given industry is the repository of *tacit collective knowledge*, person-embodied rather than information-embodied (Patel & Pavitt, 1991). Offshoring of the workforce results in dissipating accumulated knowledge, capabilities, collective routines, and problem-solving capacity, therefore potentially negatively impacting upon sectoral productivity.

3.2 Asymmetric positioning and dependency theory

If GVCs are not only commodity chains but also *labour-value chains* (Suwandi, 2019), to better frame the idea of *positioning* in the international division of labour we rely on two further approaches. First, the core–periphery notion deriving from dependency theory (Gereffi, 1994; Prebisch, 1950), linked with the aforementioned structuralist perspective, which is actually a forerunner of the global commodity chains studies that emerged in the mid-1990s (Gereffi & Korzeniewicz, 1994) and of the more recent global value chains literature (Ponte et al., 2019). Dependency theory has the advantage of studying economic development from the perspective both of external constraints and of the internal structure of production, including the social and political spheres (Kvangraven, 2021; Santos, 1970). The interest in the internal structure of production is shared by the structuralist perspective (Cimoli & Dosi, 1995; Hirschman, 1958; Prebisch, 1950), which has recently been focusing on the role of weakening of technological capacity, bad employment, and sectoral specialization to explain economic downgrading (Dosi et al., 2021; Gomez & Virgillito, 2022).

Although dependency theory took developing countries (principally in Latin America) as its object of analysis—highlighting, for instance, the dependence of the *periphery* on the strategic choices of the *centre* —we seek to apply these insights to the current state of dependence on foreign labour, and the associated embodied knowledge, that is common to many mature economies characterized by deindustrialization and offshoring manufacturing. It is a useful theoretical underpinning for our approach insofar as it advances a relational and hierarchical view of the international structure of production, and hints at the ensuing division of labour.

Secondly, we take advantage of the analysis put forward by the so-called world-systems theory (Doner, 1991; Gereffi & Korzeniewicz, 1990; Henderson, 2002; Hopkins & Wallerstein, 1977, 1986; Wallerstein, 1974, 2004) that more explicitly drew on Marxist ideas of imperialism and capitalist exploitation. This school of thought—less focused on productive structures and more on exchange relationships—relates the structural position of countries and sectors in the global production network with the role played by the *hierarchical* international division of labour. However, the approach is not far from the second wave of globalization studies (Selwyn & Leyden, 2022). In Gereffi's words (1994, p. 214), world-systems scholars argued that '[l]eaving one structural position implies taking on a new role in the international division of labor, rather than escaping from the system', thus implying that there are limited possibilities for 'autonomous paths of development'. These last two approaches are useful for framing the concepts of labour dependence and asymmetric positioning, bridging them with the GVC concepts of headquarter and factory economies (Baldwin, 2013; Baldwin & Lopez-Gonzalez, 2015; Stöllinger, 2021).

As a result, at the core of our analysis we construct a new indicator that we label *Bilateral Net Labour Dependence*. *Bilateral* because we emphasize the country-by-country trade relationships; *Net* in the spirit of GVCs positioning measures (Koopman et al., 2010; Baldwin & Freeman, 2021) that compare *backward* and *forward* linkages information; and *Labour Dependence* because we look at the offshoring of labour, which according to our conjecture is an offshoring of the knowledge embodied in the workforce, resulting therefore in dissipated productive capabilities.

4 Methodology: from employment multiplier matrices to BNLD indicator

The GVC literature generally extracts measures of vertical integration and participation in supply chains from a matrix of value-added embodied in intermediary inputs flows (Constantinescu et al., 2019; Jona-Lasinio & Meliciani, 2019; Koopman et al., 2014; Kummritz, 2016; Los et al., 2015; Timmer et al., 2014). Such measures resemble traditional indicators of offshoring activities, such as the share of imported inputs in producing goods according to final demand or exports. Since the seminal works by Feenstra and Hanson (1996, 1999), the literature has focused on the foreign component of backward linkages to calculate offshoring indicators. Such measures have been extensively used to relate changes in the performance of a sector not only to variation of its characteristics, but also to changes taking place in the productive structure triggered by inter-sectoral linkages and final demand, and thus to its degree of vertical integration or in terms of its participation in GVCs.

Although it is acknowledged only to a limited extent, the construction of the matrix of value-added in trade takes advantage of the notion of vertically integrated sectors developed in the 1970s by Pasinetti, as an enrichment of the so-called analysis of industrial interdependencies, and specifically building upon the analytical scheme proposed by Leontief (1951) with the use of input–output tables (Cardinale, 2018; Di Berardino, 2017; Landesmann & Scazzieri, 1993, 1996; Pasinetti, 1973, 1977; Scazzieri, 1990). The idea behind the concept of vertically integrated sectors is that of the existence of sequential stages of the production process, which compose a production chain (or supply chain), aimed at producing a given final commodity using the inputs produced at each round. Every chain can be seen as a sub-part of the economic system and can be called a subsystem or *vertically integrated sector*.[1]

Vertically integrated sectors can be calculated from input–output data and used to reclassify a sectoral variable (as value-added or employment) into an industry-by-subsystem matrix representation. In particular, we will calculate the so-called Employment Multipliers matrices (Baker & Lee, 1993; Bivens, 2003, 2019; Cresti & Virgillito, 2022; Miller & Blair, 2009), whose coefficients inform us of the potential number of jobs generated within the sector and along the supply chain, given a *fixed* amount of final demand in the period under consideration.

In order to capture the participation of sectors in the international division of labour, we take advantage of the aforementioned established methodology, based on the Leontief Inverse, a matrix that allows the quantification of the sequential effects on the branches of the economy induced by a one-unit initial increase in the production of a final good.[2]

4.1 Data

We take symmetric industry-by-industry Input–Output tables $\boldsymbol{Z}$ from the OECD Inter-Country Input–Output (ICIO) Tables,[3] which include 76 countries (+Rest of the World aggregate) and 45 sectors, from 1995 to 2020. Information on sectoral employment has been taken from the OECD Trade in Employment (TiM) database.[4] Final demand and gross output have been taken from ICIO, while other variables such as wages and gross fixed capital formation have been extracted from the OECD STAN database for Structural Analysis.[5] First of all, we had to exclude some developing and emerging economies from the I–O table in order to construct the employment multipliers matrices because of a lower coverage provided by TiM, thus reducing countries' availability to 61 economies. Secondly, in order to construct the panel dataset for the econometric analysis we restrict our analysis to the period 2000–2019 and to a country coverage of 38 economies (the number of industries remain unchanged), resulting in a panel of 11,400 observations. All variables are provided at 2-digit level of aggregation based on the International Standard Industrial Classification of all economic activities, Revision 4 (ISIC Rev. 4). For the descriptive analysis in Sect. 5 we exploit the larger dataset of 61 countries, 15 industries, but restricting the focus to the 2000–2019 period to have consistency with the econometric analysis in Sect. 6, for which we had to use the shorter dataset of 38 countries, 15 industries and 20 years.

[1] Further theoretical considerations on the algorithm of vertically integrated sectors can be found in Di Berardino (2017) and Cresti et al. (2023).

[2] In Input–Output analysis, every sector (or economic branch) of the economy is assumed to produce a homogeneous good. Available I–O tables measure trade flows in monetary terms, usually in million of US$. As a result, in the Leontief inverse framework, one unit of final demand stands for one million of US dollars.

[3] OECD Inter-Country Input–Output Database, http://oe.cd/icio.

[4] Trade in Employment, https://www.oecd.org/en/data/datasets/trade-in-employment.html.

[5] STAN Database for Structural Analysis, https://www.oecd.org/en/data/datasets/structural-analysis-database.html.

4.2 BNLD construction

After having accessed the input–output matrix $\boldsymbol{Z}$ of intermediate deliveries, we can construct the matrix $\boldsymbol{A}$ of direct inter-industry coefficients, post-multiplying $\boldsymbol{Z}$ by the inverse of the diagonal matrix of sectoral output $\hat{x}$[6]:

$$\boldsymbol{A} = \boldsymbol{Z}x^{-1} \tag{1}$$

Every element a_{ij} stands for the technical coefficient of the input produced by industry i and sold to industry j, that is the intermediary amount z_{ij} over the total gross output x_j. Matrix $\boldsymbol{A}$ is used to solve the accounting equations, describing the economic system composed by N industries, each producing a homogeneous good, represented as a vector of gross outputs x which equals a vector of intermediate production $\boldsymbol{Z}i$ and a vector of final demand d:

$$x = \boldsymbol{Z} + d \tag{2}$$

$$x = \boldsymbol{A}x + d \tag{3}$$

Solving by x yields:

$$(\boldsymbol{I} - \boldsymbol{A})x = d \tag{4}$$

$$x = (\boldsymbol{I} - \boldsymbol{A})^{-1}d \tag{5}$$

The first element on the right-hand side is called the Leontief Inverse matrix,

$$\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \tag{6}$$

with $\boldsymbol{I}$ representing the identity matrix and assuming that the inverse of $(\boldsymbol{I}-\boldsymbol{A})$ exists. Considering N industries with $i, j=1,\ldots, N$, every $l_{i,j}$ element of the standard Leontief matrix $(\boldsymbol{L}=(\boldsymbol{I}-\boldsymbol{A})^{-1})$ captures the direct and indirect requirements of increased output of industry i needed to produce one additional unit of final good in industry j. Capturing direct and indirect inputs exactly corresponds to the attempt to include the entire amount of intermediaries each sector is providing to another one. That is, we track not only the flow of inputs produced by a sector i and delivered directly to sector j, but also the flow of inputs still produced by sector i, but used by other sectors to produce in turn the intermediaries then provided to the same sector j. Such a matrix allows the construction of the matrix of the direct and indirect contributions of the labour of each sector to produce the goods in the economy activated by one more unit of final good:

$$E = \hat{l}\hat{x}^{-1}L \tag{7}$$

[6] The hat over variables stands for the transformation from vector to diagonalized matrix.

where l is the diagonal matrix of sectoral employment which, divided by x, the diagonal matrix of sectoral output, results in a diagonal matrix of technical labour coefficients. Every cell of matrix $\boldsymbol{E}$ captures the so-called employment multipliers, i.e., the amount of employees activated in each country-industry of the supply chain– which can be called a subsystem– by a fixed amount of final demand (in our case 1 mn USD). $\boldsymbol{E}$ is a country-industry × country-subsystem matrix built for every year from 2000 to 2019. By summing over columns (rows) we get the so-called forward (backward) linkages indicators expressing how important a sector is in providing (requiring) labour embodied in intermediate inputs flows. Simple (closed model with exogenous households) employment multipliers for generic matrix $\boldsymbol{E}$ can be computed as:

$$\boldsymbol{m}\,(\mathrm{e})_{\mathrm{Backward}} = \mathrm{i}\prime\boldsymbol{E} \qquad \boldsymbol{m}\,(\mathrm{e})\,\mathrm{Forward} = \boldsymbol{E}\mathrm{i}$$

Or, in alternative notation:

$$m\,(e)_{jk}^{Backward} = \sum_{i=1}^{n}\sum_{c=1}^{m} e_{ic,jk}$$

$$m\,(e)_{jk}^{Forward} = \sum\nolimits_{j=1}^{n}\sum\nolimits_{k=1}^{m} e_{ic,jk}$$

where (j, k) is a generic subsystem-country unit (column identifier), while (i, c) stands for industry-country unit (row identifier). However, before extracting information from matrix $\boldsymbol{E}$, we remove rows (industries) and columns (subsystems) that are different from manufacturing activities, being service sectors generally less traded, particularly in the period under investigation.[7] Having focused on manufacturing trade, we want then to analyse bilateral industry/subsystem trade between each couple of countries, for instance the bilateral relationship between Italy and Germany in the automotive sector and its subsystems. Hence, we focus on bilateral employment activation. Taking the Italian automotive sector/subsystem—and its trade relationship with Germany—as a reference point:

- from domestic subsystems (automotive) to foreign industries (of all kinds), the backward *bilateral* linkage is the number of employees *activated* in the German manufacturing industries by automotive final production in Italy (e.g., cars).
- from domestic industry (automotive) to foreign subsystems (of all kinds), the forward *bilateral* linkage is the number of employees in the Italian automotive sector *provided* (i.e., embodied in the intermediaries sold) to German subsystems.

