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

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Abstract

This work aims at addressing the positioning of countries and sectors in the international division of labour by leveraging on bilateral input-output linkages. The latter are obtained by constructing time series of vertically integrated sectors containing information on direct and indirect labour requirements embodied in intermediate goods trade, proxing the amount of employees belonging to the production process of each final commodity in the global economy (Pasinetti, 1973, 1981). The idea to rely on bilateral flows of labour stems from the need to account for specific trade linkages between countries, that highlight peculiar power relationships in labour requirements and the dependence from embodied knowledge. Exploiting the World Input-Output Database (Timmer et al., 2015), we propose an indicator of Bilateral Net Labour Dependence, building upon methodological insights by Koopman et al. (2010) and more recently by Baldwin and Freeman (2021). The novelty stands for specifically accounting for labour bilateral relationships and then to take advantage of the information we get from this measure to estimate its relationship with a variable of performance of industries, as labour productivity, seeking to challenge the literature findings on a positive effect of GVCs participation, often in terms of value added embodied in trade, on productivity of sectors (Criscuolo and Timmis, 2017; Ahn and Duval, 2017; Constantinescu et al., 2019; Battiati et al., 2020). Our guess is that being in a weak position in terms of labour provider results in an overall weakening of the capabilities of the productive structure. We test this conjecture with a panel analysis of OECD countries and industries for the time period 2000-2014.

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1 Introduction and state-of-the-art

In the last three decades we have witnessed an increasing process of relocation of productive activities, often from mature to developing and emerging economies. This phenomenon - to be addressed within the broader global fragmentation of production and the rise of the so-called Global Value Chains - has had profound impacts on the economic structure in terms of employment, incomes, innovation and capabilities development. The debate on whether the increasing delocalization of production was beneficial or detrimental for an economy has so far led scholars to investigate the relationship between proxies of such offshoring activity on a measure of performances of firms, sectors, countries.

Focusing on sectoral and country level evidence, the literature has commonly found a positive effects of this so-called GVCs participation on performance variables such as labour productivity. That is, offshoring part of productive process results in productivity benefits and this is motivated by a wide spectrum of arguments (Formai and Vergara Caffarelli, 2016; Taglioni and Winkler, 2016; Criscuolo and Timmis, 2017; Jona-Lasinio and Meliciani, 2019; Constantinescu et al., 2019). Learning-by-exporting, learning-by-supplying, training by lead firms, imitation and reverse engineenering are the main motivations within the broader phenomenon of technology transfer and knowledge spillovers. Then, other *static* and *dynamic* positive effects are pointed out. The former entail the greater access to better-quality or more diverse inputs and at lower cost, the latter reallocation of factors towards more efficient tasks (thus outsourcing of activities performed less efficiently in-house). Taglioni and Winkler (2016, p. 29) stress the role of what they call *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. The concept of the embodiment of knowledge in the workforce is of great interest and we will build our analysis around it, but rather pointing out the relevance of this argument when labour is offshored.

We have some criticism toward this literature. First of all, the motivations put forward for the benefits of participating to GVCs appear quite generic and often relevant only for a firm-level perspective. Such benefits fall under the too optimistic view of development through GVCs through the lens of the comparative advantage trade theory. As an example, the World Bank's 2020 World Development Report titled *Trading for Development in the Age of Global Value Chains* (World

Development Report, 2020) is stressing the developmental potential offered by GVCs, neglecting power relations, unequal exchange or asymmetric positioning (Selwyn and Leyden, 2022). This current conventional approach to GVCs claim for *mutual gains* for suppliers and headquarter firms thanks to specialization in complementary activities. In the Report's words: 'GVCs allow countries to benefit from the efficiency gained from a much finer international division of labour. GVCs exploit the fact that countries have different *comparative advantages* not only in different sectors, but also in different stages of production within sectors' (World Development Report, 2020, p. 69)

Secondly, 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 value-added in trade statistics, even though in the broader literature of GVCs some scholar has 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; Bontadini et al., 2019; Pahl et al., 2019; Bontadini et al., 2022; Fana and Villani, 2022; Wirkierman, 2022). We thus aim to bridge these two streams of research, by investigating the relationship between the positioning of sectors to the international division of labour and a measure of their economic performance, as labour productivity. The main reason relies on the fact that labour is the most crucial input for production as it embodies also the know-how and the tacit knowledge to produce artifacts.[1] Whenever labour is offshored, these 'productive capabilities' get inevitably lost. This might be realised by looking at geographical areas that substantially lost manufacturing activities and together with them also the manufacturing capabilities gathered by the workforce. Therefore we want to challenge the literature arguing that increasing offshoring of labour inputs might worsen the macro sectoral performances of countries. We focus on mature economies (a selection of OECD countries) as this phenomenon has been particularly in place there.

