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

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

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Abstract

Focusing on labour requirements incorporated into GVCs, in the following, we develop a novel, non conventional measure of learning capabilities, represented by knowledge embodied along the division of labour within global production networks. In order to capture the division of labour, and the ensuing division of embodied knowledge, we move from monetary flows of production, or value-added embodied, to labour embodied in the I-O linkages. We focus on mature economies as offshoring has been particularly in place there. After constructing a new indicator of *Bilateral Net Labour Dependence*, we estimate its relationship with a measure of performance of industries, namely, labour productivity, seeking to challenge the established findings generally reporting a positive effect of GVCs participation for sector-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 the loosing productive structure. We corroborate the conjecture with a panel analysis of OECD countries and industries for the time period 2000-2014.

Keywords: input-output, global value chains, international division of labour, dependency theory
JEL classification codes: F16, F6, J24, L6, O14

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1 Introduction

In the last three decades economies have witnessed an increasing process of relocation abroad of productive activities, often from mature to developing and emerging countries. This phenomenon - to be addressed within the broader global fragmentation of production and the rise of the so-called Global Value Chains (GVCs) (Gereffi, 2014; Baldwin, 2013; Ponte et al., 2019) or Global Production Networks (GPNs) (Henderson et al., 2002; Neilson et al., 2014; Coe and Yeung, 2019) - has had profound impacts on the economic structure in terms of employment, incomes, innovation and capabilities development. The possible detrimental outcomes for an economy due to increasing delocalization of inputs - often defined as offshoring or global sourcing - have found limited place in the research agenda. Scholars have largely focused on investigating the benefits of reducing costs and increasing efficiency due to offshoring, often with a firm-level perspective. Within the broader concept of economic *upgrading*, which refers to the possibility for firms, regions or countries to move into higher value-added stages or to make better products or more efficiently, eventually triggering spillovers for productivity and innovation, the literature has focused on *economic upgrading* defined as the general economic gain from participating in GVCs (Kaplinsky and Morris, 2000; Gereffi, 2005; Giuliani et al., 2005; OECD, 2013; Marcato and Baltar, 2021). Recently, scholars in GVCs literature have started addressing also the *social* dimension of upgrading which relates to the impact on employment, wages, working conditions, workers' rights (Selwyn, 2013; Lee and Gereffi, 2015).

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. The conventional wisdom identifies 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) or *entry into a GVC by a new actor* (Fernandez-Stark et al., 2014) and *end-marketing upgrading*. Marcato and Baltar (2021), describing different forms of upgrading, point out that, particularly the end-market scope reveals a naive notion of upgrading rooted in the idea of higher rooms of appropriations of products' value via GVCs participation. The very same view is also shared by the so-called smile-curve climbing, according to which a strategic participation into GVCs would imply moving away from assembly production stages, given the low value added, toward pre- (R&D, design) or post- (branding, marketing) production activities (Baldwin, 2013; Ye et al., 2015).

Although various scholars emphasise that economic upgrading through GVCs participation is not to be taken for granted, a general optimistic view seems to prevail, according to which participating into GVCs is eventually inducing productivity enhancement. For instance, there is increasing evidence on the positive relationship between proxies of offshoring activity - i.e. measure of GVCs participation from backward linkages perspective - and the performance (i.e., usually productivity) of sectors and countries (Amiti and Wei, 2009; Winkler, 2010; Kummritz, 2016; Constantinescu et al., 2019).

The extant literature, however, tends to neglect that GVCs benefits are hardly automatic and, in order to acquire advantages from a participation into GVCs, actors (firms, sectors, countries) require capabilities development and accumulation, and primarily *ability to learn* in order to achieve economic upgrading and boost productivity (Dosi et al., 1995; Kaplinsky and Readman, 2001; Giuliani et al., 2005; Nathan and Sarkar, 2013).

Measuring learning capabilities is all but an easy task, even more so when studying GVCs. A good candidate, poorly empirically explored, is the amount of labour incorporated into production activities. Labour is the most crucial input for production as it embodies know-how and tacit knowledge to produce ensuing artifacts. Indeed, if anything, the ability to learn inside productive units occurs at the labour process level, and labour requirements are not only a proxy for the amount of units of hours of work necessary to produce a final unit of output, but they also represent the underlying knowledge incorporated into the latter. In addition, the production chain perspective expands the labour process in a given establishment/sector 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. With reference to manufacturing of electronic chips relocated in Asia, 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. '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 and Sarkar (2013)).

So far, the literature has addressed mainly innovation-related kinds of embodiment, as the measures of R&D embodied in I-O linkages (Marengo and Sterlacchini, 1990; Leoncini and Montresor, 2003; Hauknes and Knell, 2009; Franco et al., 2011; Taalbi, 2020; Cresti et al., 2023). The importance of absorptive capacities for capturing the benefits from technology diffusion is stressed also in the specific stream of research on inter-sectoral knowledge diffusion (see DeBresson, 1996; Foster-McGregor et al., 2017). Whenever labour is offshored, the underlying productive capabilities get inevitably lost. This is clearly linked with a changing geography of production, with some geographical areas that substantially lost manufacturing activities and together with them also the manufacturing capabilities gathered by the workforce and by the organizations therein.

Focusing on labour requirements incorporated into GVCs, in the following, we develop a novel, non conventional measure of learning capabilities, represented by knowledge embodied along the division of labour within global production networks. In order to capture the division of labour, and the ensuing division of embodied knowledge, we move from monetary flows of production, or value-added embodied, to labour embodied in the I-O linkages. We focus on mature economies as offshoring has been particularly in place there. After constructing a new indicator of *Bilateral Net Labour Dependence* (BNLD hereafter), we estimate its relationship with a measure of performance of industries, namely, labour productivity, seeking to challenge the established findings generally reporting a positive effect of GVCs participation for sector-level productivity (Formai and Vergara Caffarelli, 2016; Taglioni and Winkler, 2016; Criscuolo and Timmis, 2017; Jona-Lasinio and Meliciani, 2019; Constantinescu et al., 2019; Pahl and Timmer, 2020; Battiati et al., 2020). 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 loosing productive structure. We test this conjecture with a panel analysis of OECD countries and industries for the time period 2000-2014.

We thus aim to bridge the dependency theory and the capability-based theory of economic development with the literature on GVCs participation, by investigating the relationship between the positioning of sectors with respect to the international division of labour and the ensuing impact upon their economic performance. 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 brings about are, first, contributing to the productivity-GVCs participation nexus by investigating the unexplored dimension of *positioning* in the international division of labour; second, taking into account *bilateral* interdependencies and structured links between countries rather than addressing whole chains; third, empirically operationalizing the concept of *collective knowledge* embedded into the workforce and distributed along stages of production; fourth, shedding light on the possible detrimental outcomes, especially for *mature economies*, of massive process of labour offshoring and related weakening of industrial capabilities.[1]

[1] The notion of weak ties we employ is somewhat different from the one puts forward by Granovetter (1973).

The paper is structured as follows: in section 2 we critically review the state-of-the-art of the empirical literature on GVCs participation - measured by Input-Output tables - and the relationship with labour productivity. In section 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 employment multipliers matrices, which represent the main source of information to construct our indicator. In section 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 section 7 lays out our concluding remarks and future lines of research.

2 The benefits of GVCs participation: the state-of-the-art and what is left aside

Although several quantitative measures of economic upgrading have been proposed by the literature (see Milberg and Winkler, 2011; Marcato and Baltar, 2021), the stream of research adopting input-output tables to compute measures of participation in GVCs has been largely focusing on effects upon productivity as a proxy of performance of countries and sectors. Such literature has commonly found positive effects of the so-called GVCs participation on labour productivity (Formai and Vergara Caffarelli, 2016; Taglioni and Winkler, 2016; Criscuolo and Timmis, 2017; Jona-Lasinio and Meliciani, 2019; Constantinescu et al., 2019; Pahl and Timmer, 2020; Battiati et al., 2020). 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' one 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, technologies thus fostering production upgrading, and in that, facilitating gains from specialization (Battiati et al., 2020).

In particular, the backward indicator, computed by applying the trade-in-value added approach

However, we deem the reference to weak ties appropriate since our indicator synthetically incorporates knowledge flows inside a network structure, and in that, not so distant from the literature on social network analysis. In addition, the notion of the weakness of ties in our paper refers to being a dominant (net supplier) rather than a dependent (net demanding) sector in the international division of labour.

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 largely used to assess the positive link with productivity (see in particular Amiti and Wei, 2009; Winkler, 2010; Kummritz, 2016; Constantinescu et al., 2019). In a nutshell, offshoring segments of the production process results in productivity benefits and this is motivated by a wide spectrum of arguments that often falls under the broader phenomenon of technology transfer and knowledge spillovers: learning-by-exporting, learning-by-supplying, training by lead firms, imitation and reverse engineering. In this respect, scholars mainly refer to (*forward linkages*) type of participation driven by lead firms and generating positive outcomes for learning and development potential of supplier firms and territories, particularly in the context of developing economies (Gereffi, 2018; De Marchi and Alford, 2022).

The theoretical explanation resembles the one puts forward by the related literature on FDI spillovers that 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 more access to better-quality or more diverse inputs (also called *supply effect*) and at lower cost (also called *price effect*), the latter 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 define *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 upgrading of productive capabilities. However, the authors also stress that true benefits arise if a proper absorptive capacity of domestic actors is built through investments to upgrade technical capacity.

In parallel to these results, the literature also partially acknowledged that benefits from GVCs participation are not deterministic and are heavily dependent on strategic interests of lead firms, absorptive capacity of a given industrial system and its technological endowment, the institutional context therein and asymmetric relations between countries located in different hierarchical positions or between multinational and local firms (Kaplinsky and Readman, 2001; Morrison et al., 2008; Pietrobelli and Rabellotti, 2011; Nathan and Sarkar, 2013; OECD, 2013; on Trade and Development, 2013; Selwyn, 2015; Shepherd, 2015; UNIDO, 2015; Barrientos et al., 2016; Fridell and Walker, 2019; Bandick, 2020).

Having said that, a series of criticisms applies to this literature. First of all, the fallacy of aggregation. In fact, the motivations put forward for the benefits of participating into GVCs appear somewhat generic and often appropriate only for a firm-level perspective, while, on the contrary, 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 this broad level of aggregation, offshoring segments of productive activities could entail in the aggregate a completely different composition effect rather than the purported static and dynamic spillovers, producing coordination failures. For instance, the shutting down of entire factories operated by chunks of industrial activities is not necessarily connected with strategic relocation of less efficient tasks at the industry level, although some specific firms could individually put in place this strategy.

Second, the undervaluation of the role of positioning in the chain. While for multinational companies gains are more credible, strategies to move toward higher value-added activities, outsourcing labour intensive tasks, and increasing value capture and learning opportunities are not equally accessible for other non-multinational firms. Aggregating at the industry level, 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, asymmetric positioning, for instance between global lead firms and their fragmented supplier base, or directly between countries and sectors (Ponte and Ewert, 2009; Blažek, 2016; Alford and Phillips, 2018; Selwyn and Leyden, 2022), are completely neglected by leading policy reports as the World Bank's 2020 World Development Report (World Development Report, 2020). Broadly speaking, the benefits pointed out by the literature erroneously fall again under the realm of the comparative advantage trade theory (Dosi and Tranchero, 2021; Dosi et al., 2022) claiming for *mutual gains* for suppliers and headquarter firms thanks to specialization in complementary activities. Therefore, GVCs represent an other opportunity of cost minimization and expand the possibility of better specialization in different stages of production. Countries, in line with prediction of neoclassical trade theory, should exploit their comparative advantages, given their factor endowments, not only in different sectors but also in different stages of production within sectors (World Development Report, 2020; Grossman and Rossi-Hansberg, 2008). 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 of given artifacts is left aside from the mainstream analysis of benefits from GVCs.

Third, the conventional approach does not put relevance on persistent, *bilateral* trade flows. Indeed, in *global* value chains, *bilateral* (country-by-country) international trade is extremely relevant and exchange are not equal across all countries/sectors. For example, Italy is vertically integrated with Germany, Germany with Visegrad countries, the US with Mexico. The GVCs literature is dramatically falling short on this aspect, considering that GVCs indicators are generally about participation rather than positioning.

Fourth, to our knowledge, this stream of research has focused only on pure productive dimension of GVCs participation, measured in monetary value of production or in the well established Trade in value-added (TiVA) statistics, even though in the broader literature of GVCs some scholars 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 (Garbellini and Wirkierman, 2014; Baldwin and Lopez-Gonzalez, 2015; Foster-McGregor et al., 2016; Pahl et al., 2019; Bontadini et al., 2022; Fana and Villani, 2022; Wirkierman, 2022; Cresti and Virgillito, 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 characterise the notion of embodied knowledge in labour requirements along GVCs, we build upon two well known streams of research. First of all, the Pasinettian structuralist tradition (Pasinetti, 1981; Scazzieri, 1990; Landesmann and Scazzieri, 1996; Andreoni and Scazzieri, 2014; Scazzieri, 2014; Cardinale and Scazzieri, 2020) 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 overcoming the traditional boundaries of sectors 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 workers therein, belonging to various sectors and countries. With the upsurge of globalization, such interdependencies have become increasingly global and constitute now international supply chains whose weights (the contribution of each country-industry) are constantly changing in size, reflecting changing importance of branches and economies. This disproportionate dynamics is at the core also of the international division of labour that led manufacturing activity - and now also services (Baldwin and Freeman, 2021) - to be spatially and vertically fragmented.