While summing the employment multipliers across rows (along backward linkages) provides a consistent account of the inter-industry flows as the number of

[7] Among manufacturing branches, we exclude Coke, refined petroleum products (C19 code), as it is highly subject to price dynamics, and Paper products and printing (C17_18 code) because this aggregate is not available in STAN and TiM.

employees in each supplier industry is activated by the same final demand, summation across columns (along forward linkages) might undervalue the different weights that each industry exerts in the economy. Summing employees activated by a fixed amount, say one mn USD of sector-specific final demands, might devalue demand effects and heterogeneity across industries. To account for cross-industry heterogeneity, we perform a demand-weighted adjustment for each employment multiplier, that is we multiply each given entry of the employment multiplier matrix $e_{ic,jk}$ (number of employees supplied by industry i in country c for the final production of commodity j in country k) for the share of final demand for commodity j (d_{jk}) over the total for country k (d_k). In mathematical notation we have:

$$\text{Normalised employment multiplier} = {e_{ic,jk}}^{Norm} = \frac{e_{ic,jk} * d_{jk}}{d_k} \tag{8}$$

Such a procedure assigns weights that correspond to the relevance of the final demand of each industry at the economy level. Once weighted, employment multipliers can be summed across rows and columns, without undervaluing the importance of each specific industry.[8] Given H (J), the number of manufacturing industries (subsystems), we define the total sectoral level backward and forward bilateral measures as[9]:

$$BackwardBilateral_i = \sum_{h=1}^{H} e_h^{Norm} \tag{9}$$

$$ForwardBilateral_i = \sum_{j=1}^{J} e_j^{Norm} \tag{10}$$

Merging these two sources of information we obtain a measure of GVC positioning [in the spirit of Koopman et al., (2010) and Baldwin and Freeman (2022)], which combines—as a ratio—backward and forward linkages, for every bilateral trade between industry/subsystem i in country c and country k:

[8] The need for this weighting procedure stems also from the concern highlighted in Miller and Blair (2009, p. 558) regarding the fact that the forward linkages computed with the Leontief Inverse ‘are generated by a peculiar stimulus– a simultaneous increase of one unit in the final demand of every sector.’ In the literature, this dissatisfaction led to the suggestion of using the Ghosh model to compute total forward linkages, resulting in the total (direct and indirect) intermediate sales by sector i as a portion of the value of i’s total output. Using backward linkages from the Leontief inverse and forward linkages from the Ghosh inverse is common in the GVC literature investigating degrees of upstreamness vs. downstreamness of sectors. However, to our knowledge the rows of the Ghosh inverse matrix inform us about the distribution of sectoral sales across chains similarly to a diversification measure. Our interest lies more in understanding how a sector participates in different subsystems (GVCs), hence in the different productive processes activated by qualitatively different final demands, but quantitively fixed. Moreover, if we use Ghosh for forward linkages we would end up with a ratio of backward computed with Leontief and forward computed with Ghosh, which is harder to interpret.

[9] By sectoral level we simply mean that the measure is computed for each country-sector unit of analysis, but the information it contains is obtained by merging the one at industry (forward linkage) level with the one at subsystem (backward linkage) level.

$$GVCpositioning_{i,c;k} = \frac{BackwardBilateral}{ForwardBilateral} = \frac{\sum_{h=1}^{H} e_h}{\sum_{j=1}^{J} e_j} \tag{11}$$

where H (J) is the number of manufacturing industries (subsystems) for every country. In our case H and J are identical, as every industry i in country c is providing labour to each subsystem h of country k, but at the same time every subsystem i in country c is demanding labour from each industry j of country k. Taking into account all bilateral relations ($n-1$, as n is the number of countries), the Bilateral Net Labour Dependence (BNLD) indicator we propose (for a generic industry/subsystem i in country c) is given by:

$$BNLD_{i,c} = ln\left(\sum_{k=1}^{n-1} GVCpositioning_{i,c;k}\right) \tag{12}$$

where k is a generic country with which industry/subsystem i in country c trades. We compute it for each manufacturing sector in each country.

This measure incorporates all specific bilateral GVC positionings in the international division of labour, determined by the matrices of employment multipliers. BNLD accounts for the *net* dependence on foreign labour, that is whether a country-industry is overall requiring more labour than the amount it provides to other countries. Hence, it captures asymmetric (dominant vs. dependent) positioning in GVCs, i.e., weak or strong ties in the international division of labour, likely reflected in weak or strong sectoral performances. If BNLD increases, this might be due to an overall rise in the backward bilateral flows or to an overall decline in forward bilateral flows (or both). The former means that the country-sector is requiring more labour inputs, the latter that it is providing more of it. As a result, an increase in BNLD accounts for an increasing net dependence on foreign labour, that is labour not related to activity performed within the national boundaries. In the following, we adopt a min–max normalization procedure of the indicator in order to remove scale effects in data visualization and to perform an appropriate country/industry comparison.

4.3 Key attributes of the BNLD indicator

Below we provide a concise account of the key attributes (summarised also in Table 1) of the BNLD when compared to the already established GVC participation and positioning measures—those belonging to the galaxy of OECD TiVA statistics (Guilhoto et al., 2022). In short:

1. Leveraging on the more recent Trade-in-Employment statistics, BNLD takes into account the labour required in I–O linkages, which we assume to be a proxy for the collective knowledge embedded in the workforce, while GVC participation and positioning indexes mainly account for value-added in intermediaries' trade.
2. The embodiment of labour is captured by means of employment multipliers matrices, which exclude the effective components of final demand in order to

rule out the role of market positioning, while TiVA-based measures usually take into account effective domestic or foreign exports. Therefore we are interested in technical employment requirements, rather than effective ones.

3. BNLD is constructed in the spirit of GVC *positioning* measures (Baldwin & Freeman, 2022; Koopman et al., 2010), which are often meant as comparisons between forward and backward linkages.[10]
4. BNLD is an enrichment of standard *positioning* indexes, as it takes into account *bilateral* linkages between each country-sector pair for every backward and forward component. Bilateral flows are particularly relevant in the trade by intermediates, including parts and components (Baldwin & Taglioni, 2014; Los & Timmer, 2018).

5 BNLD across countries and value chains: geographical and time series trends

We start by presenting the geography of production and the unequal localization of employment flows emerging out of the constructed indicators. We map backward and forward bilateral linkages, taking automotive final production in Italy as an example (i.e., we look at the bilateral flows along column and row dimensions). Figure 1 presents the amount of labour input the Italian automotive industry requires from various countries in the world (column/subsystem perspective) in changes from 2000 to 2019. In contrast, Fig. 2 shows the respective amount of labour that the Italian automotive industry delivers as input to the final productions of various countries in the world (row/industry perspective) in changes over the same period of reference. From the different intensity of the indicators of labour supplied/demanded by the Italian automotive industry compared to other countries, the importance emerges of taking into account bilateral production-exchange and not simply considering the overall world flow. The specific bilateral relationships signal the relevance of considering the position rather than the sheer participation of industries in GVCs. In addition, such relationships are not random and/or equally important among countries, but rather are specific, persistent, and variously structured, and this allows us to consider the preferential attachment schemes of trading activities.

At the worldwide level, we observe the increasing role played by labour requirements sourced from Mexico and Vietnam (red). The emerging role of China, Turkey, India, and Saudia Arabia in the last twenty years is well captured by our indicator. In

Table 1 Key attributes of the BNLD indicator

Categories	BNLD indicator
Variable	Labour (and knowledge) embodied in I–O linkages
Final demand	Excluded (Employment multipliers)
Structure of relations	*Positioning* index: relative, backward versus forward
Geography	Country-by-country bilateral inter-dependencies

[10] Note that the literature on GVC-productivity nexus (see Sects. 1, 2, 3) has primarily focused on the advantage from participation in GVCs, rather than from positioning.

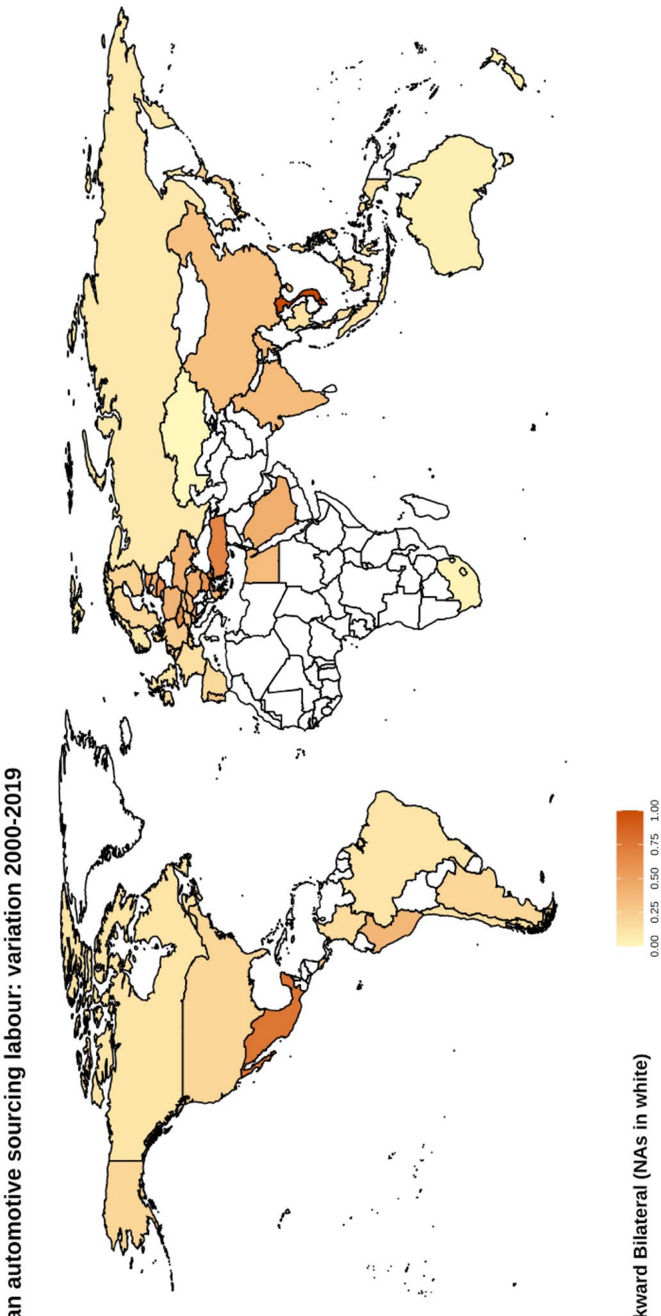

Fig. 1 Backward Bilateral: variation 2000–2019 of employees activated in order to produce 1 mn USD of final commodity of Italian automotive subsystem

addition, the new European geography of production, accelerated since the accession of the Visegrad countries, stands as a major validation of the indicator. In Fig. 2, the patterns of outsourcing reveal the relevance of the increasing integration of Italian automotive value chains towards Eastern Europe and various extra-EU countries like Turkey, Vietnam and Mexico.