A third main concern relates to the argument that although we deal with *global* value chains, the *bilateral* (country-by-country) international trade is extremely relevant. Italy is vertically integrated with Germany, Germany with Visegrad countries, USA with Mexico, and so on. Therefore we will try to emphasise this bilateral dimension in the international division of labour, also by preferring GVCs *positioning* indicators rather than *participation* ones.

[1] So far, the literature has addressed mainly innovation-related kinds of embodiment, as the measures of R&D embodied in I-O linkages (Leoncini and Montresor, 2003; Hauknes and Knell, 2009; Franco et al., 2011; Taalbi, 2020; Cresti et al., 2022). The importance of absorptive capacities for capturing the benefits from technology diffusion is stressed also in this specific stream of research (see Foster-McGregor et al., 2017).

2 Countries and industries in the international division of labour: a tentative conceptual framework

2.1 Division of labour, division of (embodied) knowledge

We build our investigation upon two well known streams of research. Firs of all, the Pasinettian structuralist tradition (Pasinetti, 1981; Scazzieri, 1990; Landesmann and Scazzieri, 1996; Andreoni and Scazzieri, 2014) tells us the role of industrial interdependencies, i.e. the productive linkages between economic branches, for the dynamics of economic systems. This view has stimulated researchers to address productive structures overcoming the traditional boundaries of sectors as defined in standard classifications. Indeed, production process does not take place in isolated productive units but rather in sequential stages of activities entailing several factories belonging to various sectors and countries. Since the so-called economic globalization of the early 1990s, such interdependecies 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 in 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 delocalization, 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

Secondly, our theoretical background builds also 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. Hence, also every chain is composed by branches very heterogeneous in terms of technological content. Moreover, the evolutionary traditions and the capability-based theory of the firm remind us that 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 the workers. Cimoli et al. (2009) pointed out that the process of accumulation of knowledge and capabilities - that can hardly be captured by synthetic innovation statistics - is at the core of virtuous structural transformation. From a policy perspective, the authors claim that this argument calls for industrial policy to govern sectoral and technological specialization. Neglecting this tool 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). Although the economic theory and empirics has focused mainly of the machine-embodiment, knowledge, in all its multifaceted nature, is embodied also in the workforce with clear substantial heterogeneity depending on where labour is employed (e.g. the sector-specific technological regimes). Embodied knowledge can also be increased through learning by using (or by doing) features (Rosenberg, 1982; Andreoni, 2014). Considering labour as a generic input neglecting its (cumulative) knowledge content results in missing one side of the story. This insight is of particular importance given the unit of analysis of our interest, that is country-industry at a broad level of aggregation (2-digit). At this level of investigation, the concept of offshoring of labour cannot simply be related to strategic motivations for relocate production - spillovers or efficient reallocation of factors for instance - 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 whole productive units closing, thus loosing the productive capacity of the workforce without any efficiency result. Indeed, an important concept to bear in mind is the role of knowledge embodied in the *collective* workforce employed in a given sector, that is, assuming they are related to similar productive activities. Dismantling this collective workforce result in dissipating accumulated knowledge, capabilities, collective routines and problem-solving capacity.