Such process has been driven mainly 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 (Dosi, 1982; Pavitt, 1984; Breschi and Malerba, 1997). Indeed, sectors have different learning patterns and innovation sources. Therefore, also every chain is composed by 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 good extent embodied in the organizational routines and in the 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 all its multifaceted nature - is embodied also 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) (Rosenberg, 1982; Dosi and Nelson, 2010; Andreoni, 2014). Considering labour as a generic productive factor, neglecting its (cumulative) knowledge content and the *socially embedded* dimension of capabilities (Barrientos et al., 2011; Andreoni et al., 2021) results in missing a crucial element to understand 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 strategic motivations for relocating production abroad or to pure technical progress making the sector more capital intensive (and thus less labour intensive). On the contrary, reduced workforce in a sector in favor of labour inputs coming from abroad often is related to entire factories closing, thus loosing employment and productive capacity, causing social costs. Indeed, the workforce employed in a given sector is the repository of *tacit collective knowledge*, person-embodied rather than information-embodied (Patel and 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 result to be not only commodity chains but also *labour-value chains* (Suwandi, 2019), to better frame the *positioning* in the international division of labour we rely on two further approaches. First, the core-periphery notion of dependency theory (Prebisch, 1950; Gereffi, 1994), linked with the aforementioned structuralist perspective, actually a forerunner of the global commodity chains studies emerged in the mid-1990s (Gereffi and Korzeniewicz, 1994) and of the more recent global value chains literature (Ponte et al., 2019). Dependency theory has the pros of studying economic development from both the perspective of external constraints and of internal structure of production, including social and political spheres (Santos, 1970; Kvangraven, 2021). The interest towards the internal structure of production is shared by the structuralist perspective (Hirschman, 1958; Prebisch, 1950; Cimoli and Dosi, 1995) recently focusing on the role of weakening of technological capacity, bad employment and sectoral specialization to explain economic downgrading (Dosi et al., 2021; Gomez et al., 2022).

Although dependency theory had (Latin America's) developing countries as object of analysis - highlighting for instance the dependence of the *periphery* from the strategic choices of the *centre* - we seek to apply these insights to the current state of dependence from foreign labour, and knowledge incorporated, common to many mature economies largely featuring deindustrialization and manufacturing offshoring. For our approach it is a useful theoretical underpinning insofar 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 (Wallerstein, 1974; Hopkins and Wallerstein, 1977, 1986; Wallerstein, 2004; Henderson, 2002; Gereffi and Korzeniewicz, 1990; Doner et al., 1991) 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 dramatically so far from the second wave of globalization studies (Selwyn and Leyden, 2022). In Gereffi (1994, p. 214)'s words, 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 resulting in the limited possibilities for 'autonomous paths of development'. These last two approaches are useful in better framing the concepts of labour dependence and asymmetric positioning and bridging them with the GVCs concepts of headquarter and factory economies (Baldwin, 2013; Baldwin and Lopez-Gonzalez, 2015; Stöllinger, 2021).

Differently from the standard object of investigation of dependency theory, we focus not on the dependent position of developing countries but rather on the one of mature economies in which processes of deindustrialization and offshoring of manufacturing activities are resulting in weakening the performances in terms of productive and technological capacities. As a result, at the core of our analysis there will be the construction of a new indicator that we label *Bilateral Net Labour Dependence*. *Bilateral* because we emphasise the country-by-country trade relationships; *Net* in the spirit of GVCs positioning measures (Koopman et al., 2010; Baldwin and Freeman, 2021) that compare *backward* and *forward* linkages information; *Labour dependence* because we look at offshoring of labour which in our conjecture is an offshoring of the embodied knowledge in the workforce resulting therefore in dissipated productive capabilities.

4 Methodology: from employment multipliers matrices to BNLD indicator

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

Although poorly acknowledged, 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 (Pasinetti, 1973, 1977; Scazzieri, 1990; Landesmann and Scazzieri, 1993, 1996; Di Berardino, 2017; Cardinale, 2018). The idea behind the concept of vertically integrated sectors is that of the existence of sequential stages of the production process, that 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 *subsystem* or *vertically integrated sector*.[2]

Vertically integrated sectors can be calculated from input-output data and can be used to reclassify a sector 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 and Lee, 1993; Bivens, 2003; Miller and Blair, 2009; Bivens, 2019; Cresti and Virgillito, 2022), 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 to 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.[3]

4.1 Data

We take symmetric industry-by-industry Input-Output tables $\boldsymbol{Z}$ from the World Input-Output Database (WIOD) (Timmer et al., 2015), which includes also the Socio and Economic Account (SEA) dataset providing variables at two-digit level of aggregation (NACE Rev. 2 classification) as employment, value added, gross fixed capital formation, labour compensation and so on. WIOD (2016 Release) is available for the period 2000-2014, for 43 countries (plus one Rest of the World) and 56 sectors. We use the number of persons engaged as employment variable, l, to construct a global employment multipliers matrix, from which we exclude RoW (Rest of the World) as SEA does not contain available information on sectoral variables of interest as employment. We end up with a 2408x2408 matrix.[4]

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

[3] 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 it is the case for World Input-Output Tables. As a result, in the Leontief inverse framework, one-unit of final demand stands for one million US dollars.

[4] Rows and columns corresponding to the Rest of the World country are removed *after* the Leontief Inverse matrix is computed, just *before* the pre-multiplication by the diagonalized vector of employment.

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 $\hat{x}$[5]:

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

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:

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

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

$$\tag{4}$$

Solving by x yields:

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

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

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

$$\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \tag{7}$$

With $\boldsymbol{I}$ representing the identity matrix and assuming that the inverse of $(\boldsymbol{I} - \boldsymbol{A})$ exists. Considering N industries with $i, j = 1, ..., N$, 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 stands exactly for 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

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

by other sectors to produce in turn the intermediaries then provided to the same sector j. Such matrix allows the construction of the matrix of direct and indirect contributions of labour of each sector to produce the goods in the economy activated by one more unit of final good:

$$\boldsymbol{E} = \hat{l}\,\hat{x}^{-1}\,\boldsymbol{L} \tag{8}$$

Where $\hat{l}$ is the diagonal matrix of sectoral employment which, divided by $\hat{x}$, 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 subsystem - by a fixed amount of final demand (in our case 1 mn USD). $\boldsymbol{E}$ is a 2408x2408 country-industry x country-subsystem matrix (56 economic branches by 43 countries), built for every year from 2000 to 2014. By summing over columns (rows) we get the so-called forward (backward) linkages indicators expressing how much a sector is important 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:

$$\boldsymbol{m}(e)^{Backward} = i'\,\boldsymbol{E} \qquad \boldsymbol{m}(e)^{Forward} = \boldsymbol{E}\,i$$

Or, in alternative notation:

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

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.[6] 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

[6] Among manufacturing branches, we exclude only Coke, refined petroleum products (C19 code) as it is highly subject to price dynamics.

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 Italian automotive sector *provided* (i.e. embodied in the intermediaries sold) to German subsystems.

Given H (J) the number of manufacturing industries (subsystems), we define the total sectoral level backward and forward bilateral measures as:[7]

$$\text{Backward Bilateral}_i = \sum_{h=1}^{H} e_h \tag{9}$$

$$\text{Forward Bilateral}_i = \sum_{j=1}^{J} e_j \tag{10}$$

Merging these two information we obtain a measure of GVCs positioning (in the spirit of Koopman et al. (2010) and Baldwin and Freeman (2021)), which combines - as a ratio - backward and forward linkages, for every bilateral trade between industry/subsystem i in country c and country k:

$$\text{GVCs positioning}_{i,c;k} = \frac{\text{backward bilateral}}{\text{forward bilateral}} = \frac{\sum_{h=1}^{H} e_h}{\sum_{j=1}^{J} e_j} \tag{11}$$

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 to 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:

$$\text{BNLD}_{i,c} = \ln\left(\sum_{k=1}^{n-1} \text{GVCs positioning}_{i,c;k}\right) \tag{12}$$

[7] With *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.

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

This measure incorporates all specific bilateral GVCs positioning in the international division of labour, determined by the matrices of employment multipliers. BNLD accounts for the *net* dependence from 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 it 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 from foreign labour, that is labour not related to activity performed within the national boundaries.

4.3 BNLD vs standard TiVA indicators

The main differences between BNLD and already established GVCs participation measures - as the ones belonging to the galaxy of OECD TiVA statistics (Guilhoto et al., 2022) - are summarised in Table 1. In short:

1. BNLD takes into account labour required in I-O linkages, what we assume being collective knowledge embedded in the workforce, while GVCs participation indexes account mainly 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 usually GVCs participation takes into account effective domestic or foreign exports;

3. BNLD is constructed in the spirit of GVCs *positioning* measures which are often meant as comparisons between forward and backward linkages (sometimes referred to basic upstreamness and downstreamness measures), while in assessing the effect on productivity the literature has used the two indicators separately;

4. BNLD is an enrichment of standard *positioning* indexes as it takes into account *bilateral*, and not overall, linkages between each pair of country-sector for every backward and forward component.

Categories	TiVA-type indicator	BNLD indicator
Variable	Value-added embodied in I-O linkages	Labour (and knowledge) embodied in I-O linkages
Final demand	Included (usually as export components)	Excluded (Employment multipliers)
Structure of relations	*Participation* index: absolute, backward or forward separately	*Positioning* index: relative, backward versus forward
Geography	Total global chain	Country-by-country bilateral interdependencies

Table 1: Differences between TiVA type indicator and BNLD indicator.

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

Before investigating cross-sectional and time dimensions of BNLD, we start presenting the geography of production and unequal exchange emerging from the underlying sources of our indicator. We map backward and forward bilateral linkages, taking automotive final production in Italy in 2014 as an example (i.e. we look at the bilateral flows along column and row dimensions). Figure 1 shows the amount of labour inputs Italian automotive requires from various countries in the world (column/subsystem perspective). In contrast, Figure 3 shows the amount of labour that Italian automotive delivers as input to the final productions of various countries in the world (row/industry perspective). We present a specific focus on European countries (see Figures 2 and 4). The two supply and demand perspectives emerge clearly as China and India, for instance, are delivering considerable amount of labour to Italian automotive which in turn provides its labour mainly to European countries, especially eastern ones and Spain. This exercise could be repeated for every country-subsystem and every year from 2000 to 2014. In the appendix we replicate the exercise for the automotive sectors of Germany, the US and China. From the different intensity of the indicators of labour supplied/demanded by the Italian automotive industry compared to other countries, it clearly emerges the importance of taking into account bilateral production exchange and not simply considering the entire flow. The specific bilateral relationships signal the relevance of considering position rather than sheer participation of industries into GVCs. In addition, such relationships are not random and/or equally important but are rather specific, persistent, in a way structured, and in that they allow to consider preferential attachment schemes between countries.

We now turn to our main indicator. Figure 5 shows the density distribution of BNLD in 2014,

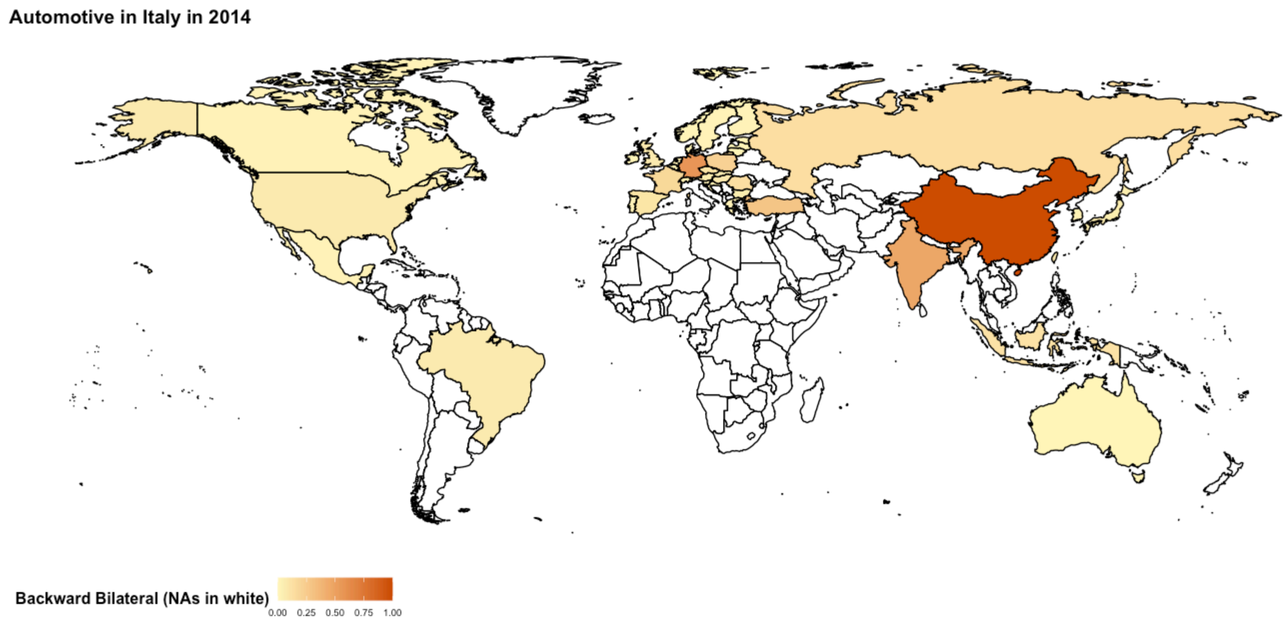

Figure 1: Backward Bilateral: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of Italian automotive subsystem.

with values normalized between 0 and 1. Our measure, after a logarithmic transformation, is well centered around the mean value, with a unimodal distribution.