We plot the ranking for the top 20 country-subsystems in 2019 (Fig. 3).[11] Top positions in the ranking are occupied by small countries lacking a proper industrial structure and heavily reliant on acquisition of labour inputs from abroad (Iceland, Perù, Cyprus, Malta, Luxembourg). These countries register a considerable magnitude in Bilateral Net Labour Dependence, thus importing lots of inputs from abroad that embody labour. Conversely, Fig. 4 lists the 20 country-subsystems at the bottom of the ranking in 2019. Bottom positions are occupied by Chinese industries, together with production from Indonesia, India, and Japan, among others.

In the following plots we show the ranking within four countries of interest (China, Germany, Italy, and the US) with values normalized in [0,1]. Here, we account for the Pavitt class of belonging in order to detect the technological dimension of bilateral net labour dependence. The Pavitt Taxonomy (Pavitt, 1984) is a sectoral classification that allows us to gather productive sectors into four classes characterized by different technological attributes, by various internal learning processes and, one could argue, by heterogeneous positioning along value chains. Such a taxonomy is distinguished into:

- Science-Based firms (e.g., Pharmaceutical), whose technological progress is strongly linked to those of basic and applied research.
- Specialized Suppliers (e.g., Machinery and Equipment), which provide capital tools and components to a large spectrum of downstream sectors. Learning relies on innovative efforts both through formal expenditures on R&D and through tacit knowledge in artefact design and customization.
- Scale- and Information-Intensive firms (e.g., Automotive), in which innovation capabilities arise from technological adoption of capital inputs but also from the ability to develop internally complex products and to manage complex organizations. Learning is cumulative and its effect is amplified by scale economies, also thanks to the production of basic materials, services, and consumer durables.
- Supplier-Dominated firms (e.g., Textile), typical of traditional manufacturing industries in which innovation and learning depend on intermediate and capital goods purchased from other sectors.

Figure 5a–d show the BNLD multiplier ranking for Chinese, US, German and Italian subsystems in 2000 and 2019. China is the only one presenting a net reduction in the BNLD indicator for each industry (i.e., the 2019 value is lower than the 2000 one), except for the motor vehicle sector. The latter is the leading industry in terms of net

[11] We refer to country-subsystem as the emphasis is put on the net dependence from foreign labour, that is on backward linkages net of forward ones. Hence the subsystem dimension is the starting point of the analysis. However, in the following description of the evidence we refer to subsystems, sectors, or branches interchangeably.

labour dependence for 2019, followed by Pharmaceuticals, and this holds true also for the US. On the contrary, Germany and Italy present higher dependence in less strategic industries as Food and Tobacco. Italy shows a clear progressive dependence on the entire automotive segment, both in transport equipment and motor vehicles. For US, Germany and Italy we detect a more stable specialization patterns by comparing 2000 and 2019. Unlike China, where we register a marked reduction of its net labour dependence from abroad in most industries, this does not hold for the established industrialized countries, where we see a more heterogenous picture with BNLD overall remaining more stable.

In Fig. 6 we present time trends for the BNLD values for two selected industries, Pharmaceutical (red line) and Automotive (light-green line), in the usual four selected countries (China, Germany, Italy, and the US). Time trends allow us to assess whether a country in a given industry has become more or less net dependent on foreign labour. We focus on Pharmaceutical and Automotive as they have shown a considerable size effect in supply chains given their fragmentation of production. The BNLD presents a general increasing trend in the US and Italy (only Pharmaceutical), and a decreasing or stable pattern in China and Germany. The Automotive sector in Italy shows a dual phase behaviour, with a maximum in 2007 and then a decline. The crisis period coincides with some fluctuations, but then a recovery afterwards is visible. Although 2008 is considered the year of the great trade collapse, emerging evidence (Timmer et al., 2021, see Fig. 2 therein) shows that part of the decline in GVCs after the 2008 crisis is due to measurement issues, namely nominal values employed in GVC indicators, which tend to overestimate the decline in trade fragmentation, while the real trade fragmentation indicator shows that the 2008 crisis has not affected trade fragmentation in the long run. Our time series show idiosyncratic country-industry dynamics, which we will address in our econometric setting.

Figure 7a and b provide a glimpse into the occupational compositions of traded employment by different occupational qualifications using EU-LFS. Unfortunately, such data are limited in time (2011–2019) and restricted to Europe; however, they already provide some insight into the diversified structure underlying traded employment. Comparing labour inputs sourced by Germany and Italy from each respective trading partner, it is clear how the former sources a quite diversified type of knowledge, equally including top and medium occupations, ranging from technicians and professionals to service and sales and trade workers; while the latter instead sources more high-level occupations, although medium-level ones still emerge as being quite significant among the sourced labour input. The evidence that traded employment is not only concentrated into high-level occupations providing technical or professional knowledge, but also involves occupations with applied and procedural knowledge, supports our choice of including the entire employment composition, to avoid any bias towards R&D workers. Finally, the lack of strong concentration in the shares of traded occupations empirically supports the notion of knowledge as collectively shared across occupations and not just retained by distinct types of skills.

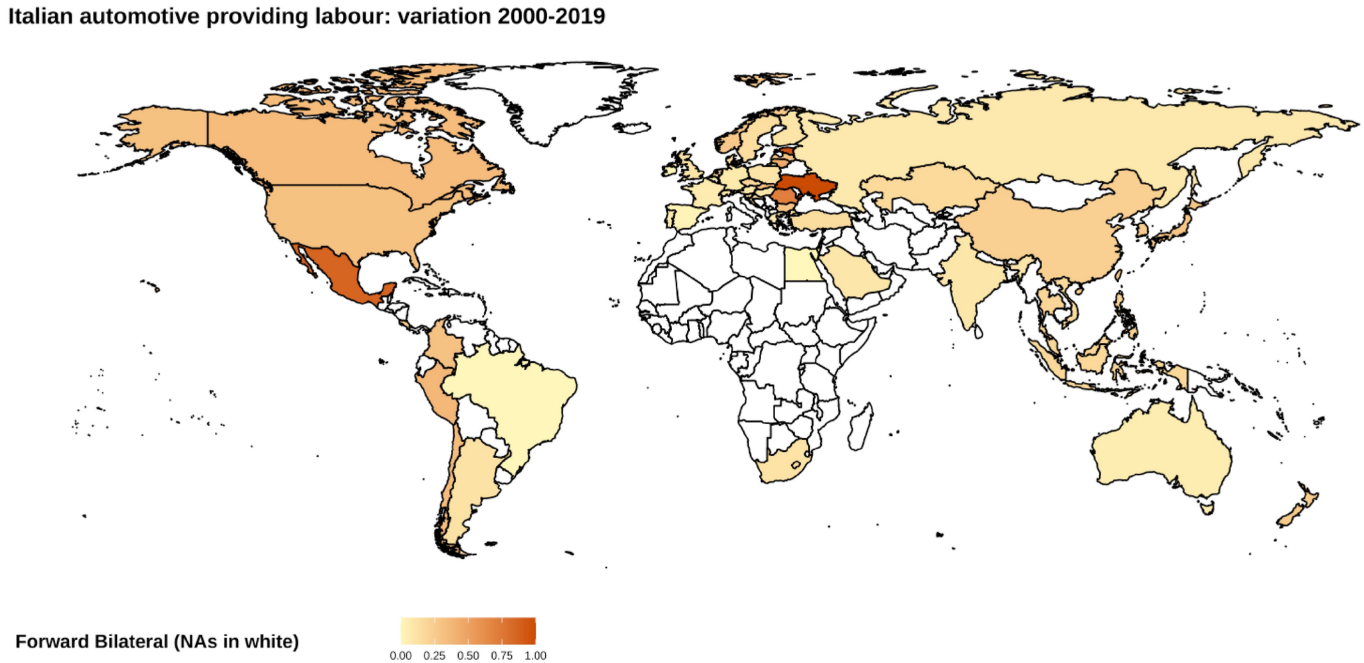

Fig. 2 Forward Bilateral: variation 2000–2019 of employees provided by Italian automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world

6 BNLD and productivity: econometric specification

The literature (Battiati et al., 2020; Constantinescu et al., 2019; Criscuolo & Timmis, 2017; Formai & Vergara Caffarelli, 2016; Jona-Lasinio & Meliciani, 2019; Pahl & Timmer, 2020; Taglioni & Winkler, 2016) has usually addressed the productivity–GVC participation nexus by means of an econometric specification with productivity in levels, explanatory variables usually lagged, a battery of fixed effects, and various controls, mainly related to capital intensity and intangible assets. We construct a comparable specification with *BNLD* as the main explanatory variable. The list of employed variables can be found in Table 2. Our panel dataset includes a restricted sample of 38 countries, 15 manufacturing industries for the period from 2000 to 2019 (11,400 observations), in order to match data availability between OECD ICIO Tables, OECD TiM and OECD STAN databases and to avoid spurious results due to the COVID-19 crisis in 2020. Tables 9 and 11 in the appendices provide the complete list of industries and countries, while Tables 4 and 5 show the correlation matrix and descriptive statistics.

Since labour productivity is highly persistent over time, we include its lagged value on the right-hand-side of the equation. As a result, our specification takes the following form:

$$LP_{i,t} = \alpha LP_{i,t-1} + \beta_1 BNLD_{i,t-1} + \beta_2 KE_{i,t-1} + \beta_3 FD_{i,t-1} + \beta_4 W_{i,t-1} + \delta_t + \mu_{i,t} + \varepsilon_{i,t}$$

where $t=2000,\ldots, 2019$, $i=1,\ldots, 570$.

Where $LP_{i,t}$ is (log) labour productivity (gross output over number of persons engaged) in levels, *BNLD* (in log terms and then normalized in the [0,1] interval by a min–max procedure) is our main explanatory variable, *KE* is (log) capital per employee, *FD* is (log) final demand, and *W* is (log) average wage (labour compensation over number of persons engaged). Time dummies and country-industry fixed effects are included. Our baseline specification accounts for persistence in labour productivity, degree of mechanization represented by the capital per employee ratio, demand dynamics à la Kaldor-Verdoorn, and average sectoral labour costs in order to control for different wage levels across sectors.