2.2 Asymmetric positioning and the concept of dependence

As said in the former section, we put labour at the center of our analysis of global value (or commodity) chains hinting to what Suwandi (2019) call the *labour-value chains*. However, here we do not emphasize the Marxist embodiment of value into labour, but rather push for the embodiment of knowledge and capabilities as explained in the previous sections. In order to better frame the *positioning* in the international division of labour we rely on two further approaches. First, we want to take advantage also of the core-periphery features of dependency theory (Prebisch, 1950; Gereffi, 1994), linked also with the aforementioned structuralist perspective, that has been seen as forerunner of the global commodity chain studies emerged in the mid-1990s (Gereffi and Korzeniewicz, 1994) and of the more recent global value chains literature (Ponte et al., 2019)[2]. We refer to Santos (1970)'s argument that different forms of dependency for an economy are related not only to the

[2]Please see Kvangraven (2021) for an appraisal on how dependency research program can fruitfully engage with the rise of GVCs by also going beyond such literature

development and expansion of the other countries in the global economy, bur also to the internal structures of production, as well as to the social and political structures (see also Kvangraven, 2021). An argument similar to Prebisch (1950)'s claim that the fundamental economic problem is given by the structure of production, including the technological capacity, labour market and sectoral specialization.[3] Although dependency theory had (Latin America) 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 OECD economies and to the current state of dependence from foreign labour and knowledge common to many mature economies in which features of deindustrialization and manufacturing offshoring are by now a main characteristic.

Secondly, we also take advantage of the analysis put forward by the so-called World-systems theory (Wallerstein, 1974, 2004; Henderson, 2002; Gereffi and Korzeniewicz, 1990, 1994; Doner et al., 1991) that more explicitly drew on Marxist ideas of imperialism and capitalist exploitation (Gereffi, 1994). This school of though - less focused on productive structures and more on exchange relationships - to relate the structural position of countries and sectors in the global production network with the role played in the *hierarchical* international division of labour. 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). The main peculiarity we adopt is to focus not on the dependence position of developing countries but mainly to 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 an indicator that we call *Bilateral Net Labour Dependence*. *Bilateral* because we want to emphasise all the country-by-country trade relationships; *Net* in the spirit of GVCs positioning measures (Koopman et al., 2010; Baldwin and Freeman, 2021) which compares *backward* and *forward* linkages information; *Labour dependence* because we look at offshoring of labour which in our conjecture is an offshoring also of the knowledge embodied in the workforce results in dissipating knowledge and capabilities.

[3]The reader might correctly find similarities with Hirschman (1958)'s thesis that sectoral specialization and structural change have considerable relevance in explaining growth polarizations across local and national economies, together with the emphasis on the role of backward and forward linkages.

3 Methodology

GVCs literature generally extracts measures of vertical integration and participation to supply chains from a matrix of value added embodied in input 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 GVCs 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 the changes taking place in the productive structure triggered by inter-sectoral linkages and final demand and thus on its 'position' in terms of vertical integration or in terms of its participation to GVCs.

Although scarcely recognized, the construction of the matrix of value added in trade takes advantage of the notion of vertically integrated sectors developed in the 1970s by economist Luigi Pasinetti, as an enrichment of the so-called analysis of industrial interdependecies and specifically building upon the analytical scheme proposed by Leontief (1951) with Input-Output tables (Pasinetti, 1973, 1977; Scazzieri, 1990; Landesmann and Scazzieri, 1993, 1996; Di Berardino, 2017; Cardinale, 2018). The idea behind the theory of vertically integrated sectors is that of the existence of sequential sectoral interdependencies, i.e. over several stages of the production process, which for the sake of simplicity we can associate with the concept of a production chain (or supply chain). In order to configure this dynamic interdependence, it is necessary to divide the entire economic system into sub-parts, called subsystems, each of which produces a final good and requires, depending on a certain amount of final demand, direct and indirect inputs from every other industry integrated with it.[4]

On a theoretical ground, the algorithm of vertical integration allows to move from a *circular* industry-by-industry representation of the production process, common to standard Input-Output analysis developed by Leontief (1951), to a *vertical* industry-by-subsystem configuration. In our framework, this logical device is useful in assessing the parallel dynamics of technology, demand and structural change, originally put forward by Pasinetti (1981), bringing together an evolution-

[4] Please notice that taking into account also the indirect inputs stands exactly for the attempt to include the entire amount of intermediaries a 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.