Then, we move to the value chain dimension. We plot the ranking for the top 20 country-subsystem, in 2014 (Figure 6).[8] 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 (as Cyprus, Estonia, Ireland, Luxembourg, Malta). These countries register a considerable magnitude in Bilateral Net Labour Dependence, thus importing lots of inputs from abroad that embody labour. Conversely, Figure 7 lists the 20 country-subsystems at the bottom of the ranking in 2014. Several Chinese sectors are present, together with one from Russia, one from Indonesia and some others from India. These are big countries with labour intensive activities likely supplying smaller advanced economies. This evidence could help highlighting possible outliers, or at least extreme values, which could be useful to exclude from econometric estimation.

In Figures 8 and 9 we show the ranking within four countries of interest (China, Germany, Italy and the US) and values normalized in [0,1]. Here, we account for the Pavitt class of belonging

[8]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.

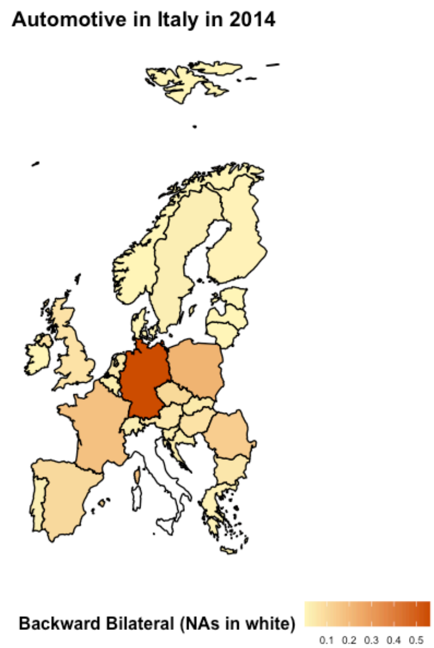

Figure 2: Backward Bilateral: employees activated in 2014 in the European countries in order to produce 1 mn USD of final commodity of Italian automotive subsystem.

in order to detect the technological dimension of bilateral net labour dependence. The Pavitt Taxonomy (Pavitt, 1984) is a sectoral classification that allows to collect productive sectors in four classes characterized by different technological attributes, by various internal learning processes and, one could argue, by heterogeneous positioning along value chains. Such taxonomy is distinguished into:

- Science Based firms (e.g. Pharmaceutical), whose technological progresses are strongly linked to those of basic and applied research.

- Specialised 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 (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 production of basic materials, services and consumer durables.

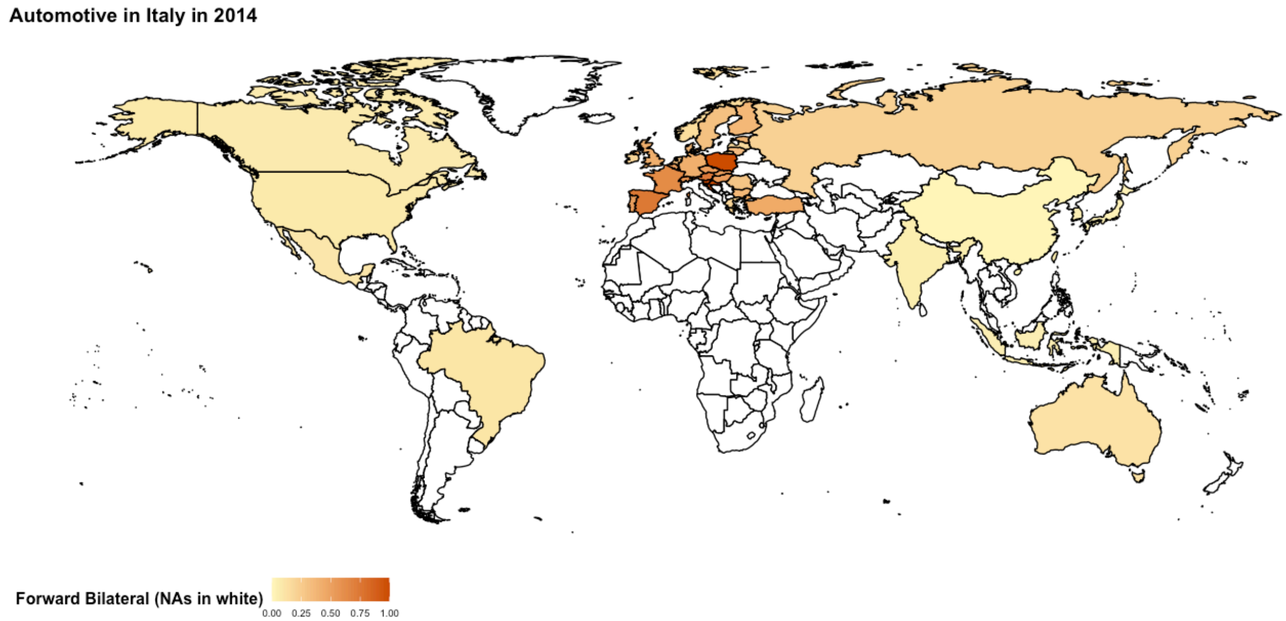

Figure 3: Forward Bilateral: employees provided in 2014 to the (43-1) WIOD countries by Italian automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

- Suppliers Dominated firms (e.g. Textile), typical of traditional manufacturing industries in which innovation and learning depend from intermediate and capital goods purchased from other sectors.

In Figure 9, by looking at the BNLD multiplier ranking for Italian subsystems, we detect a more prominent role for upstream Pavitt classes (SB and SS) with respect to other countries. This reveals a weak positioning in the international division of labour also in terms of strategic high-tech productions and it is in line with recent findings on Italy employing total foreign employment multipliers (Cresti and Virgillito, 2022).

Thirdly, we present time trends of BNLD values for Pharmaceutical (Figure 10) and Automotive (Figure 11) industries in the usual four selected countries (China, Germany, Italy and the US). We focus on Pharmaceutical and Automotive as they have shown a considerable size effect in supply chains considering their fragmentation of production. BNLD presents a general increasing trend in all countries, excluding China, the factory of the world at that time, hence a positive dynamics for Bilateral Net Labour Dependence. Time trends allow to assess whether a country in a given sector has become more or less net dependent from foreign labour. In Table A in the appendix we compute changes in BNLD (2000-2014).

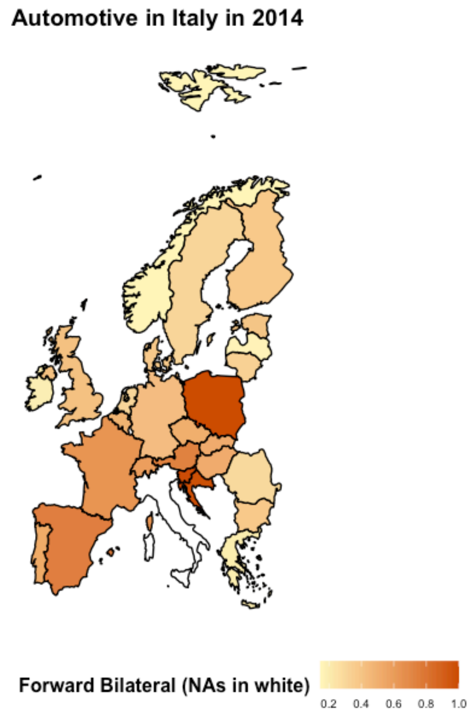

Figure 4: Forward Bilateral: employees provided in 2014 to the European countries by Italian automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

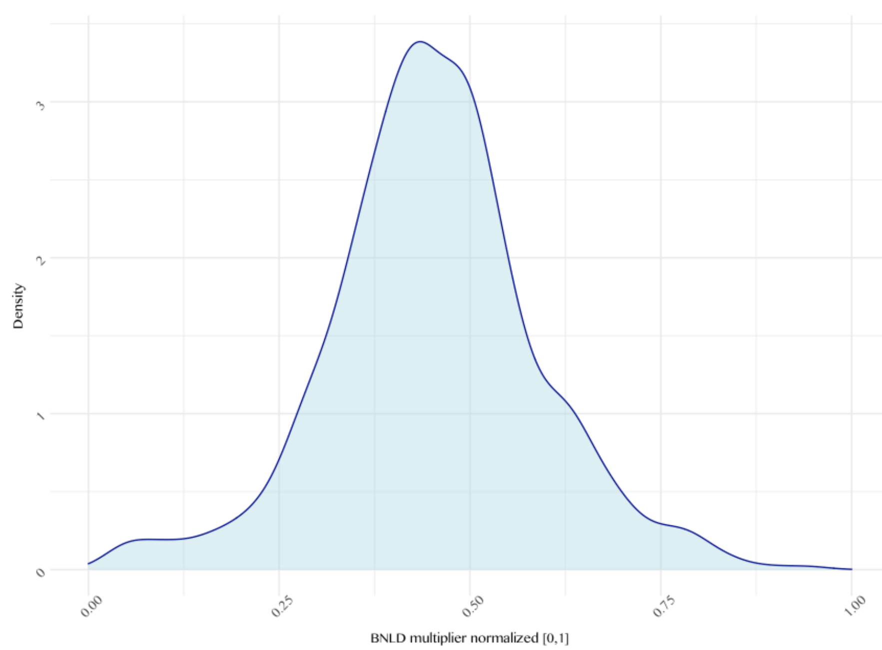

Figure 5: BNLD density distribution in 2014 for BNLD normalized in [0,1] range.

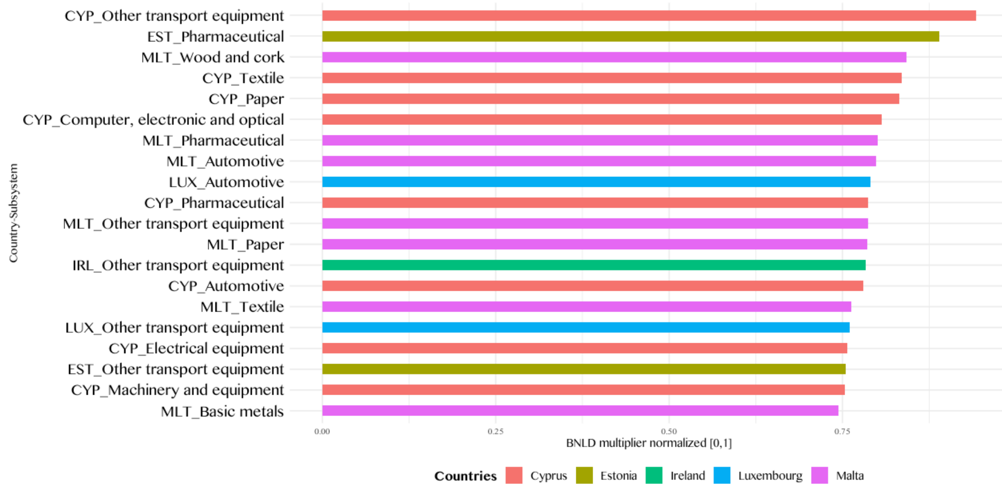

Figure 6: Top 20 country-subsystem in 2014 for BNLD normalized in [0,1]

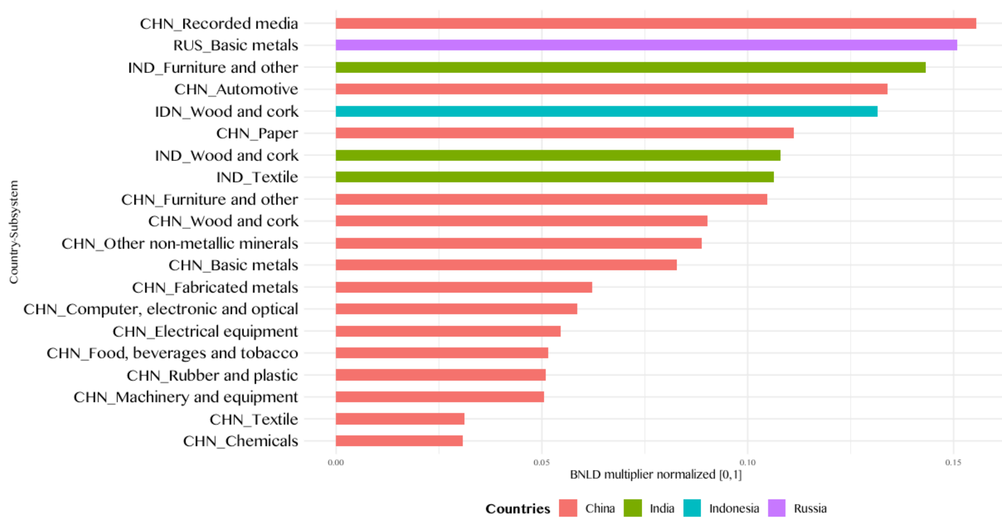

Figure 7: Bottom 20 country-subsystem in 2014 for BNLD normalized in [0,1]

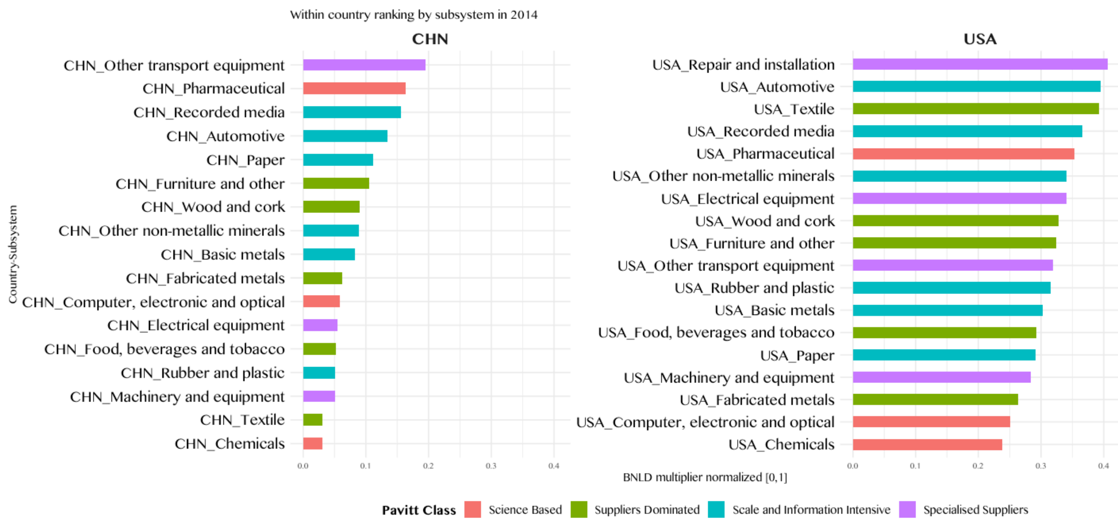

Figure 8: Ranking in BNLD normalized in [0,1] in China (CHN) and the US (USA). Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD).