Concerning the estimation technique, the literature usually adopts Fixed Effects estimators, acknowledging, however, the relevance of the endogeneity problem when assessing the determinants of productivity. The estimation could suffer from omitted variables bias, tackled by including a battery of fixed effects and by adding control variables, and reverse causality, because it is argued that the most productive sectors could be the ones more involved in GVCs (Kalogeresis & Labrianidis, 2010; Sethupathy, 2013). A first solution entails lagging the explanatory variables, as we do. Concerning potential multicollinearity, we have run Variance Inflation Factors (VIF) analysis, in addition to the standard correlation matrix (see Table 4). The VIF test detected possible multicollinearity between lagged labour productivity and lagged average wage. Removing average wage (since we want to keep lagged productivity in order to capture the persistent dynamics of the dependent variable) leads to Variance Inflation Factors always lower than 5. We kept average wage as a control in

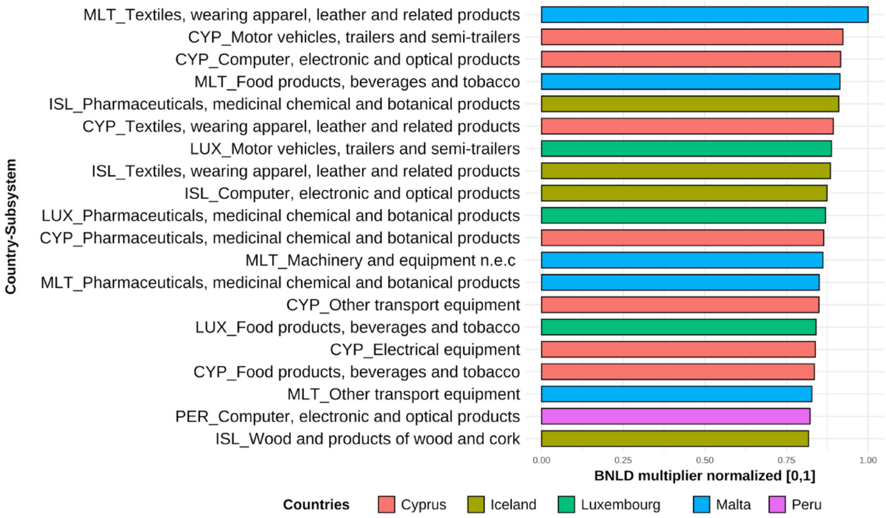

Fig. 3 Top 20 country-subsystem in 2019 for BNLD normalized in [0,1]

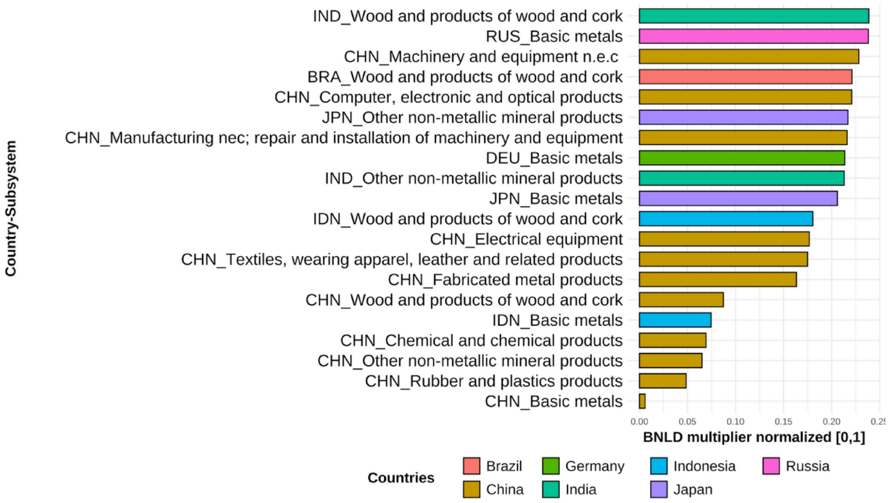

Fig. 4 Bottom 20 country-subsystem in 2019 for BNLD normalized in [0,1]

some specifications of the estimation. In the following, therefore, coefficients have to be interpreted as associations, without any claim of causality.

Table 3 displays the results of Fixed Effect estimations. Columns from FE (1) to FE (8) represent alternative baseline specifications varying the inclusion of controls, done one at the time, to check if the sign, magnitude, and significance of the main explanatory variable are stable and robust. FE (9) also controls for country-year fixed effects, while FE (10) adds industry-year fixed-effects.

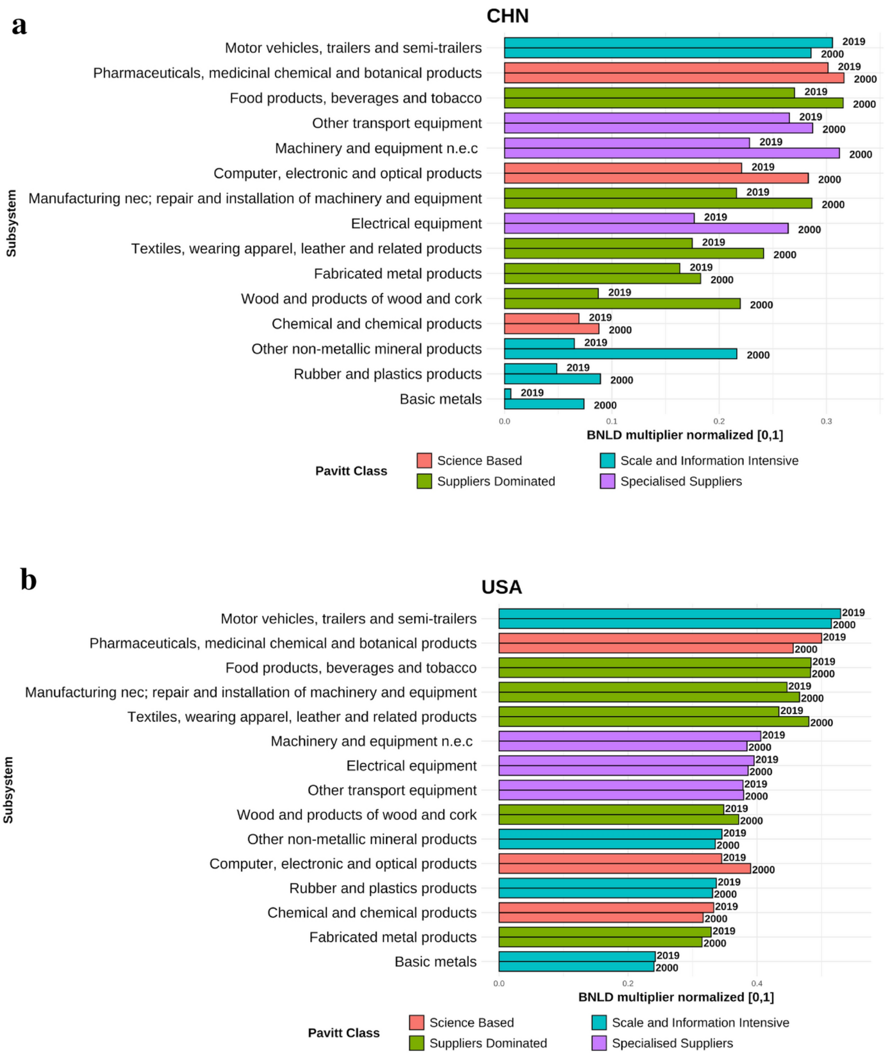

Fig. 5 **a** Ranking in BNLD normalized in [0,1] in China in 2019 and 2000, ranked by 2019 value. **b** Ranking in BNLD normalized in [0,1] in USA in 2019 and 2000, ranked by 2019 value. **c** Ranking in BNLD normalized in [0,1] in Germany in 2019 and 2000, ranked by 2019 value. **d** Ranking in BNLD normalized in [0,1] in Italy in 2019 and 2000, ranked by 2019 value

BNLD always displays a negative and significant coefficient across all specifications. The magnitude of the coefficient is rather stable, ranging more or less from –0.3 (the most saturated model also with country-year controls) to –0.5. With reference to the effects of other control variables, *KE* shows positive and significant coefficients, while *FD* and *W* show weak, positive, and sometimes non-significant associations.

How should we interpret the negative association of BNLD on labour productivity? Given an industry, becoming more net labour dependent is negatively associated with the overall performance in terms of labour productivity. It signals a weak tie of

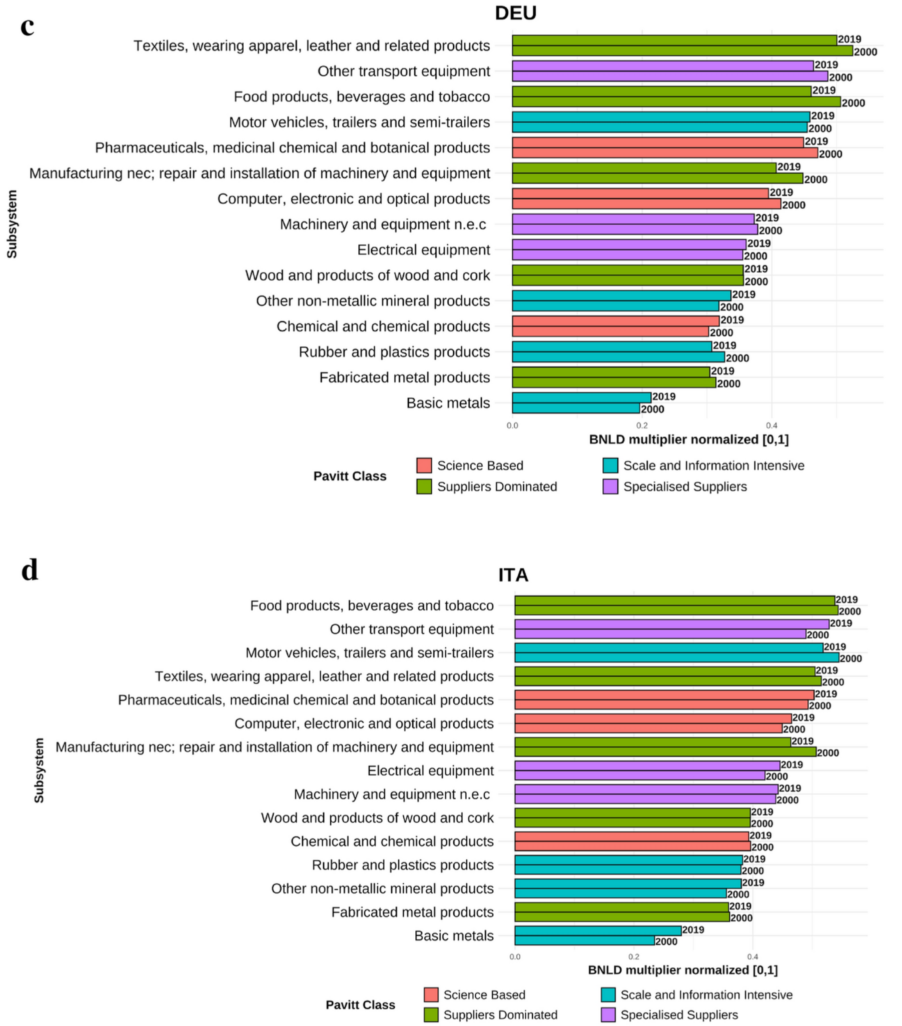

Fig. 5 (continued)

the industry/country inside global production chains, wherein the notion of weakness derives from a dependent position inside the chain. The interpretation links in a straightforward manner to the negative side effects that economies undergoing massive delocalization strategies are facing.