ary attention to the heterogeneous nature of technical change and the 'structural' emphasis on the role of demand (Pianta, 2001; Antonucci and Pianta, 2002; Crespi and Pianta, 2007). As recently highlighted by Di Berardino (2017) and Antonioli et al. (2020), it can be seen as a powerful tool to overcome the traditional "horizontal" sector-based perspective of the production systems, which considers sectors as separate from one another, thus neglecting user-producer interactions. Vertically integrated sectors can be calculated from Input-Output data, starting from the well known Leontief inverse, and be used to reclassify a sector variable (as value added or employment) into a industry-by-subsystem matrix representation. In particular, we will calculate the so-called Employment Multipliers matrices (Baker and Lee, 1993; Bivens, 2003, 2019), whose coefficients inform us of the potential number of jobs generated internally and externally by each sector given a *fixed* amount of final demand in the period under consideration. We take advantage of the approach put forward by Baker and Lee (1993) and Bivens (2003) to account for the amount of 'secondary' jobs supported by single industries in an economy. In this sense, the employment multipliers we construct aim specifically to measure how one-unit variation in final demand in particular industries translates into wider employment changes throughout the economy. By taking into account final demand it is possible to measure the effective number of employees activated by true components of final demand. However, at this stage of analysis, we are mainly keeping final demand fixed, namely we consider one-unit increase per period, in order to rule out the role of demand. That is the reason why they are called multipliers. Multipliers represent a crucial part of input-output analysis with Miller and Blair (2009) devoting one entire chapter to them, as they enable to extract a considerable amount of information from an I-O table, linking variation in final demand to the repercussions through the whole productive structure. Although we refer mainly to Baker and Lee (1993) and Bivens (2003) approach, employment multipliers have been studied for instance also by Valadkhani (2005), Foster-McGregor et al. (2012) and Cresti and Virgillito (2022), among others.

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 crucial tool of 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[5]. Analytically,

[5]In Input-Output analysis, every sector (or economic branch) of the economy is assumed to produce an 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.

the starting point is always the generic available input-output matrix $\boldsymbol{Z}$ of intermediate deliveries, from which we compute 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]:

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

Consequently, the Leontief inverse matrix is built:

$$\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \tag{2}$$

With $\boldsymbol{I}$ representing the identity matrix and assuming that the inverse of $(\boldsymbol{I} - \boldsymbol{A})$ exists[7]. 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. Such matrix is crucial in moving to 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 (1) or by effective components of final demand (2):

$$\boldsymbol{E^{Mult}} = \hat{l}\,\hat{x}^{-1}\,\boldsymbol{L} \tag{3}$$

$$\boldsymbol{E^{Eff}} = \hat{l}\,\hat{x}^{-1}\,\boldsymbol{L}\,\hat{d} \tag{4}$$

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. $\boldsymbol{L}$ is the Leontief Inverse matrix and $\hat{d}$ is the diagonal matrix of final demand. Every cell of matrix $\boldsymbol{E^{Mult}}$ captures the so-called employment multipliers, i.e. the amount of employees activated in each country-industry of the supply chain - which the literature call subsystem - by a fixed amount of final demand (in our case 1 mn USD). On the contrary, the elements of matrix $\boldsymbol{E^{Eff}}$ accounts for the employees activated by the effective amount of final demand, different for every country-subsystem for each

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

[7]The Leontief inverse matrix, or 'total requirements matrix', derives from the solution of economic system described by the accounting equations put forward by Leontief (1951) where N industries are represented as a vector of outputs x and a vector of final demand d:

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

Hence, in order to have a unique solution, $(\boldsymbol{I} - \boldsymbol{A})$ needs to be singular, i.e. it depends whether or not $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ exists(Pasinetti, 1977; Miller and Blair, 2009).

year. $\boldsymbol{E}^{Mult}$ and $\boldsymbol{E}^{Eff}$ are 2408x2408 industry x subsystem matrix (56 sectors by 43 countries). We build them 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 $\boldsymbol{E}$ (either $\boldsymbol{E}^{Mult}$ and $\boldsymbol{E}^{Eff}$) 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, since we adopt global I-O tables, we want to take advantage of the richness of information they provide by emphasising bilateral trade between each couple of countries focusing on single industries/subsystems. That is, for instance, taking automotive in Italy as object of analysis, the bilateral relationship with Germany is given by the backward *bilateral* linkages - i.e. the number of employees activated in the German manufacturing industries by car (final good) production in Italy- and by the forward *bilateral* linkages - i.e. the amount of labour in Italian automotive sector *provided* (i.e. embodied in the intermediaries sold) to the German manufacturing subsystems. Given H (J) the number of manufacturing industries (subsystems) for every country, we define backward and forward bilateral measures as:

$$\text{Backward Bilateral} = \sum_{h=1}^{H} e_h \;\; \text{Forward Bilateral} = \sum_{j=1}^{J} e_j$$