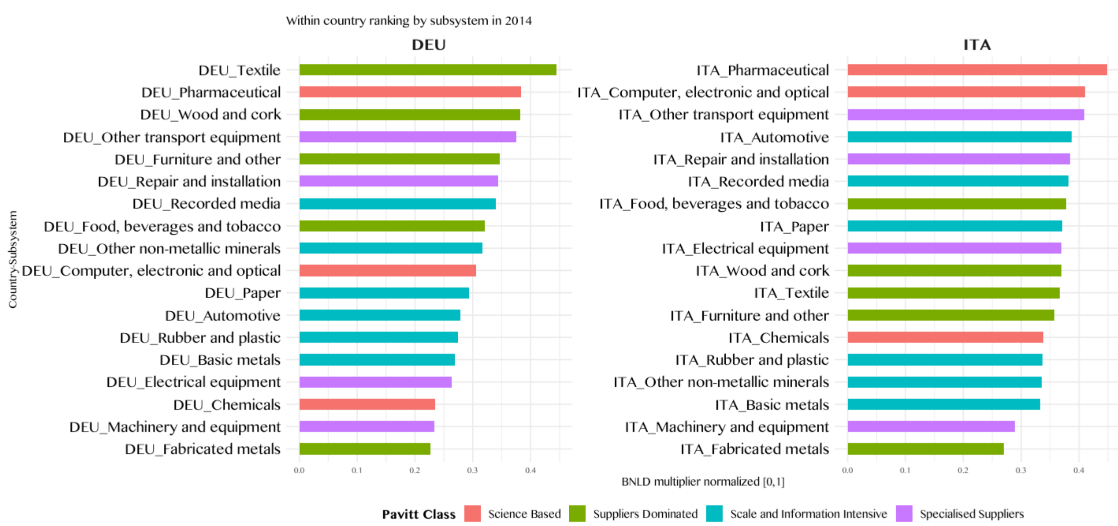

Figure 9: Ranking in BNLD normalized in [0,1] in Germany (DEU) and Italy (ITA). Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD).

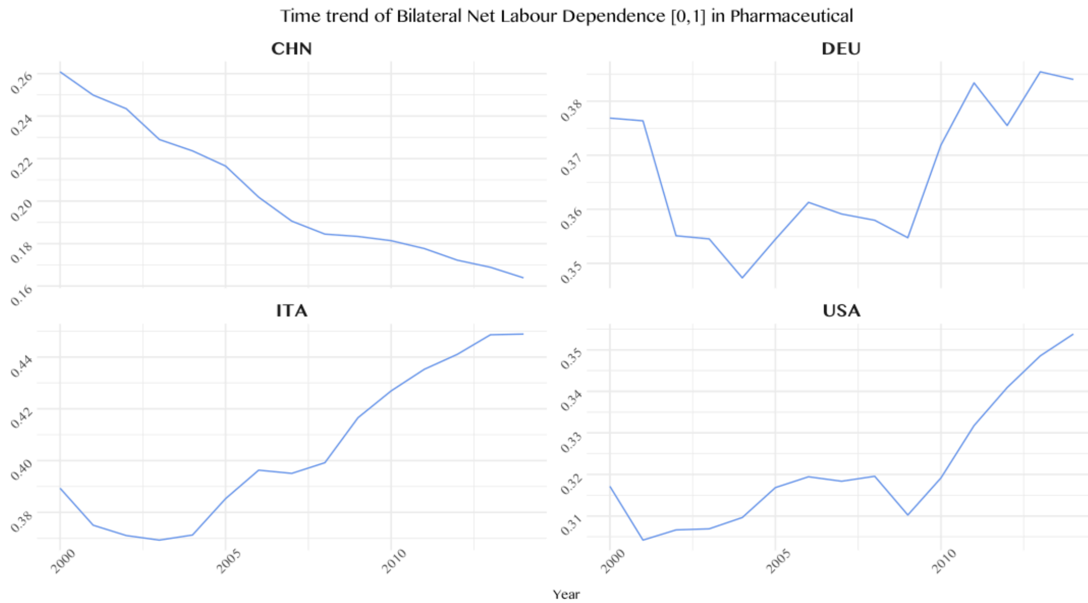

Figure 10: Trend in BNLD normalized [0,1] for Pharmaceutical in selected countries: China (CHN), Germany (DEU), Italy (ITA) and the US (USA).

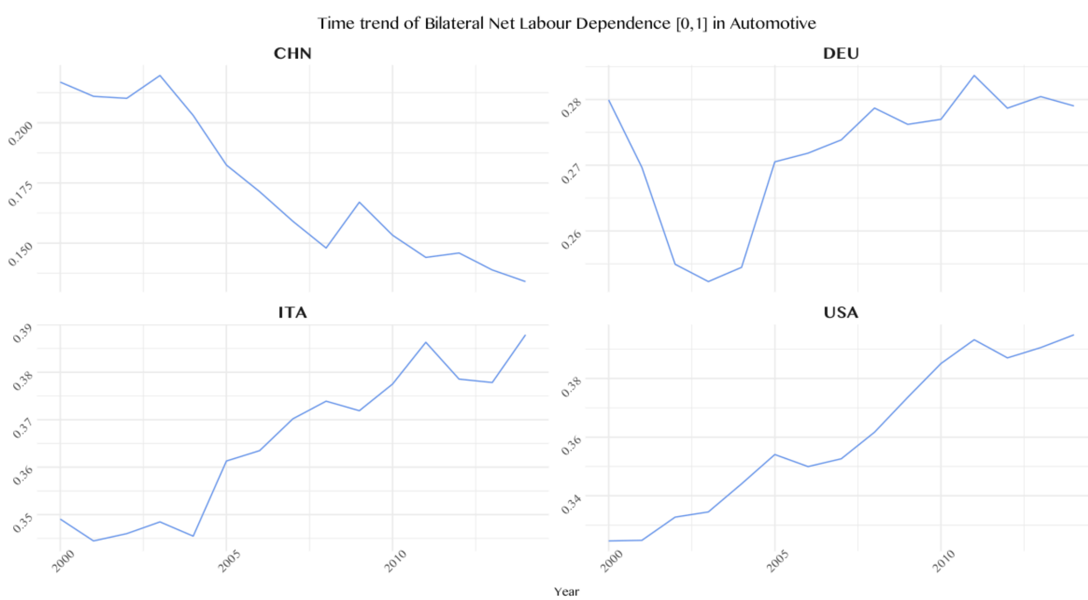

Figure 11: Trend in BNLD normalized [0,1] for Automotive in selected countries: China (CHN), Germany (DEU), Italy (ITA) and the US (USA).

6 BNLD and productivity: econometric specification

In this section we seek to challenge the literature on GVCs upgrading benefits. Participation in GVCs, as it has been conceived and measured, it is likely to induce productivity enhancement by means of a simple accounting relationship. Indeed, considering an increase in offshoring indicators or in vertical specialization measures - i.e. backward linkages dimension captured by TiVA indicators - they essentially capture the amount of productive activity which has moved from one sector/country to others abroad. If offshoring is concentrated in more labour intensive activities, as the literature suggests, then it is likely to record labour productivity increases at a broad sectoral level and a negative impact of GVCs participation for sectoral employment. The positive effect on labour productivity might however derive by the fact that gross output reduces less than the loss in employment. This argument opens various criticisms with respect to the chosen dependent variable, labour productivity, which according to the used indicator of GVCs participation might provide mechanistic results. Nonetheless, we perform our estimation on labour productivity at the sectoral level to be comparable with the literature.

The literature (Formai and Vergara Caffarelli, 2016; Taglioni and Winkler, 2016; Criscuolo and Timmis, 2017; Jona-Lasinio and Meliciani, 2019; Constantinescu et al., 2019; Pahl and Timmer, 2020; Battiati et al., 2020) has addressed the productivity-GVCs 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 main explanatory variable. The list of employed variables from WIOD and SEA databases can be found in Table 2. In appendices, Tables 5 and 6 show correlation matrix and descriptive statistics.

Variable	Dataset	Availability
$\boldsymbol{LP}$: Labour productivity (Gross output / persons engaged)	SEA	43 countries 2000-2014
$\boldsymbol{BNLD}$: Bilateral Net Labour Dependence	WIOD+SEA	43 countries 2000-2014
$\boldsymbol{W}$: Average wage (Labour compensation / persons engaged)	SEA	43 countries 2000-2014
$\boldsymbol{FD}$: Final Demand	WIOD	43 countries 2000-2014
$\boldsymbol{KE}$: Capital per employee (Nominal capital stock / persons engaged)	SEA	43 countries 2000-2014

Table 2: List of country-sector variables. The sectoral availability is at two digit manufacturing industries. See Table 11 in the appendix.

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:

$$LP_{i,t} = \alpha LP_{i,t-1} + \beta_1 BNLD_{i,t-1} + \beta_2 KE_{i,t-1} + \beta_3 FD_{i,t-1} + \beta_4 W_{i,t-1} + \delta_t + \mu_{i,t}, + \varepsilon_{i,t} \quad \text{where } t = 2000,...,2014,\ i = 1,...,612 \tag{13}$$

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 as well. 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, total sectoral labour costs in order to control for different wage levels across sectors.

Concerning the estimation technique, the literature usually adopts Fixed Effects estimators but stressing the relevance of 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 and Labrianidis, 2010; Sethupathy, 2013). A first solution entails lagging the explanatory variables, as we do. In addition, looking at Figure 6 we record that, differently from TiVA indicators, sectors registering the highest values of BNLD are not necessarily the most productive ones. Hence we might suffer less from such bias.[9] Concerning potential multicollinearity, we have run Variance Inflation Factors (VIF) analysis, in addition to standard correlation matrix (see Table 5). VIF test detected possible multicollinearity between lagged labour productivity and lagged average wage. Removing average wage (as we want to keep lagged productivity in order to capture the persistent dynamics of the dependent variable) lead to a Variance Inflation Factors always lower than 5. We kept average wage as a control in some specifications of the estimation.

Table 3 displays 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, and the sample, to check if sign, magnitude and significance of the main explanatory variable are stable and robust. China, Brazil, Indonesia, India, Mexico, Cyprus, Malta, Russia and Luxembourg might represent possible outliers given their large and small industrial structure, and are therefore initially

[9] As we include the lagged dependent variable in eq (7), another form of endogeneity might occur. In this case the usual solution would be SYS-GMM which however is more appropriate for shorter time spans in order to correctly identify instruments.

removed from the sample and then included in FE (9) as a robustness check. $BNLD$ always displays a negative and significant coefficient across all specifications. The magnitude of the coefficient is rather stable, ranging from -0.624 to -0.766, with the inclusion of average wage (W) as the control that reduces the coefficient the most. On the contrary, the degree of mechanization represented by capital per employee (KE) seems not to influence the $BNLD$ coefficient. We perform Likelihood-ratio test and Wald test to assess the relevance of each explanatory variable. The former highlights that adding only KE does not improve the model explanatory power. The latter confirms this result but also seems to suggest that adding FD in FE (5) and in FE (3) is also not crucial to improve the estimation.

With reference to the effects of other control variables, KE and FD show positive coefficients, although only KE is significant and only in FE (7), hinting at a role for short-term demand effects (FD) and of capital intensity (KE) in boosting productivity.[10] Sectoral wages, on the contrary, are found to be negatively related with productivity with the exception of FE (9) including all WIOD countries. Regarding wages, according to our correlation table, wages and productivity are positively correlated, while wages and BNLD are negatively related. This means that industries progressively net dependent from foreign labour also experience lower wages. In this respect, net labour dependence from foreign labour exerts a negative externality on the wage bill of domestic labour.

How interpreting the negative effect of BNLD on labour productivity? Given a sector, becoming more dependent from foreign labour as an input, rather than provider of domestic labour as an output for foreign industries, hampers the overall performance in terms of labour productivity. It signals a weak tie of the industry/country inside global production chains, wherein the notion of weakness derives from a dependent position inside the chain. Given the economies we are considering, the interpretation links in a straightforward manner to the negative effects that economies undergoing massive delocalization strategies, that entail domestic loss of productive capabilities and tacit knowledge, are facing. The increasing dependence from foreign labour inputs exerts negative effects for domestic internal labour productivity.