7 Concluding remarks

By offering a novel perspective, this work seeks to contribute to the literature investigating the link between GVC participation and labour productivity. Our results provide evidence in support of the fact that the way in which a country-industry is

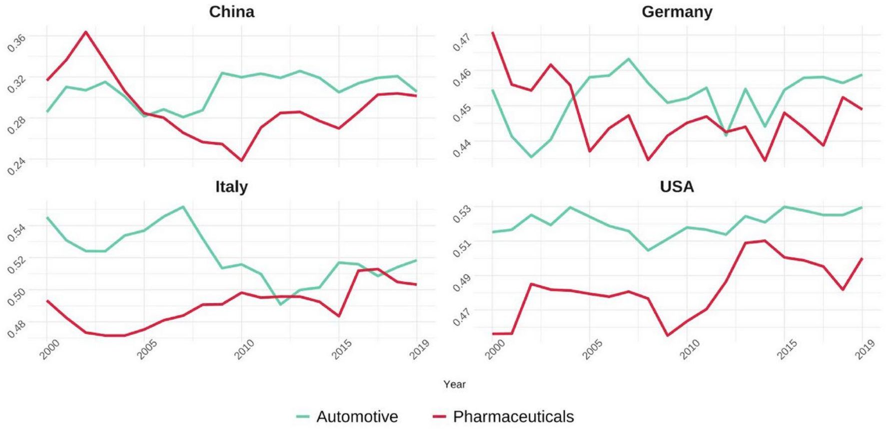

Fig. 6 Trend (1995–2020) in BNLD normalized [0,1] for Automotive (light-green) and Pharmaceutical (red) in China, Germany, Italy, and US

positioned in the international division of labour, i.e., whether it is a net provider or buyer of labour, is related to sectoral performance in terms of labour productivity. The proposed indicator presents a robust negative and significant association with labour productivity. In this respect, we were able to construct a novel proxy for weak positioning in the international division of labour in terms of industry-country *net* dependence. Our framework of analysis might prove useful for studying how the delocalization of manufacturing activities might relate to country-level productive performance.

From a policy perspective, our findings call for industrial policy to take on the role of governing sectoral and technological specialization, and to guide the positioning in the international division of labour. Neglecting the use of industrial policies not only to govern internal sectoral specialization but also to advise on positioning within GVCs, results in 'the acceptance of the current international division of intellectual and physical labour, and with that the current distribution of learning opportunities' (Cimoli et al., 2009, p. 3), which, we argue, is tantamount to accepting the weak performances of countries and sectors that are massively engaged in delocalizing activities.

There are a number of potential extensions to this work. First of all, the Pavitt Taxonomy could be exploited to characterize the quality of knowledge embedded in the construction of the BNLD indicator, namely measuring labour dependence in relation to specific Pavitt classes. Alternatively, we could further explore the disentanglement of employment by occupation to study labour dependence across production stages, highlighting not only the overall international division of labour but also the functions executed by different occupations, in line with other recent contributions measuring the functional division of labour (Coveri & Zanfei, 2023a; Timmer et al., 2019). The role of functions and occupations has become very relevant, particularly in a phase of rising trade on intermediate service activities, which is altering the face of globalization (Baldwin et al., 2024). Both represent complementary ways to move from quantity to quality/type of knowledge/functions of employment. Sec-

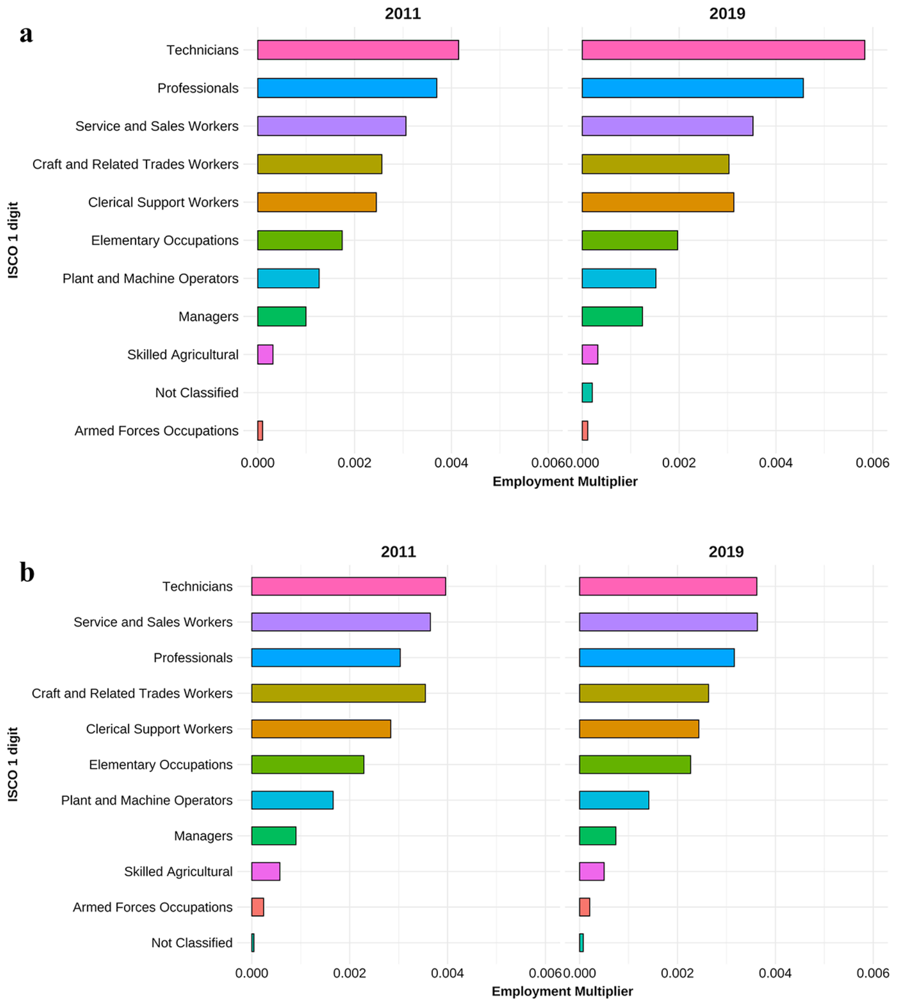

Fig. 7 **a** Italian automotive sourcing labour from Germany (i.e., backward bilateral towards Germany) in 2011 and 2019, disentangled by ISCO occupations. **b** German automotive sourcing labour from Italy (i.e., backward bilateral towards Italy) in 2011 and 2019, disentangled by ISCO occupations.

Table 2 List of country-sector variables

Variable	Dataset
LP: Labour productivity (Gross output / persons engaged)	ICIO + TiM
BNLD: Bilateral Net Labour Dependence	ICIO + TiM
W: Average wage (Labour compensation / persons engaged)	STAN
FD: Final Demand	ICIO
KE: Capital per employee (Nominal capital stock / persons engaged)	STAN + TiM

We include 15 two-digit manufacturing industries and 38 countries. The temporal availability is from 2000 to 2019

Table 3 FE estimation with LP in levels

Dependent variable: country-sector labour productivity in levels (*LPt*)										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$LPt-1$	0.791***	0.746***	0.722***	0.698***	0.776***	0.756***	0.708***	0.744***	0.676***	0.713***
	(0.014)	(0.021)	(0.022)	(0.021)	(0.018)	(0.016)	(0.021)	(0.017)	(0.025)	(0.022)
$BNLD^{[0,1]}_{t-1}$	– 0.421***	– 0.476***	– 0.52***	– 0.482***	– 0.452***	– 0.382***	– 0.417***	– 0.458***	– 0.294*	– 0.514***
	(0.083)	(0.113)	(0.116)	(0.13)	(0.085)	(0.096)	(0.106)	(0.113)	(0.173)	(0.122)
$KEt-1$		0.021***	0.021***	0.016**			0.016**		0.028***	0.02***
		(0.006)	(0.006)	(0.007)			(0.007)		(0.006)	(0.006)
$FDt-1$			0.028**	0.023	0.02*			0.026*	0.01	0.043***
			(0.013)	(0.021)	(0.011)			(0.015)	(0.018)	(0.015)
$Wt-1$				0.025		0.019*	0.041***	0.001		
				(0.02)		(0.011)	(0.011)	(0.014)		
Constant	1.3***	1.522***	1.455***	1.452***	1.245***	1.363***	1.436***	1.379***	1.741***	1.387***
	(0.08)	(0.121)	(0.123)	(0.107)	(0.08)	(0.093)	(0.107)	(0.09)	(0.171)	(0.123)
Observations	10,742	7690	7690	6946	10,742	7894	6946	7894	7690	7690
R-squared	0.87	0.863	0.864	0.871	0.871	0.87	0.87	0.87	0.887	0.875
FE	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and time dummies)	Country-industry (and country-time dummies)	Country-industry (and industry-time dummies)

Clustered standard errors in parentheses for variables' coefficients. All variables in log terms

*, ** and ***denote significance level at 10%, 5% and 1%

ond, the role of labour dependence might be studied with respect to other phenomena of interest, primarily the declining labour share, both in the standard sectoral dimension (Guschanski & Onaran, 2022) and along the vertical one, that is along chains of production as documented by Riccio et al. (2024). Finally, the possibility of constructing comparable firm-level measures, in terms of off-shoring of productive inputs, together with the underlying motives behind delocalization decisions, leveraging extensive business surveys (Costa et al., 2023), might represent an external fine-grained validation of our results. This becomes particularly important in the post-Covid phase characterized by increasing geopolitical tensions marked by the restructuring of international GVCs and, eventually, the partial reconfiguration of the international division of labour towards Regional Value Chains.

Appendices

A. Further evidence

We here present some further evidence on BNLD.

Figure 8 shows the negative correlation—in most sectors—between BNLD normalized by [0,1] and labour productivity. This is in line with our conjecture that the BNLD multiplier indicator could be used to assess a weak positioning in the international division of labour that is eventually detrimental for sectoral performances. These scatter plots refer to 2005 as an example (but the evidence is robust across periods) and observations are plotted by highlighting different sectoral belonging.

We also plot the time dynamics of BNLD for each sector from Italy, Germany, the US (Fig. 9), and China (Fig. 10). We can notice the overall decreasing trend of the sectoral BNLD indicator for China, while a stable or increasing one is detected for the other three mature economies, in line with our reasoning.

Lastly, we provide the correlation matrix (Table 4) and descriptive statistics (Table 5) of the variables used in the econometric analysis, together with the list of industries (Table 9) and of countries for the descriptive and econometric analysis (Tables 10 and 11).

B. Robustness checks

In this section we provide further robustness checks on the econometric estimation. Table 6 shows estimates with the dependent variable in first differences. In Table 7 we control for different lag structures of BNLD, keeping the specification without wages as the preferred one. In Table 8 we use BNLD not normalized in [0,1]. Except for one specification (column 4 in Table 7), the significance and sign of the BNLD coefficient are always robust.