Focusing on China[11] that in the years of interest become the world-wide labour supplier, we detect a positive trend in BNLD and a corresponding positive effect on labour productivity in the domestic sectors, becoming *net* provider of labour to mature economies with the rise of global value

[10] The only exception concerning the sign is for KE in FE (9) where we include all WIOD countries.
[11] Results are available upon request.

chains. However, a lower BNLD is not necessarily associated with higher labour productivity. In fact, positioning as a net provider of labour does not necessarily entail for the supplying sector to be able to benefit in terms of economic upgrading. Indeed, benefits from GVCs participation for a supplier country arise only after it is able to internally develop and accumulate capabilities and eventually to supply foreign final productions at a certain stage, possibly with a given degree of autonomy and power to control the chain. Otherwise the country is likely to get trapped in subordinated low value-added activities (Lee and Gereffi, 2015; Lee et al., 2018, 2020). Hence, for developing countries it might be not sufficient to attract considerable amount of labour from abroad by supplying advanced economies. Indeed, including all samples of countries, even large development ones, the average estimated coefficient kept negative.

In section B of the appendix, we provide further robustness checks by adopting a dependent variable in first differences (Table 7), by changing the lag structure of BNLD (Table 8), by avoiding the normalization in [0,1] of BNLD (Table 9), or by sub-sampling in terms of years and groups of countries (Table 10). Results are always confirmed.

Table 3: FE estimation with LP in levels

Dependent variable: country-sector labour productivity in levels (LP_t)									
	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)	FE (6)	FE (7)	FE (8)	FE (9)
LP_{t-1}	0.736***	0.728***	0.718***	0.748***	0.722***	0.766***	0.753***	0.758***	0.736***
	(0.0152)	(0.0194)	(0.0235)	(0.0296)	(0.0170)	(0.0255)	(0.0259)	(0.0284)	(0.0260)
$BNLD^{[0,1]}_{t-1}$	-0.687***	-0.688***	-0.647***	-0.624***	-0.647***	-0.669***	-0.665***	-0.629***	-0.766***
	(0.177)	(0.177)	(0.163)	(0.160)	(0.163)	(0.175)	(0.173)	(0.162)	(0.132)
KE_{t-1}		0.0108	0.00509	0.0233			0.0266*		-0.000827
		(0.0144)	(0.0145)	(0.0154)			(0.0151)		(0.0137)
FD_{t-1}			0.0137	0.0127	0.0136			0.0124	0.0200**
			(0.0116)	(0.0116)	(0.0114)			(0.0115)	(0.00980)
W_{t-1}				-0.0677**		-0.0451*	-0.0591**	-0.0548**	0.00411
				(0.0292)		(0.0263)	(0.0279)	(0.0272)	(0.0210)
Observations	8229	8227	7945	7945	7947	8229	8227	7947	10036
Time dummies	✓	✓	✓	✓	✓	✓	✓	✓	✓
LR test (chi2)	73.74	1.64	11.10	26.00	10.95	14.44	21.32	20.00	
(p-value)	(0.000)	(0.200)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Wald test (F)	15.14	0.57	1.40	5.39	1.42	2.94	4.50	4.05	
(p-value)	(0.000)	(0.452)	(0.2373)	(0.021)	(0.234)	(0.087)	(0.034)	(0.045)	

Notes: Clustered standard errors in parentheses for variables' coefficients. All variables in log terms. Time dummies included, country-industry fixed effect.*, ** and *** denote significance level at 10%, 5% and 1%. Fe (1) to FE (8) exclude developing or small countries and China. FE (9) includes all WIOD countries

7 Concluding remarks

This work seeks to contribute, offering a novel perspective, to the literature investigating the link between GVCs participation and labour productivity. The motivation lies in three gaps identified in the literature: first of all, the global fragmentation of labour is a largely neglected dimension, while we argue that it is a crucial element to be assessed even from a pure *productive* perspective, as the workforce offshored embodies collective knowledge which if lost might entail negative feedback effects. In fact, offshoring labour might result in a loss of productive capabilities eventually detrimental for sectoral/country performances; second, bilateral interdependencies are generically ignored, while although we refer to global chains, production exchange takes place mainly between specific countries, actually leading to sticky and persistent bilateral production flows like the US-Mexico directrix, the Germany-Visegrad, the China-South East Asia more recently, entailing preferential structure of relations; third, the lack of importance assigned to power relations, asymmetric positioning and unequal exchange when studying GVCs: countries and sectors are not equal and they might occupy both dominant or subordinated positions.

We intend to fill this gap by developing a novel indicator of Bilateral Net Labour Dependence (BNLD), aimed at capturing asymmetric positioning of each country-sector in the international division of labour (and thus of knowledge). The indicator offers a clear picture of patterns of bilateral labour dependence both in cross-sectional and in temporal perspectives. China and other developing countries have seen their sectoral BNLD decreasing over time and displaying the lowest values in magnitude, while mature economies record a generalised increase in BNLD, especially after the 2008 crisis, with large magnitudes, although the within country ranking varies a lot depending on the productive specialization and the strategic positioning in GVCs. For instance, Italy shows many science based and specialised supplier industries, i.e. the most advanced technological classes, as largely net dependent from foreign labour, while German sectors in the top ranking are characterised by suppliers dominated activities with a lower technological content.

Our results provide evidence in support of the fact that division of labour, ensuing country positioning and bilateral ties are relevant for economic upgrading/downgrading: the way in which country-sector are located in the international division of labour, i.e. if they are net provider or buyer of labour, is related to sectoral performance in terms of labour productivity. In line with the literature of GVCs, we estimate the relationship of BNLD with labour productivity. The aim is to challenge the arguments of automatic benefits from GVCs participation, the latter providing only a partial analysis and dismissing other dimensions, as labour and knowledge. Our indicator presents a robust negative and significant coefficient with labour productivity. In this respect, we were able to identify a novel proxy for weak positioning in the international division of labour in terms of *net* dependence, i.e. demanding more foreign labour than the amount of domestic one provided to foreign final productions. In addition, we do find evidence of a negative correlation between industry domestic wages and industries dependence from foreign labour requirements.

Our framework of analysis might be useful to address the massive delocalization of manufacturing activities from mature to emergent and developing economies, pointing out the negative aspects of increasing offshoring of labour. From a policy perspective, our findings call for industrial policy at the scope of governing sectoral and technological specialization and directing the positioning in the international division of labour. Neglecting the use of industrial policies not only to govern internal sectoral specialization but also positioning in 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) and, we add, also the weak performances of countries and sectors massively delocalizing activities.

There are a number of potential extensions. First of all, the exploitation of the Pavitt Taxonomy to characterise the quality of knowledge embedded in the construction of BNLD indicator, namely measuring labour dependence in relation to specific Pavitt classes. Alternatively, disentangling 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 (Timmer et al., 2019). Both represent complementary ways to move from quantity to quality/type of knowledge/functions of employment. Second, the impact of labour dependence might be studied on other phenomena of interest, primarily the labour share and its decline along the vertical dimension, that is along chains of production as documented by Riccio et al. (2022). Third, the analysis might be extended over time and uncovering more countries making use of newly released OECD I-O data. Finally, the possibility to construct comparable firm-level measures, in terms of off-shoring of productive inputs, together with the underlying motives behind the decisions of off-shoring, leveraging on extensive business surveys (Costa et al., 2021), might represent an external fine-grained validation of our results. This becomes particularly important in the post-Covid phase marked by the restructuring of international GVCs and eventually the partial reconfiguration of the international division of labour towards Regional Value Chains.

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Appendices

A Further evidence

We present here some further evidence on BNLD. Figures from 12 to 17 show the maps of backward and forward bilateral for automotive of Germany, the US and China. The specific bilateral relationships we referred to in the paper here emerge clearly. Then we present the density distribution in 2014 disaggregated by subsystem (Figure 18), normalized within the range [0,1].

Figure 19 shows the correlation between BNLD normalized by [0,1] and labour productivity. This is in line with our conjecture that BNLD multiplier indicator could be used to assess a weak positioning in the international division of labour eventually detrimental for sectoral performances. These scatter plots refer to 2005 as an example and observations are plotted by highlighting different sectoral belonging. We have removed China, Brazil, Indonesia, India, Mexico, Cyprus, Malta, Russia and Luxembourg which are either outliers or developing countries that we exclude from the preferred econometric estimation.

We also plot the time dynamics of BNLD for each sector from Italy, Germany, the US and China (see Figures 20 to 23).

Table A alternatively shows the change in BNLD for the period 2000-2014. We account for sectoral heterogeneity and classify countries with respect to an upward or downward trend. The former entails an increasing (net) dependence, the latter a decreasing one. In the upward column we find in the majority of cases advanced countries and some emerging and developing economies mainly belonging to Eastern Europe, while the downward column is usually characterized by emerging and developing economies, with some exceptions. Concerning sectors, the majority of them registers more countries in the upward column, with the exception of Furniture and other manufacturing, Repair and installation of machinery and equipment. Lastly, we provide correlation matrix (Table 5) and descriptive statistics (Table 6) of the variables used in the econometric analysis.

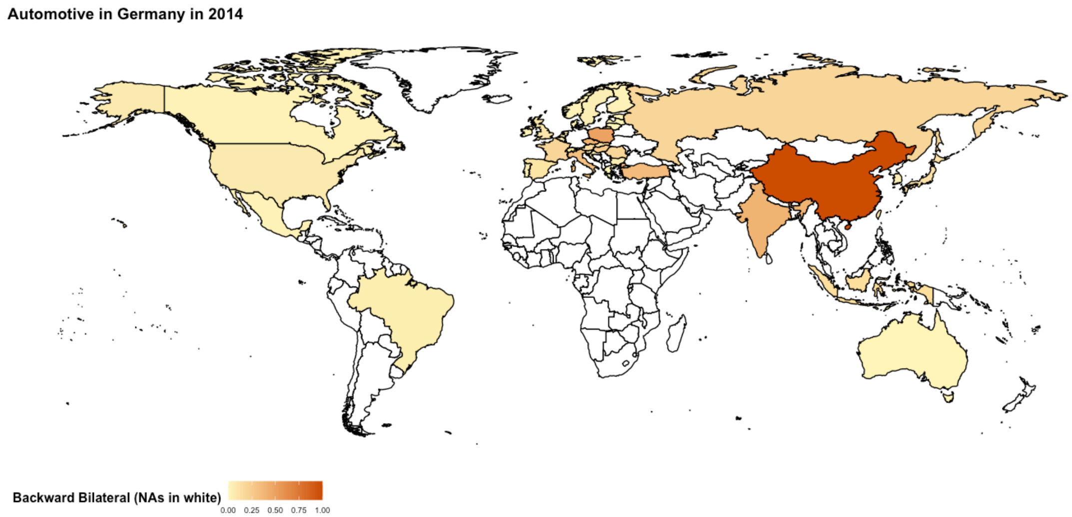

Figure 12: Backward Bilateral: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of German automotive subsystem.

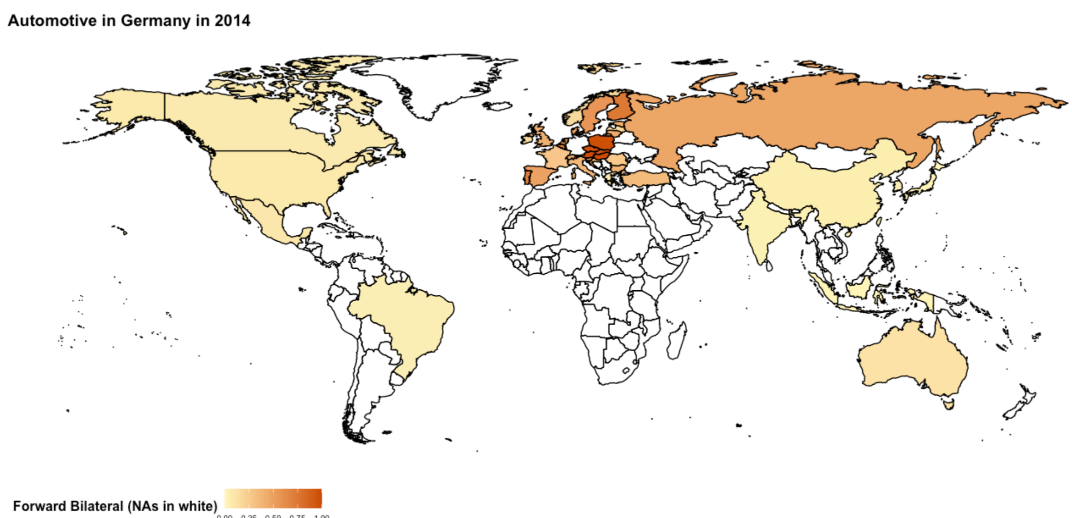

Figure 13: Forward Bilateral: employees provided in 2014 to the (43-1) WIOD countries by German automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

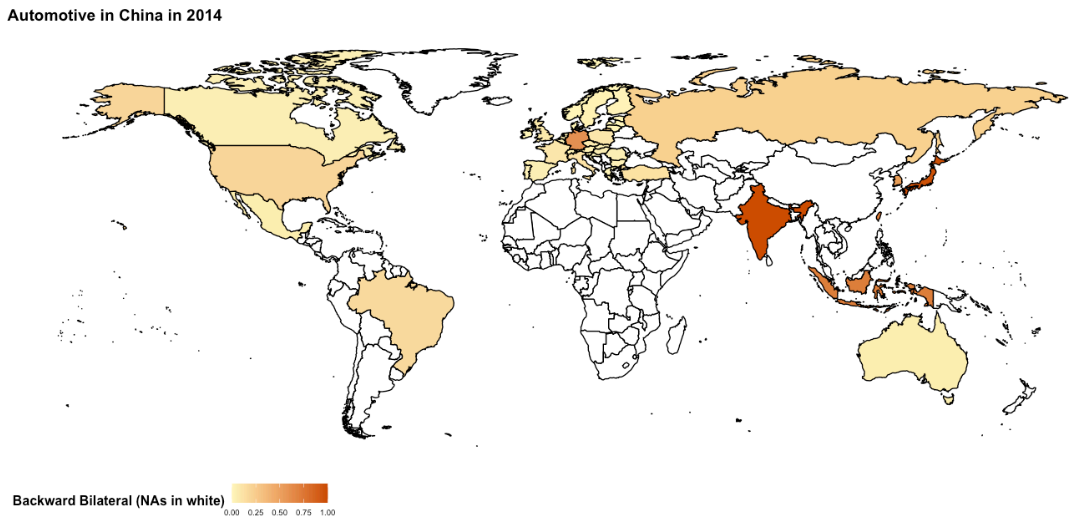

Figure 14: Backward Bilateral: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of Chinese automotive subsystem.

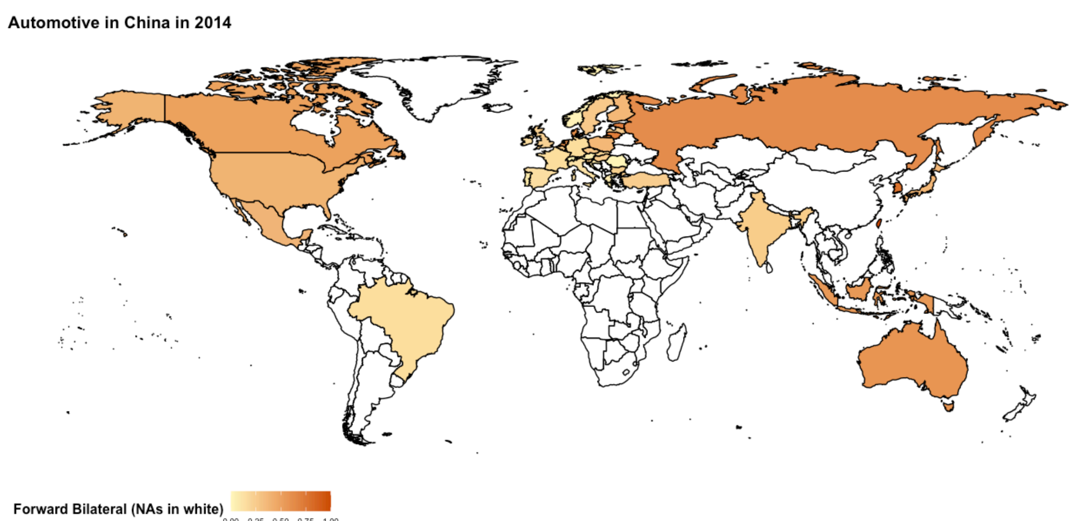

Figure 15: Forward Bilateral: employees provided in 2014 to the (43-1) WIOD countries by Chinese automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

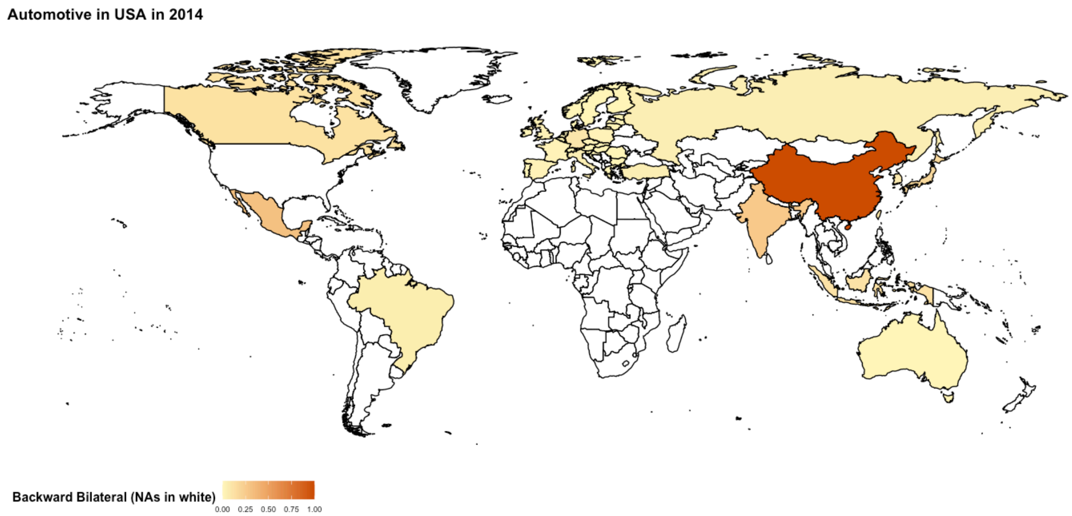

Figure 16: Backward Bilateral: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of US automotive subsystem.

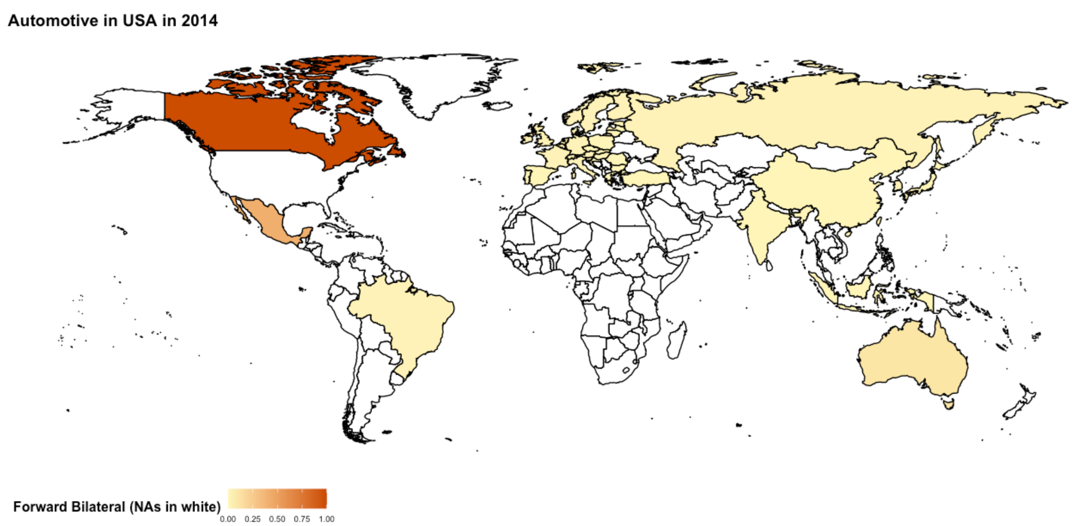

Figure 17: Forward Bilateral: employees provided in 2014 to the (43-1) WIOD countries by US automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

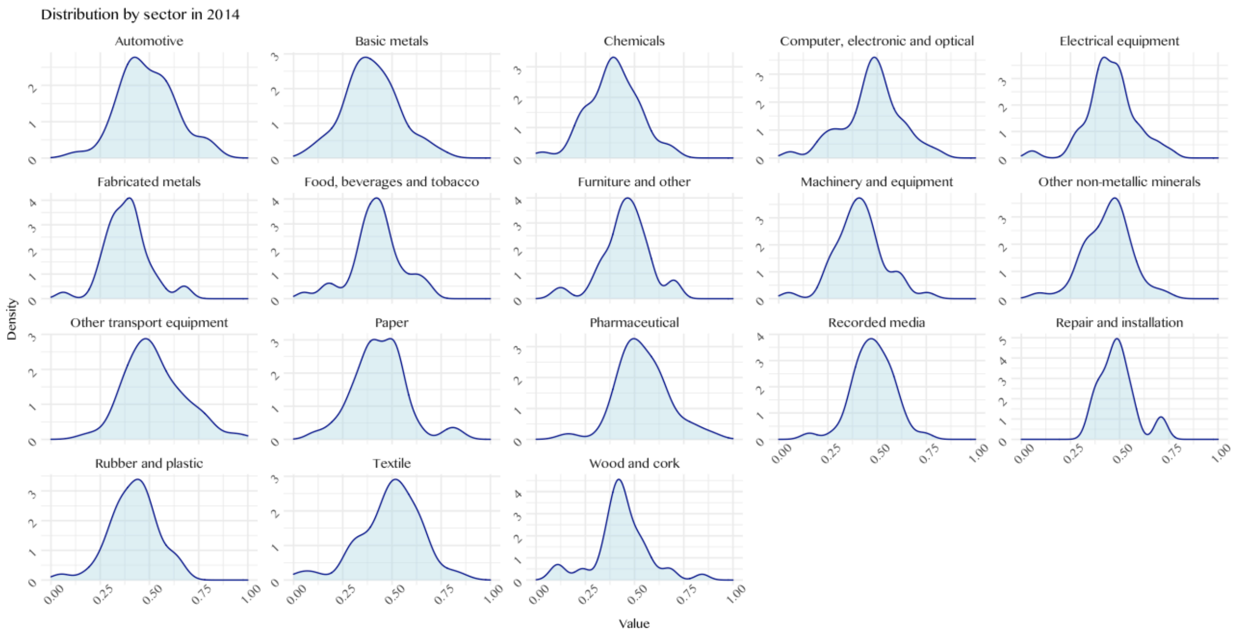

Figure 18: BNLD density distribution in 2014 for BNLD normalized in [0,1].

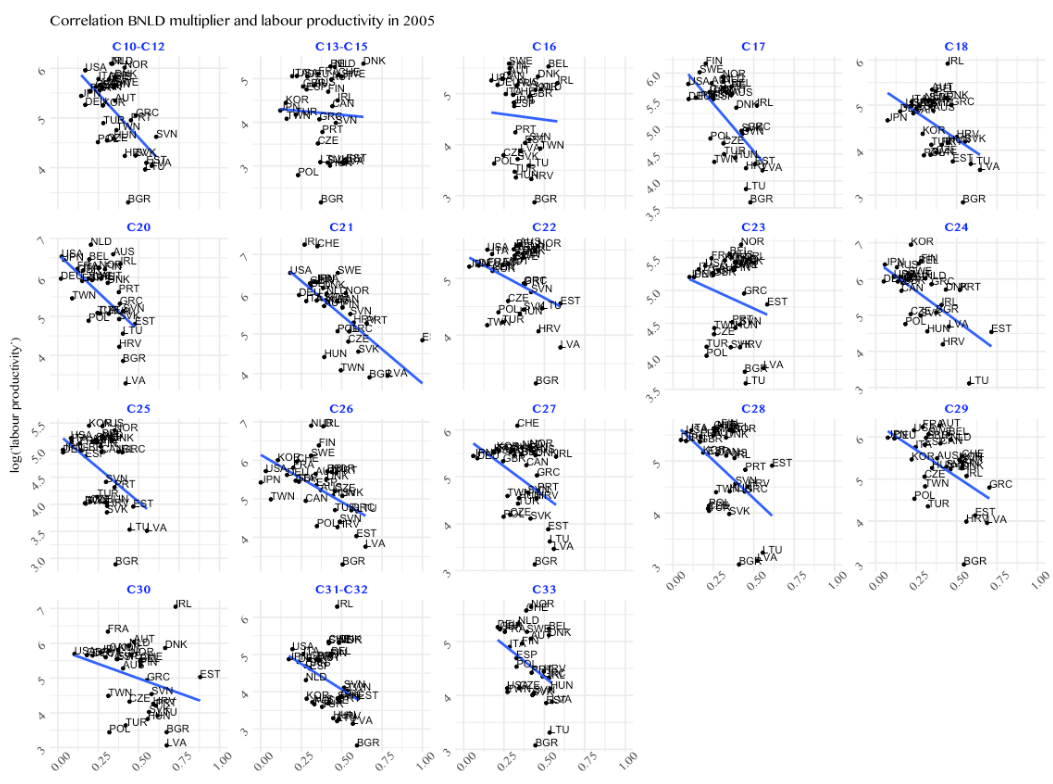

Figure 19: Scatter plot BNLD [0,1] and labour productivity by industry code in 2005

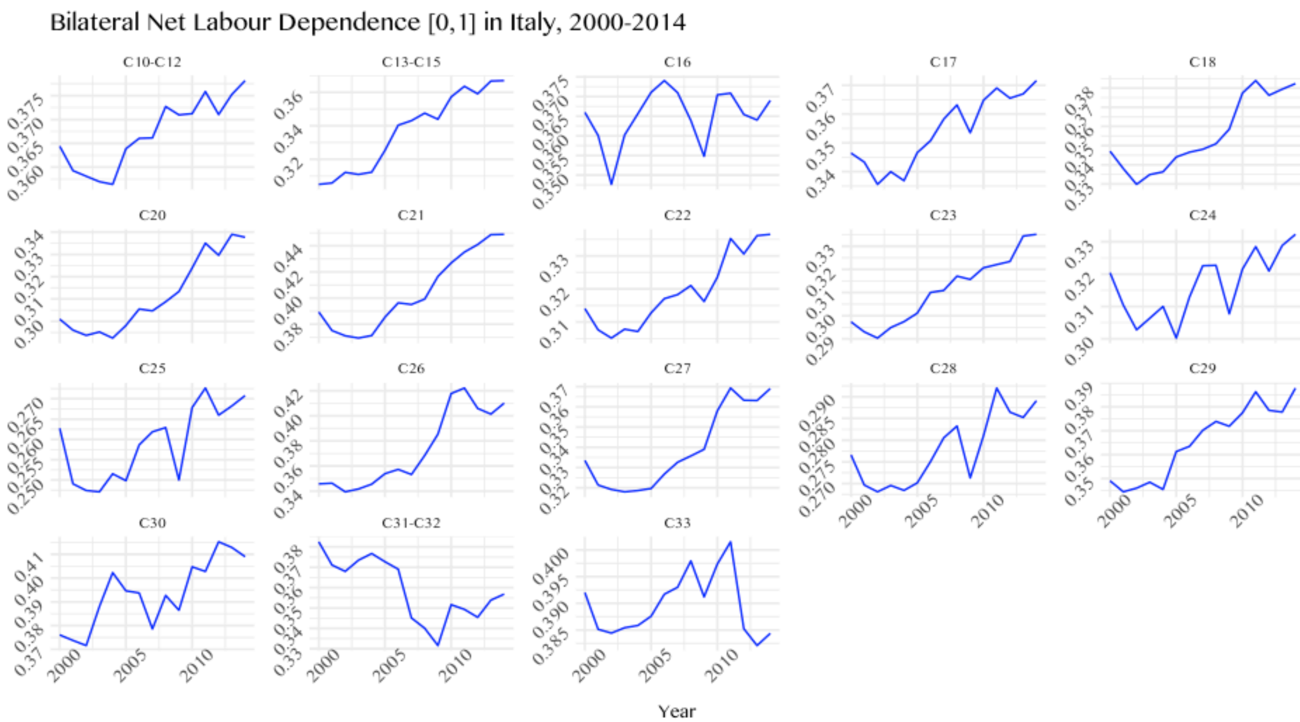

Figure 20: Trend in BNLD normalized [0,1] for Italy.