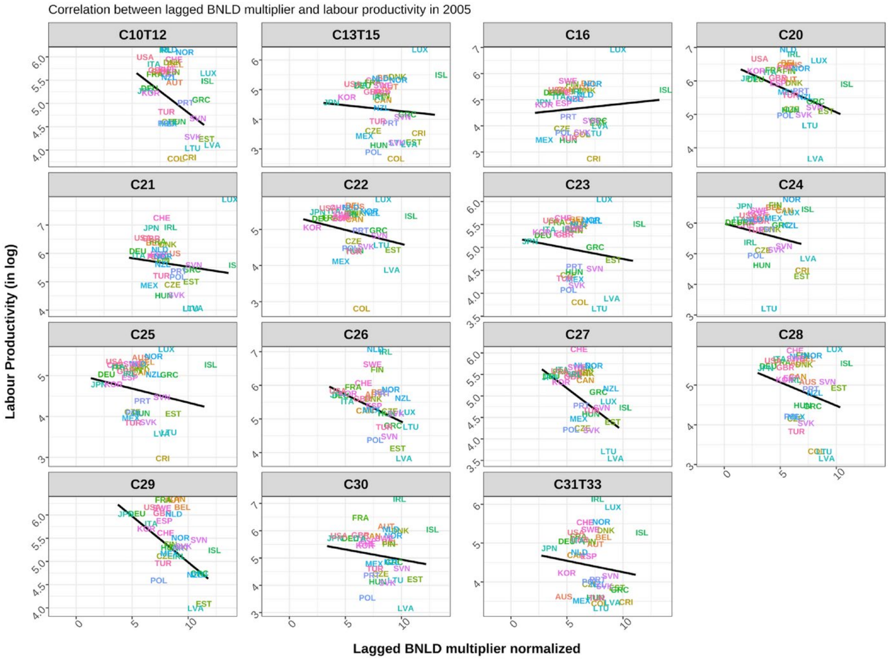

Fig. 8 Scatter plot between lagged BNLD [0,1] and labour productivity (in log terms) by industry code in 2005

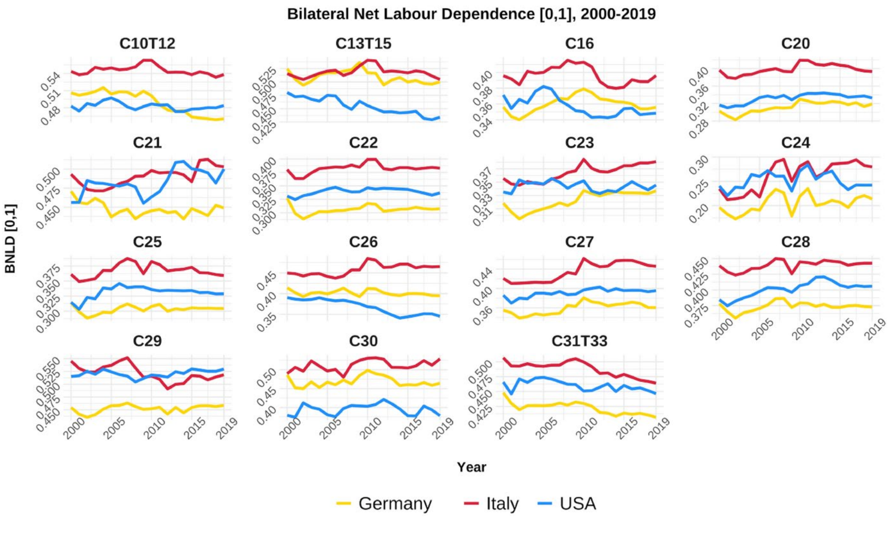

Fig. 9 Trend (1995–2020) in BNLD normalized [0,1] for Germany, Italy, and the US

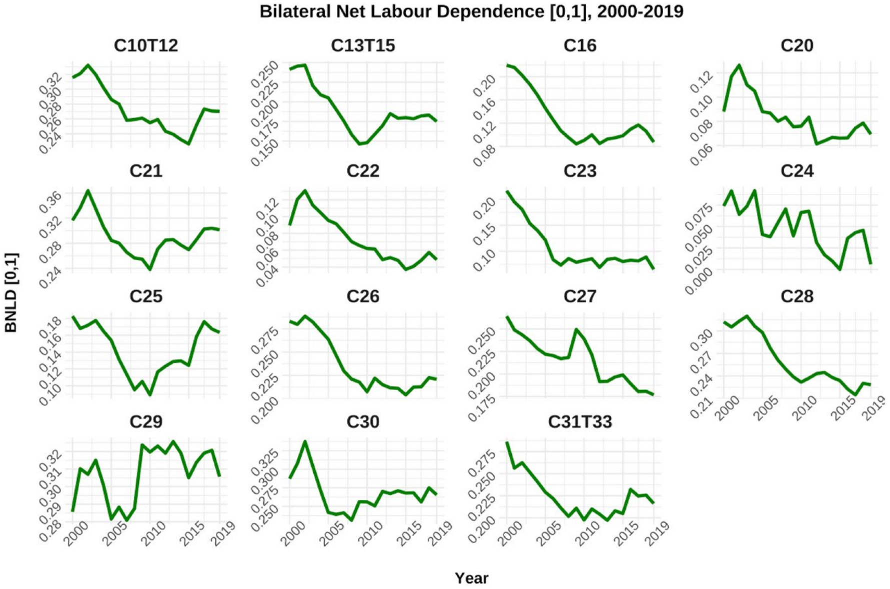

Fig. 10 Trend in BNLD normalized [0,1] for China

Table 4 Correlation matrix

Spearman's rank correlation coefficients						
Variables	LP	LP_{t-1}	KE_{t-1}	FD_{t-1}	W_{t-1}	$BNLD^{[0,1]}{}_{t-1}$
Labour productivity (LP)	1.000					
Lagged Labour productivity (LP)	0.981	1.000				
Lagged Capital per employee (KE)	0.817	0.827	1.000			
Lagged Final demand (FD)	0.377	0.386	0.287	1.000		
Lagged Average wage (W)	0.396	0.403	0.293	0.906	1.000	
Lagged BNLD [0,1] ($BNLD^{[0,1]}$)	−0.137	−0.133	−0.133	−0.308	−0.595	1.000

Spearman rho = −0.595

Table 5 Descriptive statistics for the period 2000–2019

Variable	Obs	Mean	Std. Dev	Min	Max
Labour productivity (LP)	11312	5.13	0.938	0.813	9.544
Capital per employee (KE)	7878	2.351	1.067	−4.158	6.988
Final Demand (FD)	11312	7.499	2.184	−1.534	13.355
Average Wage (W)	8101	6.65	2.02	−0.997	11.842
BNLD [0,1] ($BNLD^{[0,1]}$)	11312	0.46	0.156	0	1

All variables in log terms

Table 6 FE estimation with LP in differences

Dependent variable: country-sector labour productivity in differences(ΔLPt)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$BNLD^{[0,1]}_{t-1}$	−1.066***	−1.079***	−0.736***	−0.699***	−0.748***	−1.107***	−1.125***	−0.745***
	(0.093)	(0.129)	(0.129)	(0.145)	(0.093)	(0.118)	(0.135)	(0.131)
KE_{t-1}		−0.022***	−0.008	−0.015**			−0.02***	
		(0.006)	(0.006)	(0.007)			(0.007)	
FD_{t-1}			−0.095***	−0.11***	−0.079***			−0.086***
			(0.012)	(0.025)	(0.008)			(0.019)
W_{t-1}				0.024		−0.084***	−0.068***	−0.011
				(0.024)		(0.009)	(0.01)	(0.02)
Constant	0.469***	0.532***	1.08***	1.021***	0.938***	1.073***	1.025***	1.066***
	(0.043)	(0.063)	(0.11)	(0.094)	(0.072)	(0.084)	(0.088)	(0.091)
Observations	10742	7690	7690	6946	10742	7894	6946	7894
R-squared	0.334	0.355	0.377	0.396	0.351	0.377	0.384	0.385

Clustered standard errors in parentheses. All variables in log terms. Time dummies included, country-industry fixed effect.*, ** and *** denote significance level at 10%, 5% and 1%

Table 7 FE estimation with LP in levels and BNLD with different lags

Dependent variable: country-sector labour productivity in levels (LP_t)

	(1)	(2)	(3)	(4)
LP_{t-1}	0.722***	0.707***	0.676***	0.659***
	(0.022)	(0.025)	(0.03)	(0.027)
$BNLD_{t-1}$	−0.52***			
	(0.116)			
$BNLD_{t-2}$		−0.345**		
		(0.166)		
$BNLD_{t-3}$			−0.215*	
			(0.129)	
$BNLD_{t-4}$				−0.076
				(0.117)
$log(KE)_{t-1}$	0.021***	0.022***	0.025***	0.018***
	(0.006)	(0.006)	(0.007)	(0.007)
$log(FD)_{t-1}$	0.028**	0.015	0.011	0.002
	(0.013)	(0.014)	(0.017)	(0.016)
Constant	1.455***	1.558***	1.688***	1.81***
	(0.123)	(0.138)	(0.16)	(0.17)
Observations	7690	7310	6936	6560
R-squared	0.864	0.823	0.76	0.676

Clustered standard errors in parentheses. All variables in log terms. Time dummies included, country-industry fixed effect. *, ** and ***denote significance level at 10%, 5% and 1%

Table 8 FE estimation with LP in levels and BNLD not normalized

Dependent variable: country-sector labour productivity in levels (LP_t)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$log(LP)t-1$	0.791***	0.746***	0.722***	0.698***	0.776***	0.756***	0.708***	0.744***
	(0.014)	(0.021)	(0.022)	(0.021)	(0.018)	(0.016)	(0.021)	(0.017)
$BNLDt-1$	−0.029***	−0.033***	−0.036***	−0.034***	−0.032***	−0.027***	−0.029***	−0.032***
	(0.006)	(0.008)	(0.008)	(0.009)	(0.006)	(0.007)	(0.007)	(0.008)
$log(KE)t-1$		0.021***	0.021***	0.016**			0.016**	
		(0.006)	(0.006)	(0.007)			(0.007)	
$log(FD)t-1$			0.028**	0.023	0.02*			0.026*
			(0.013)	(0.021)	(0.011)			(0.015)
$log(W)t-1$				0.025		0.019*	0.041***	0.001
				(0.02)		(0.011)	(0.011)	(0.014)
Constant	1.291***	1.513***	1.444***	1.443***	1.236***	1.356***	1.428***	1.37***
	(0.08)	(0.12)	(0.123)	(0.106)	(0.08)	(0.092)	(0.106)	(0.09)
Observations	10742	7690	7690	6946	10742	7894	6946	7894
R-squared	0.87	0.863	0.864	0.871	0.871	0.87	0.87	0.87

Notes: Clustered standard errors in parentheses. All variables in log terms. Time dummies included, country-industry fixed effect. *, ** and ***denote significance level at 10%, 5% and 1%

C. Data details

See Tables 9, 10 and 11.

Table 9 List of the 15 manufacturing sectors in 2-digit ISIC Rev. 4 classification

Code	Manufacturing industry descriptions	Pavitt Class
C10-C12	Manufacture of food products, beverages and tobacco products	SD
C13-C15	Manufacture of textiles, wearing apparel and leather products	SD
C16	Manufacture of wood and of products of wood and cork, except furniture	SD
C20	Manufacture of chemicals and chemical products	SB
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	SB
C22	Manufacture of rubber and plastic products	SII
C23	Manufacture of other non-metallic mineral products	SII
C24	Manufacture of basic metals	SII
C25	Manufacture of fabricated metal products, except machinery and equipment	SD
C26	Manufacture of computer, electronic and optical products	SB
C27	Manufacture of electrical equipment	SS
C28	Manufacture of machinery and equipment n.e.c	SS
C29	Manufacture of motor vehicles, trailers and semi-trailers	SII
C30	Manufacture of other transport equipment	SS
C31-C33	Manufacturing nec; repair and installation of machinery and equipment	SD

Pavitt classes are: Science Based (SB), Specialized Suppliers (SS), Scale and Information Intensive (SII), and Suppliers Dominated (SD)

Table 10 List of the 61 countries used for the descriptive analysis

Country code	Country description
ARG	Argentina
AUS	Australia
AUT	Austria
BEL	Belgium
BGR	Bulgaria
BRA	Brazil
CAN	Canada
CHE	Switzerland
CHL	Chile
CHN	China
COL	Colombia
CRI	Costa Rica
CYP	Cyprus
CZE	Czechia
DEU	Germany
DNK	Denmark
EGY	Egypt
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HRV	Croatia
HUN	Hungary
IDN	Indonesia
IND	India
IRL	Ireland
ISL	Iceland
ISR	Israel
ITA	Italy
JPN	Japan
KAZ	Kazakhstan
KOR	Korea
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MEX	Mexico
MLT	Malta
MYS	Malaysia
NLD	Netherlands
NOR	Norway
NZL	New Zealand
PER	Peru
PHL	Philippines
POL	Poland
PRT	Portugal

Table 10 (continued)

Country code	Country description
ROU	Romania
RUS	Russia Federation
SAU	Saudi Arabia
SGP	Singapore
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
THA	Thailand
TUR	Türkiye
TWN	Taiwan, Province of China
UKR	Ukraine
USA	United States
VNM	Vietnam
ZAF	South Africa

Table 11 List of the 38 countries used for the econometric analysis

Country code	Country description
AUS	Australia
AUT	Austria
BEL	Belgium
CAN	Canada
CHE	Switzerland
CHL	Chile
COL	Colombia
CRI	Costa Rica
CZE	Czechia
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HUN	Hungary
IRL	Ireland
ISL	Iceland
ISR	Israel
ITA	Italy
JPN	Japan
KOR	Korea
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MEX	Mexico
NLD	Netherlands
NOR	Norway
NZL	New Zealand
POL	Poland
PRT	Portugal
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
TUR	Türkiye
USA	United States

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Data availability The data that support the findings of this study are available from the corresponding author [L.C.] upon reasonable request.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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References

Alford, M., & Phillips, N. (2018). The political economy of state governance in global production networks: Change, crisis and contestation in the South African fruit sector. *Review of International Political Economy,25*(1), 98–121.

Amiti, M., & Wei, S.-J. (2009). Service offshoring and productivity: Evidence from the US. *World Economy,32*(2), 203–220.

Andreoni, A. (2014). Structural learning: Embedding discoveries and the dynamics of production. *Structural Change and Economic Dynamics,29*, 58–74.

Andreoni, A., Chang, H.-J., & Estevez, I. (2021). The missing dimensions of the human capabilities approach: Collective and productive. *The European Journal of Development Research,33*(2), 179–205.

Andreoni, A., & Scazzieri, R. (2014). Triggers of change: Structural trajectories and production dynamics. *Cambridge Journal of Economics,38*(6), 1391–1408.

Baker, D., & Lee, T. M. (1993). *Employment multipliers in the US economy*. Economic Policy Institute.

Baldwin, R. (2013). Trade and industrialization after globalization's second unbundling: How building and joining a supply chain are different and why it matters. In *Globalization in an Age of Crisis: Multilateral Economic Cooperation in the Twenty-first Century*, pp. 165–212. University of Chicago 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., Freeman, R., & Theodorakopoulos, A. (2024). Deconstructing deglobalization: The Future of trade is in intermediate services. *Asian Economic Policy Review,19*, 18–37.

Baldwin, R., & Lopez-Gonzalez, J. (2015). Supply-chain trade: A portrait of global patterns and several testable hypotheses. *The World Economy,38*(11), 1682–1721.

Baldwin, R. E., & Taglioni, D. (2014). Gravity chains: Estimating bilateral trade flows when parts and components trade is important. *Journal of Banking & Financial Economics,2*(2), 61–82.

Bandick, R. (2020). Global sourcing, productivity and export intensity. *The World Economy,43*(3), 615–643.

Barrientos, S., Gereffi, G., & Rossi, A. (2011). Economic and social upgrading in global production networks: A new paradigm for a changing world. *International Labour Review,150*(3–4), 319–340.

Barrientos, S., Knorringa, P., Evers, B., Visser, M., & Opondo, M. (2016). Shifting regional dynamics of global value chains: Implications for economic and social upgrading in African horticulture. *Environment and Planning a: Economy and Space,48*(7), 1266–1283.

Battiati, C., Jona-Lasinio, C., and Sopranzetti, S. (2020). Productivity growth and global value chain participation in the digital age. Economic Statistics Centre of Excellence (ESCoE) Discussion Papers ESCoE DP-2020–04, Economic Statistics Centre of Excellence (ESCoE).

Bivens, J. (2003). Updated Employment Multipliers for the US Economy. Report, Economic Policy Institute, August.

Bivens, J. (2019). Updated Employment Multipliers for the US Economy. Report, Economic Policy Institute, August.

Blazek, J. (2016). Towards a typology of repositioning strategies of GVC/GPN suppliers: The case of functional upgrading and downgrading. *Journal of Economic Geography,16*(4), 849–869.

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.

Breschi, S., and Malerba, F. (1997). Sectoral innovation systems: Technological regimes, Schumpeterian dynamics, and spatial boundaries. In *Systems of Innovation: Technologies, Institutions and Organizations*, ed. C. Edquist, pp. 130–156. Routledge.

Cardinale, I. (2018). A bridge over troubled water: A structural political economy of vertical integration. *Structural Change and Economic Dynamics,46*, 172–179.

Cardinale, I., & Scazzieri, R. (2020). Interdipendenze produttive, interessi e condizioni sistemiche: Elementi per un'economia politica delle strutture industriali. *L'industria,41*(1), 21–50.

Cimoli, M., & Dosi, G. (1995). Technological paradigms, patterns of learning and development: An introductory roadmap. *Journal of Evolutionary Economics,5*(3), 243–268.

Cimoli, M., Dosi, G., & Stiglitz, J. E. (2009). *Industrial Policy and Development: The Political Economy of Capabilities Accumulation*. Oxford University Press.

Coe, N. M., & Yeung, H.W.-C. (2019). Global production networks: Mapping recent conceptual developments. *Journal of Economic Geography,19*(4), 775–801.

Constantinescu, C., Mattoo, A., & Ruta, M. (2019). Does vertical specialisation increase productivity? *The World Economy,42*(8), 2385–2402.

Costa, S., De Santis, S., Dosi, G., Monducci, R., Sbardella, A., & Virgillito, M. E. (2023). From organizational capabilities to corporate performances: at the roots of productivity slowdown. *Industrial and Corporate Change*, *32*(6), 1217–1244.

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

Cresti, L., and Virgillito, M. E. (2022). Strategic sectors and essential jobs: A new taxonomy based on employment multipliers. Technical report, Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies.

Cresti, L., Dosi, G., & Fagiolo, G. (2023). Technological interdependencies and employment changes in European industries. *Structural Change and Economic Dynamics,64*, 41–57.

Criscuolo, C., & Timmis, J. (2017). The relationship between global value chains and productivity. *International Productivity Monitor,32*, 61–83.

De Marchi, V., & Alford, M. (2022). State policies and upgrading in global value chains: A systematic literature review. *Journal of International Business Policy,5*(1), 88–111.

DeBresson, C. (1996). *Economic interdependence and innovative activity*. Edward Elgar Publishing.

Di Berardino, C. (2017). Structural transformation in manufacturing and the role of business services: Evidence from the Italian economy. *L'industria,38*(4), 495–516.

Doner, R. F. (1991). *Driving a Bargain: Automobile Industrialization and Japanese Firms in Southeast Asia,* (Vol. 23). University of California Press.

Dosi, G. (1982). Technological paradigms and technological trajectories. *Research Policy,2*(3), I47-62.

Dosi, G., Marsili, O., Orsenigo, L., & Salvatore, R. (1995). Learning, market selection and the evolution of industrial structures. *Small Business Economics,7*(6), 411–436.

Dosi, G., & Nelson, R. R. (2010). Technical change and industrial dynamics as evolutionary processes. *Handbook of the Economics of Innovation,1*, 51–127.

Dosi, G., Riccio, F., & Virgillito, M. E. (2021). Varieties of deindustrialization and patterns of diversification: Why microchips are not potato chips. *Structural Change and Economic Dynamics,57*, 182–202.

Dosi, G., & Tranchero, M. (2021). The role of comparative advantage, endowments, and technology in structural transformation. In N. Foster-McGregor, L. Alcorta, A. Szirmai, & B. Verspagen (Eds.), *New perspectives on structural change: Causes and consequences of structural change in the global economy* (pp. 442–472). Oxford University Press.

Dosi, G., Virgillito, M. E., & Yu, X. (2022). Gains from trade or from catching-up? Value creation and distribution in the era of China's WTO accession. *Eurasian Business Review,13*(1), 119–166.

Ernst, D. (2002). Global production networks and the changing geography of innovation systems: Implications for developing countries. *Economics of Innovation and New Technology,11*(6), 497–523.

Fana, M., & Villani, D. (2022). Decomposing the automotive supply chain: Employment, value added and occupational structure. *Structural Change and Economic Dynamics,62*, 407–419.

Feenstra, R. C., and Hanson, G. H. (1996). Globalization, Outsourcing, and Wage Inequality. NBER working papers, National Bureau of Economic Research, Inc.

Feenstra, R. C., & Hanson, G. H. (1999). The impact of outsourcing and high-technology capital on wages: Estimates for the United States, 1979–1990. *The Quarterly Journal of Economics,114*(3), 907–940.