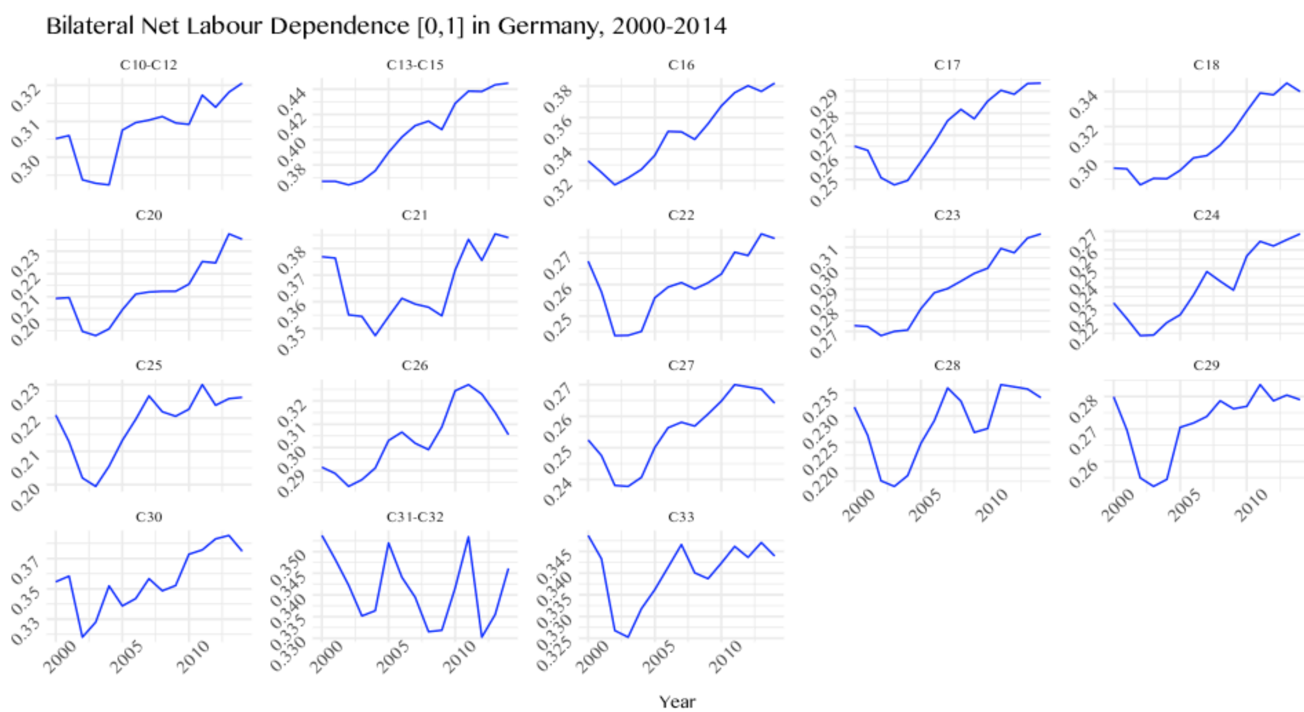

Figure 21: Trend in BNLD normalized [0,1] for Germany.

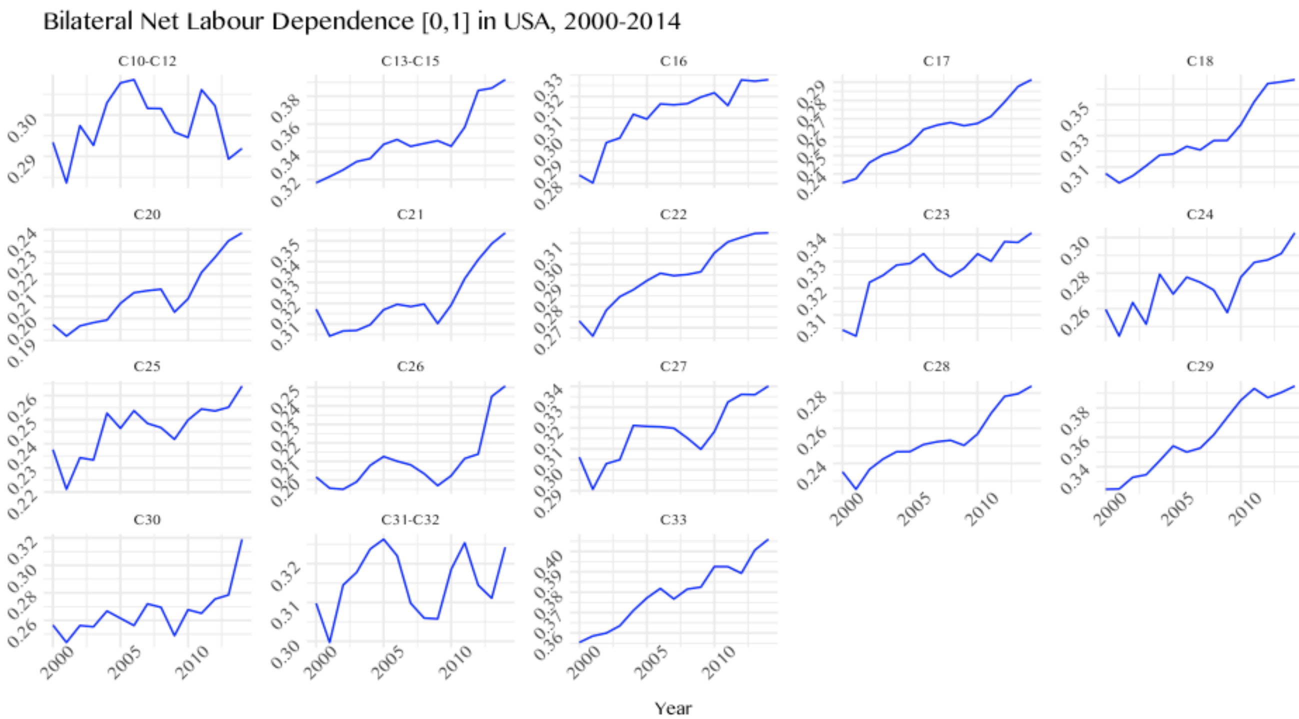

Figure 22: Trend in BNLD normalized [0,1] for the US.

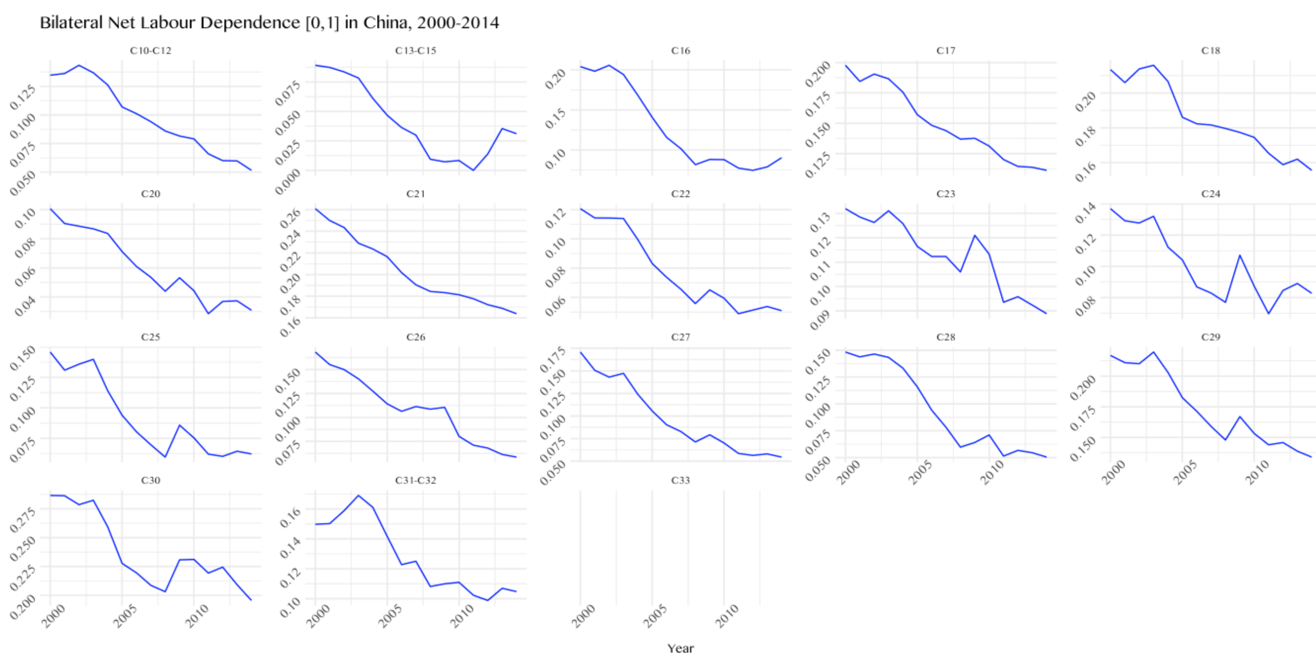

Figure 23: Trend in BNLD normalized [0,1] for China. Data for sector C33 are missing.

Table 4: Change for all countries in net labour dependence between 2000 and 2014, by sector. The correspondence between country codes and names can be found in Tables 12 and 13

	Change in $\Delta BNLD_{2000-2014}$	
Sectors	**UPWARD** (More *net* dependent)	**DOWNWARD** (Less *net* dependent)
Food, beverages and tobacco:	AUS, AUT, BEL, CAN, CHE, CZE, DEU, DNK, EST, FIN, FRA, GBR, HRV, HUN, IND, ITA, JPN, LTU, NLD, NOR, POL, ROU, RUS, SVK, SVN, SWE, TUR	BGR, BRA, CHN, CYP, ESP, GRC, IDN, IRL, KOR, LUX, LVA, MEX, MLT, PRT, TWN, USA
Textile:	AUS, AUT, BEL, BGR, BRA, CAN, CHE, CYP, CZE, DEU, DNK, ESP,EST, FIN, FRA, GBR, HRV, HUN, IDN, IRL, ITA, JPN, KOR, LTU, LUX, LVA, MEX, MLT, NLD, NOR, POL, PRT, ROU, RUS, SVK, SVN, SWE, TUR, TWN, USA	CHN, IND
Wood and cork:	AUS, AUT, BRA, CAN, CHE, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, HRV, HUN, IDN, IRL, ITA, JPN, LUX, MEX, MLT, NLD, NOR, POL, PRT, ROU, RUS, SVN, SWE, USA	BEL, BGR, CHN, CYP, GRC, IND, KOR, LTU, LVA, SVK, TUR, TWN

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Table 4: Change for all countries in net labour dependence between 2000 and 2014, by sector. The correspondence between country codes and names can be found in Tables 12 and 13 (Continued)

	Change in $\Delta BNLD_{2000-2014}$	
Sectors	**UPWARD** (More *net* dependent)	**DOWNWARD** (Less *net* dependent)
Paper:	AUS, AUT, BEL, BRA, CAN, CHE, CYP, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IND, IRL, ITA, JPN, KOR, LUX, LVA, MEX, MLT, NLD, NOR, POL, PRT, ROU, RUS, SVK, SVN, SWE, TUR, USA	BGR, CHN, CZE, IDN, LTU, TWN
Printing and recorded media:	AUS, AUT, BEL, CAN, CHE, CYP, CZE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, HRV, IND, IRL, ITA, JPN, KOR, LUX, LVA, MEX, NLD, NOR, POL, PRT, ROU, SVN, SWE, TUR, USA	BGR,BRA,CHN,EST,HUN, IDN,LTU,MLT,SVK,TWN
Chemicals:	AUS, AUT, BEL, BRA, CAN, CHE, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IND, IRL, ITA, JPN, KOR, LVA, MEX, NLD, NOR, NOR, POL, ROU, RUS, SVK, SVN, SWE, TUR, TWN, USA	BGR, CHN, CYP, IDN, LTU, LUX, MLT, PRT

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Table 4: Change for all countries in net labour dependence between 2000 and 2014, by sector. The correspondence between country codes and names can be found in Tables 12 and 13 (Continued)