Fernandez-Stark, K., Bamber, P., and Gereffi, G. (2014). Global value chains in Latin America: A development perspective for upgrading. In *Global Value Chains and World Trade: Prospects and Challenges for Latin America,* pp. 79–106, ed. Santiago: ECLAC, 2014. LC/G. 2617-P.
Formai, S., and Vergara Caffarelli, F. (2016). Quantifying the productivity effects of global sourcing. *Bank of Italy Temi di Discussione*. Working Paper, No. 1075.
Foster-McGregor, N., Poeschl, J., & Stehrer, R. (2016). Offshoring and the elasticity of labour demand. *Open Economies Review,27*(3), 515–540.
Foster-McGregor, N., Pöschl, J., & Stehrer, R. (2017). The importance of absorptive capacities: Productivity effects of international R&D spillovers through intermediate inputs. *Economics of Innovation and New Technology,26*(8), 719–733.
Franco, C., Montresor, S., & Marzetti, G. V. (2011). On indirect trade-related R&D spillovers: The 'average propagation length' of foreign R&D. *Structural Change and Economic Dynamics,22*(3), 227–237.
Fridell, G., & Walker, C. (2019). Social upgrading as market fantasy: The limits of global value chain integration. *Human Geography,12*(2), 1–17.
Garbellini, N., & Wirkierman, A. L. (2014). Blocks and circularity in labour requirements: An interplay between clusters and subsystems in the EU. *Structural Change and Economic Dynamics,28*, 60–74.
Gereffi, G., and Korzeniewicz, M. (1990). Commodity chains and footwear exports in the semiperiphery. In *Semiperipheral States in the World-economy*, pp. 45–68. Greenwood Press.
Gereffi, G. (1994). The international economy and economic development. In *The Handbook of Economic Sociology*, pp. 206–233. Princeton University Press.
Gereffi, G. (2005). The global economy: Organization, governance, and development. *In the Handbook of Economic Sociology,2*, 160–182.
Gereffi, G. (2014). Global value chains in a post-Washington Consensus world. *Review of International Political Economy,21*(1), 9–37.
Gereffi, G. (2018). *Global Value Chains and Development: Redefining the contours of 21st century capitalism*. Cambridge University Press.
Gereffi, G., & Korzeniewicz, M. (1994). *Commodity chains and global capitalism, No. 149*. Greenwood Press.
Giuliani, E., Pietrobelli, C., & Rabellotti, R. (2005). Upgrading in global value chains: Lessons from Latin American clusters. *World Development,33*(4), 549–573.
Gomez, M. C., Virgillito, M. E.. (2022). Wages and productivity in Argentinian manufacturing: A structuralist and distributional firm-level analysis. Technical report, Laboratory of Economics and Management (LEM).
Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading tasks: A simple theory of offshoring. *American Economic Review,98*(5), 1978–1997.
Guilhoto, J. M., Webb, C., and Yamano, N. (2022). Guide to OECD TiVA Indicators, 2021 edition. OECD Science, Technology and Industry Working Papers, OECD Publishing.
Guschanski, A., & Onaran, Ö. (2022). The decline in the wage share: Falling bargaining power of labour or technological progress? Industry-level evidence from the OECD. *Socio-Economic Review,20*(3), 1091–1124.
Hauknes, J., & Knell, M. (2009). Embodied knowledge and sectoral linkages: An input–output approach to the interaction of high-and low-tech industries. *Research Policy,38*(3), 459–469.
Henderson, J. (2002). *Globalisation of high technology production*. Routledge.
Henderson, J., Dicken, P., Hess, M., Coe, N., & Yeung, H.W.-C. (2002). Global production networks and the analysis of economic development. *Review of International Political Economy,9*(3), 436–464.
Hirschman, A. O. (1958). *The strategy of economic development*. Yale University Press.
Hopkins, T. K., and Wallerstein, I. (1977). Patterns of development of the modern world-system. *Review (Fernand Braudel Center)*, pp. 111–145.
Hopkins, T. K., & Wallerstein, I. (1986). Commodity chains in the world-economy prior to 1800. *Review (Fernand Braudel Center),10*(1), 157–170.
Hummels, D., Ishii, J., & Yi, K.-M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics,54*(1), 75–96.
Humphrey, J., & Schmitz, H. (2002). How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies,36*(9), 1017–1027.
Javorcik, B. S. (2015). Does FDI bring good jobs to host countries? *The World Bank Research Observer,30*(1), 74–94.
Jona-Lasinio, C., & Meliciani, V. (2019). Global value chains and productivity growth in advanced economies: Does intangible capital matter? *International Productivity Monitor,36*, 53–78.

Kalogeresis, A., & Labrianidis, L. (2010). Delocalization and development: Empirical findings from selected European countries. *Competition & Change,14*(2), 100–123.

Kaplinsky, R., & Morris, M. (2000). *A handbook for value chain research* (Vol. 113). University of Sussex.

Kaplinsky, R., & Readman, J. (2001). *How can SME producers serve global markets and sustain income growth?* University of Sussex and University of Brighton.

Koopman, R., Powers, W., Wang, Z., and Wei, S.-J. (2010). Give Credit where Credit is Due: Tracing Value Added in Global Production Chains. Technical report, National Bureau of Economic Research.

Koopman, R., Wang, Z., & Wei, S.-J. (2014). Tracing value-added and double counting in gross exports. *American Economic Review,104*(2), 459–494.

Kummritz, V. (2016). Do Global Value Chains Cause Industrial Development? Technical report, The Graduate Institute of International and Development Studies, Centre for Trade and Economic Integration.

Kvangraven, I. H. (2021). Beyond the stereotype: Restating the relevance of the dependency research programme. *Development and Change,52*(1), 76–112.

Landesmann, M. A., and Scazzieri, R. (1993). Commodity flows and productive subsystems: An essay in the analysis of structural change. In *The Dynamics of the Wealth of Nations*, pp. 209–245. Springer.

Landesmann, M., and Scazzieri, R. (1996). The production process: Description and analysis. In *Production and Economic Dynamics*, pp. 191–228. Cambridge University Press.

Lee, J., & Gereffi, G. (2015). Global value chains, rising power firms and economic and social upgrading. *Critical Perspectives on International Business,11*(3/4), 319–339.

Lee, K., Malerba, F., & Primi, A. (2020). The Fourth Industrial Revolution, changing global value chains and industrial upgrading in emerging economies. *Journal of Economic Policy Reform,23*(4), 359–370.

Lee, K., Szapiro, M., & Mao, Z. (2018). From Global Value Chains (GVC) to innovation systems for local value chains and knowledge creation. *The European Journal of Development Research,30*(3), 424–441.

Leoncini, R., & Montresor, S. (2003). *Technological systems and intersectoral innovation flows*. Edward Elgar Publishing.

Leontief, W. W. (1951). The Structure of American Economy, 1919–1939: An Empirical Application of Equilibrium Analysis. Technical report.

Los, B., & Timmer, M. P. (2018). *Measuring bilateral exports of value added: A unified framework (No. w24896)*. National Bureau of Economic Research.

Los, B., Timmer, M. P., & de Vries, G. J. (2015). How global are global value chains? A new approach to measure international fragmentation. *Journal of Regional Science,55*(1), 66–92.

Marcato, M. B., and Baltar, C. T. (2021). Economic upgrading in global value chains: Concepts and measures. *Revista brasileira de inova¸cao*, 19.

Marengo, L., & Sterlacchini, A. (1990). Intersectoral technology flows: Methodological aspects and empirical applications. *Metroeconomica,41*(1), 19–39.

Mayer, J. (2002). The fallacy of composition: A review of the literature. *World Economy,25*(6), 875–894.

Milberg, W., & Winkler, D. (2011). Economic and social upgrading in global production networks: Problems of theory and measurement. *International Labour Review,150*(3–4), 341–365.

Miller, R. E., & Blair, P. D. (2009). *Input-output analysis: Foundations and extensions*. Cambridge University Press.

Morrison, A., Pietrobelli, C., & Rabellotti, R. (2008). Global value chains and technological capabilities: A framework to study learning and innovation in developing countries. *Oxford Development Studies,36*(1), 39–58.

Nathan, D., and Sarkar, S. (2013). Innovation and Upgrading in Global Production Networks. Capturing the Gains Working Paper 23.

Neilson, J., Pritchard, B., & Yeung, H.W.-C. (2014). Global value chains and global production networks in the changing international political economy: An introduction. *Review of International Political Economy,21*(1), 1–8.

OECD (2013). *Interconnected Economies: Benefiting from Global Value Chains*.

Pahl, S., Timmer, M. P., Gouma, R., and Woltjer, P. (2019). Jobs in global value chains: New evidence for four African countries in international perspective. *World Bank Policy Research Working Paper*, (8953).

Pahl, S., & Timmer, M. P. (2020). Do global value chains enhance economic upgrading? A long view. *The Journal of Development Studies,56*(9), 1683–1705.

Pasinetti, L. L. (1973). The notion of vertical integration in economic analysis. *Metroeconomica,25*(1), 1–29.

Pasinetti, L. L. (1977). *Lectures on the theory of production*. Columbia University Press.

Pasinetti, L. L. (1981). *Structural change and economic growth: A theoretical essay on the dynamics of the wealth of nations*. Cambridge University Press.
Patel, P., & Pavitt, K. (1991). Large firms in the production of the world's technology: An important case of 'non-globalisation.' *Journal of International Business Studies,22*(1), 1–21.
Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy,13*(6), 343–373.
Pietrobelli, C., & Rabellotti, R. (2011). Global value chains meet innovation systems: Are there learning opportunities for developing countries? *World Development,39*(7), 1261–1269.
Pipkin, S., & Fuentes, A. (2017). Spurred to upgrade: A review of triggers and consequences of industrial upgrading in the Global Value Chain literature. *World Development,98*(C), 536–554.
Ponte, S., & Ewert, J. (2009). Which way is 'up' in upgrading? Trajectories of change in the value chain for South African wine. *World Development,37*(10), 1637–1650.
Ponte, S., Gereffi, G., & Raj-Reichert, G. (2019). *Handbook on global value chains*. Edward Elgar Publishing.
Prebisch, R. (1950). *The economic development of Latin America and its principal problems*. United Nations Publications.
Rasmussen, P. N. (1956). *Studies in Inter-sectoral Relations* (Vol. 15). E. Harck.
Riccio, F., Cresti, L., Virgillito, M. E. (2024). The labour share along global value chains perspectives and evidence from sectoral interdependence. *Review of World Economics*.
Rodrik, D. (1996). Coordination failures and government policy: A model with applications to East Asia and Eastern Europe. *Journal of International Economics,40*(1–2), 1–22.
Rosenberg, N. (1982). *Inside the black box: Technology and economics*. Cambridge University Press.
Santos, T. D. (1970). The structure of dependence. *The American Economic Review,60*(2), 231–236.
Scazzieri, R. (1990). Vertical integration in economic theory. *Journal of Post Keynesian Economics,13*(1), 20–46.
Scazzieri, R. (2014). A structural theory of increasing returns. *Structural Change and Economic Dynamics,29*, 75–88.
Selwyn, B. (2013). Social upgrading and labour in global production networks: A critique and an alternative conception. *Competition & Change,17*(1), 75–90.
Selwyn, B. (2015). Commodity chains, creative destruction and global inequality: A class analysis. *Journal of Economic Geography,15*(2), 253–274.
Selwyn, B., & Leyden, D. (2022). Oligopoly-driven development: The world bank's trading for development in the age of global value chains in perspective. *Competition & Change,26*(2), 174–196.
Sethupathy, G. (2013). Offshoring, wages, and employment: Theory and evidence. *European Economic Review,62*, 73–97.
Shepherd, B. (2015). Global value chains, technology transfers and innovation. *Asia-Pacific Trade and Investment Report,2015*, 147–161.
Stöllinger, R. (2021). Testing the smile curve: Functional specialisation and value creation in GVCs. *Structural Change and Economic Dynamics,56*, 93–116.
Suwandi, I. (2019). *Value chains: the new economic imperialism*. Monthly Review Press.
Taalbi, J. (2020). Evolution and structure of technological systems: An innovation output network. *Research Policy,49*(8), 104010.
Taglioni, D., & Winkler, D. (2016). *Making global value chains work for development*. World Bank Publications.
Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & De Vries, G. J. (2015). An illustrated user guide to the world input–output database: The case of global automotive production. *Review of International Economics,23*(3), 575–605.
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*(2), 99–118.
Timmer, M. P., Miroudot, S., & de Vries, G. J. (2019). Functional specialisation in trade. *Journal of Economic Geography,19*(1), 1–30.
UNIDO (2015). *Global value chains and development: UNIDO's support towards inclusive and sustainable industrial development*. United Nations Vienna.
Wallerstein, I. (1974). *The modern world-system: Capitalist agriculture and the origins of the european world-economy in the sixteenth century*. University of California Press.
Wallerstein, I. (2004). *World-systems analysis*. Duke University Press.
Winkler, D. (2010). Services offshoring and its impact on productivity and employment: Evidence from Germany, 1995–2006. *The World Economy,33*(12), 1672–1701.

Wirkierman, A. L. (2022). Productivity homogenisation trends of six advanced industrial economies: A vertically hyper-integrated approach. *Structural Change and Economic Dynamics,61*, 495–511.
World Development Report (2020). Trading for Development in the Age of Global Value Chains. Technical Report, The World Bank, Washington, DC.
Ye, M., Meng, B., Wei, S.-J., et al. (2015). Measuring smile curves in global value chains. *Oxford Bulletin of Economics and Statistics,82*(5), 988–1016.

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