	Change in $\Delta BNLD_{2000-2014}$	
Sectors	**UPWARD** (More *net* dependent)	**DOWNWARD** (Less *net* dependent)
Pharmaceutical:	AUS, AUT, BEL, BRA, CAN, CHE, CZE, DEU, ESP, EST, FIN, FRA, GBR, HRV, HUN, IND, IRL, ITA, JPN, LTU, MEX, MLT, NLD, NOR, ROU, SVK, SVN, SWE, TWN, USA	BGR, CHN, CYP, DNK, GRC, IDN, KOR, LUX, LVA, POL, PRT
Rubber and plastic:	AUS, AUT, BEL, BRA, CAN, DEU, DNK, ESP, FIN, FRA, GBR, GRC, HRV, IND, IRL, ITA, JPN, KOR, LUX, MEX, NLD, NOR, RUS, SVN, SWE, TWN, USA	BGR, CHE, CHN, CYP, CZE, EST, HUN, IDN, LTU, LVA, MLT, POL, PRT, ROU, SVK, TUR
Non-metallic mineral:	AUS, AUT, BEL, BRA, CAN, CHE, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IDN, IND, IRL, ITA, JPN, KOR, LUX, MEX, MLT, NLD, NOR, POL, PRT, ROU, RUS, SVK, SVN, SWE, TUR, USA	BGR, CHN, CYP, LTU, LVA, TWN
Basic metals:	AUS, AUT, BEL, BGR, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, HRV, IND, IRL, ITA, JPN, LTU, LUX, LVA, MLT, NLD, NOR, POL, ROU, RUS, SVN, SWE, TUR, USA	BRA, CAN, CHE, CHN, CYP, GRC, HUN, IDN, KOR, MEX, PRT, SVK, TWN

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Table 4: Change for all countries in net labour dependence between 2000 and 2014, by sector. The correspondence between country codes and names can be found in Tables 12 and 13 (Continued)

	Change in $\Delta BNLD_{2000-2014}$	
Sectors	**UPWARD** (More *net* dependent)	**DOWNWARD** (Less *net* dependent)
Fabricated metal products:	AUS, AUT, BEL, BRA, CAN, CZE, DEU, DNK, ESP, FIN, FRA, GBR, HRV, IRL, ITA, JPN, LUX, MEX, MLT, NLD, POL, ROU, SVN, SWE, USA	BGR, CHE, CHN, CYP, EST, GRC, HUN, IDN, IND, KOR, LTU, LVA, NOR, PRT, SVK, TUR, TWN
Computer, electronic and optical products:	AUS, AUT, BEL, BRA, CAN, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IDN, IRL, ITA, JPN, LTU, LUX, LVA, MEX, MLT, NLD, NOR, POL, PRT, ROU, RUS, SVK, SVN, SWE, TUR, USA	BGR, CHE, CHN, CYP, IND, KOR, TWN
Electrical equipment:	AUS, AUT, BEL, BRA, CAN, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, IDN, IRL, ITA, JPN, LTU, LUX, LVA, MEX, MLT, NLD, NOR, POL, PRT, SVN, SWE, TUR, USA	BGR, CHE, CHN, CYP, HUN, IND, KOR, LVA, ROU, SVK, TWN

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Table 4: Change for all countries in net labour dependence between 2000 and 2014, by sector. The correspondence between country codes and names can be found in Tables 12 and 13 (Continued)

	Change in $\Delta BNLD_{2000-2014}$	
Sectors	**UPWARD** (More *net* dependent)	**DOWNWARD** (Less *net* dependent)
Machinery and equipment:	AUS, AUT, BEL, BRA, CAN, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, IDN, IRL, ITA, JPN, LTU, LUX, LVA, MLT, NLD, NOR, POL, ROU, RUS, SVK, SWE, USA	BGR, CHN, GRC, HRV, HUN, IND, KOR, MEX, PRT, SVN, TUR, TWN
Automotive:	AUS, BEL, BRA, CAN, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, IRL, ITA, JPN, LTU, LUX, MEX, MLT, NLD, NOR, PRT, RUS, SWE, TWN, USA	AUT, BGR, CHE, CHN, CYP, CZE, DEU, HUN, IDN, IND, KOR, LVA, POL, ROU, SVK, SVN, TUR
Other transport equipment:	AUS, AUT, BEL, BGR, BRA, CAN, CZE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, IRL, ITA, LTU, LUX, LVA, MLT, NLD, NOR, POL, PRT, ROU, SVK, SVN, SWE, TUR, USA	CHE, CHN, CYP, HRV, HUN, IDN, IND, JPN, KOR, MEX, TWN
Furniture and other:	AUS, BRA, CAN, CZE, ESP, FIN, FRA, GBR, GRC, HRV, IRL, JPN, LUX, NLD, NOR, ROU, RUS, SVN, USA	AUT, BEL, BGR, CHE, CHN, CYP, DEU, DNK, EST, HUN, IDN, IND, ITA, KOR, LTU, LVA, MEX, MLT, POL, PRT, SVK, SWE, TUR, TWN

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Table 4: Change for all countries in net labour dependence between 2000 and 2014, by sector. The correspondence between country codes and names can be found in Tables 12 and 13 (Continued)

	Change in $\Delta BNLD_{2000-2014}$	
Sectors	**UPWARD** (More *net* dependent)	**DOWNWARD** (Less *net* dependent)
Repair and installation of m&e:	CHE, CZE, DNK, EST, FIN, FRA, GBR, IRL, LTU, MEX, MLT, NLD, POL, SVK, SVN, SWE, USA	AUT, BEL, BGR, CYP, DEU, ESP, GRC, HRV, HUN, HUN, ITA, LUX, LVA, NOR, PRT, ROU, TWN

Variables	LP_t	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)	0.984	1.000				
Lagged Capital per employee (KE)	0.838	0.850	1.000			
Lagged Final demand (FD)	0.453	0.465	0.355	1.000		
Lagged Average wage (W)	0.870	0.888	0.770	0.427	1.000	
Lagged BNLD [0,1] ($BNLD^{[0,1]}$)	-0.285	-0.286	-0.248	-0.591	-0.278	1.000

Spearman rho = 0.236

Table 5: Correlation matrix

Variables	Obs	Mean	Std. Dev.	Min	Max
Labour productivity (LP)	8818	5.015	.922	1.209	8.781
Capital per employee (KE)	8815	4.433	1.023	-.161	7.45
Final Demand (FD)	8776	7.331	2.115	-1.66	13.209
Average Wage (W)	8818	3.37	.893	-.078	7.187
BNLD [0,1] ($BNLD^{[0,1]}$)	9088	.439	.099	.184	.936

Table 6: Descriptive statistics

B Robustness Checks

In this section we provide further robustness checks of the econometric estimation. Table 7 shows estimates with dependent variable in first differences. In Table 8 we control for different lag structures of BNLD, keeping the specification without wages as the preferred one. In Table 9 we use BNLD not normalized in [0,1], while in Table 10 we adopt a sub-sampling technique by first reducing the time span (before and after 2007) and then by excluding Southern and Core European countries in one case, and Eastern European ones in the other. Significance and sign of BNLD coefficient are always robust.

Table 7: FE estimation with LP in differences

Dependent variable: country-sector labour productivity in differences(ΔLP_t)									
	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)	FE (6)	FE (7)	FE (8)	FE (9)
$BNLD_{t-1}^{[0,1]}$	-1.032***	-0.867***	-0.895***	-0.746***	-1.052***	-0.728***	-0.732***	-0.744***	-1.001***
	(0.200)	(0.186)	(0.185)	(0.166)	(0.204)	(0.170)	(0.172)	(0.165)	(0.148)
KE_{t-1}		-0.153***	-0.143***	-0.0409***			-0.0478***		-0.0875***
		(0.0117)	(0.0113)	(0.0149)			(0.0158)		(0.0183)
FD_{t-1}			-0.0279***	-0.0177*	-0.0505***			-0.0194*	-0.0181**
			(0.0104)	(0.0106)	(0.0102)			(0.0109)	(0.00893)
W_{t-1}				-0.202***		-0.241***	-0.198***	-0.239***	-0.101***
				(0.0224)		(0.0149)	(0.0208)	(0.0148)	(0.0294)
Observations	8229	8227	7945	7945	7947	8229	8227	7947	10036
Time dummies	✓	✓	✓	✓	✓	✓	✓	✓	✓
LR test (chi2)	143.37	555.61	49.06	284.75	162.84	820.81	295.22	693.92	
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Wald test (F)	26.70	170.51	7.27	81.55	24.31	261.13	90.75	258.75	
(p-value)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

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%. Fe (1) to FE (8) excludes developing or small countries and China. FE (9) includes all WIOD countries

Table 8: FE estimation with LP in levels and BNLD with different lags

Dependent variable: country-sector labour productivity in levels (LP_t)				
	FE (1)	FE (2)	FE (3)	FE (4)
LP_{t-1}	0.718*** (0.0235)	0.709*** (0.0269)	0.680*** (0.0302)	0.638*** (0.0328)
$\boldsymbol{BNLD}_{t-1}$	-0.647*** (0.163)			
$\boldsymbol{BNLD}_{t-2}$		-0.647*** (0.172)		
$\boldsymbol{BNLD}_{t-3}$			-0.558** (0.266)	
$\boldsymbol{BNLD}_{t-4}$				-0.358** (0.178)
$log(KE)_{t-1}$	0.00509 (0.0145)	0.0000911 (0.0173)	-0.000322 (0.0197)	0.00790 (0.0230)
$log(FD)_{t-1}$	0.0137 (0.0116)	0.0112 (0.0137)	0.0170 (0.0150)	0.0215 (0.0169)
Observations	7945	7383	6822	6260

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%. Fe (1) to FE (8) excludes developing or small countries and China. FE (9) includes all WIOD countries

Table 9: FE estimation with LP in levels and BNLD not normalized

Dependent variable: country-sector labour productivity in levels (LP_t)									
	FE (1)	FE (2)	FE (3)	FE (4)	FE (5)	FE (6)	FE (7)	FE (8)	FE (9)
$log(LP)_{t-1}$	0.736*** (0.0152)	0.728*** (0.0194)	0.718*** (0.0235)	0.748*** (0.0296)	0.722*** (0.0170)	0.766*** (0.0255)	0.753*** (0.0259)	0.758*** (0.0284)	0.736*** (0.0260)
$\boldsymbol{BNLD}_{t-1}$	**-0.0385***** (0.00990)	**-0.0386***** (0.00991)	**-0.0363***** (0.00913)	**-0.0350***** (0.00895)	**-0.0363***** (0.00915)	**-0.0375***** (0.00982)	**-0.0373***** (0.00970)	**-0.0353***** (0.00908)	**-0.0430***** (0.00739)
$log(KE)_{t-1}$		0.0108 (0.0144)	0.00509 (0.0145)	0.0233 (0.0154)			0.0266* (0.0151)		-0.000827 (0.0137)
$log(FD)_{t-1}$			0.0137 (0.0116)	0.0127 (0.0116)	0.0136 (0.0114)			0.0124 (0.0115)	0.0200** (0.00980)
$log(W)_{t-1}$				-0.0677** (0.0292)		-0.0451* (0.0263)	-0.0591** (0.0279)	-0.0548** (0.0272)	0.00411 (0.0210)
Observations	8229	8227	7945	7945	7947	8229	8227	7947	10036

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%. Fe (1) to FE (8) excludes developing or small countries and China. FE (9) includes all WIOD countries

Table 10: FE estimation with LP in levels and time and country sub-sampling

Dependent variable: country-sector labour productivity in levels (LP_t)				
	T < 2008 (1)	T > 2007 (2)	NO South-Core EU (3)	NO East EU (4)
$log(LP)_{t-1}$	0.753*** (0.0235)	0.735*** (0.0281)	0.605*** (0.0400)	0.469*** (0.0383)
$\boldsymbol{BNLD}_{t-1}^{[0,1]}$	-0.749*** (0.137)	-0.769*** (0.161)	-0.719** (0.289)	-0.849* (0.479)
$log(KE)_{t-1}$	-0.0175 (0.0137)	0.00890 (0.0158)	0.0246 (0.0289)	0.0114 (0.0424)
$log(FD)_{t-1}$	0.0166** (0.00715)	0.0255** (0.0128)	0.0108 (0.0179)	0.0233 (0.0210)
Observations	7066	7602	3972	3973

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%. In (1) we consider only T lower than 2008, while in (2) only T larger than 2007. (3) and (4) on the contrary drop southern and core European countries and Eastern Europe ones respectively.

C Data details

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
C17	Manufacture of paper and paper products	SII
C18	Printing and reproduction of recorded media	SII
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-C32	Manufacture of furniture; other manufacturing	SD
C33	Repair and installation of machinery and equipment	SS

Table 11: List of 18 manufacturing sectors in 2-digit NACE Rev. 2 classification. Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD)

Country	Code	Country	Code
Australia	AUS	Ireland	IRL
Austria	AUT	Italy	ITA
Belgium	BEL	Japan	JPN
Bulgaria	BGR	South Korea	KOR
Canada	CAN	Lithuania	LTU
Switzerland	CHE	Latvia	LVA
Czech Republic	CZE	The Netherlands	NLD
Germany	DEU	Norway	NOR
Denmark	DNK	Poland	POL
Spain	ESP	Portugal	PRT
Estonia	EST	Romania	ROU
Finland	FIN	Slovakia	SVK
France	FRA	Slovenia	SVN
United Kindom	GBR	Sweden	SWE
Greece	GRC	Turkey	TUR
Croatia	HRV	Taiwan	TWN
Hungary	HUN	United States	USA

Table 12: List of 34 countries used in specifications 1 to 8 in Table 3

Country	Code	Country	Code
Brazil	BRA	Luxemburg	LUX
China	CHN	Malta	MLT
Cyprus	CYP	Mexico	MEX
Indonesia	IDD	Russia	RUS
India	IND		

Table 13: List of 9 outlier countries removed in specifications 1 to 8 but kept in 9 in Table 3.