Merging this two information we can obtain a measure of GVCs positioning, which combines - as a ratio - backward and forward linkages, for every bilateral trade between industry/subsystem i in country c and country k.

$$\text{GVCs positioning}_{i,c;k} = \frac{\text{backward bilateral}}{\text{forward bilateral}} = \frac{\sum_{h=1}^{H} e_h}{\sum_{j=1}^{J} e_j} \tag{5}$$

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 the 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:

$$\text{BNLD}_{i,c} = \ln\left(\sum_{k=1}^{n-1} \text{GVCs positioning}_{i,c;k}\right) \tag{6}$$

Where k is a generic country with which industry/subsystem i in country c trades. This measure accounts for all the specific bilateral GVCs positioning in the international division of labour.

Since we can decide whether to include final demand or not, we present two measures of BNLD: with multipliers ($BNLD^{Mult}$) or with effective ($BNLD^{Eff}$) values. We thus end up with 2 indicators, although so far we use only the one in multiplier for the econometric investigation. We compute them for every manufacturing sector in each of the 43 countries of WIOD. We will argue that BNLD in multipliers specifically account for the loss of knowledge and capabilities displaying a negative relationship with labour productivity. BNLD in effective values gives importance to the market positioning, as the labour requirements are activated by heterogeneous subsystem- and country-specific final demands. In different ways they can be used to address asymmetric (dominant vs. dependent) positioning in GVCs, i.e. in the international division of labour, i.e. weak or strong ties in the international division of labour, likely reflected in weak or strong sectoral performances. Furthermore, it could be useful to normalize between 0 and 1 such indicators (BNLD in multipliers and effective values).

The economic meaning of this indicator is the following. If BNLD increases it might be due to an overall rise in the backward bilaterals or to an overall decline in forward bilaterals (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 registers an increasing net dependence from foreign labour, that is labour not related to activity performed within the national boundaries. As anticipated, we adopt two indicators (in multipliers and effective values) as we aim to detect two different effects. In this paper we argue that a rise in BNLD in multipliers specifically account for a loss of knowledge and capabilities. BNLD in multipliers considers a fixed amount of final demand for every country-subsystem that activates all the labour requirements in the supply chain, while BNLD in effective values takes into account the true amount of final demand which are obviously heterogeneous among countries and subsystems.

3.1 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 a 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 then we omit only rows and columns belonging to Rest of the World (RoW), which should represent and summarise the economies not included in the 43 countries in WIOD. We exclude RoW as SEA does not contain available information on sectoral variables of interest as employment. We end up with a 2408x2408 matrix.[8]

4 Descriptive Statistics

Before investigating the cross-sectional and time dimension of BNLD, we found useful to simply plot in a map backward and forward bilateral linkages, taking Automotive in Italy and 2014 as reference. Figure 1 shows the amount of labour inputs Italian automotive requires from various countries in the world in multiplier terms. In contrast, Figure 3 shows the amount of labour that Italian automotive delivers as input to the final productions of the various countries in the world, again in multiplier terms. We also plot the focus on European countries as it presents some heterogeneity between backward and forward (see Figures 2 and 4). In appendix the reader can find also the plots in effective terms (see Figures 13 and 14). The two supply and demand perspectives emerge clearly, as China and India, for instance, are delivering huge 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 propose it for the automotive sectors of Germany,

[8] 2408 stands for the 56 sectors in the 43 countries. As said, SEA's variables for Rest of the World are not available, hence we omit it from the Leontief before computing the employment multipliers matrix. Please also notice that we decided to use Number of persons engaged instead of standard Number of employees (both available in SEA) mainly because the latter was missing information on China.

USA and China. Specific bilateral relationships emerge from this evidence, in line with our concern about highlighting them in measures of GVCs positioning.

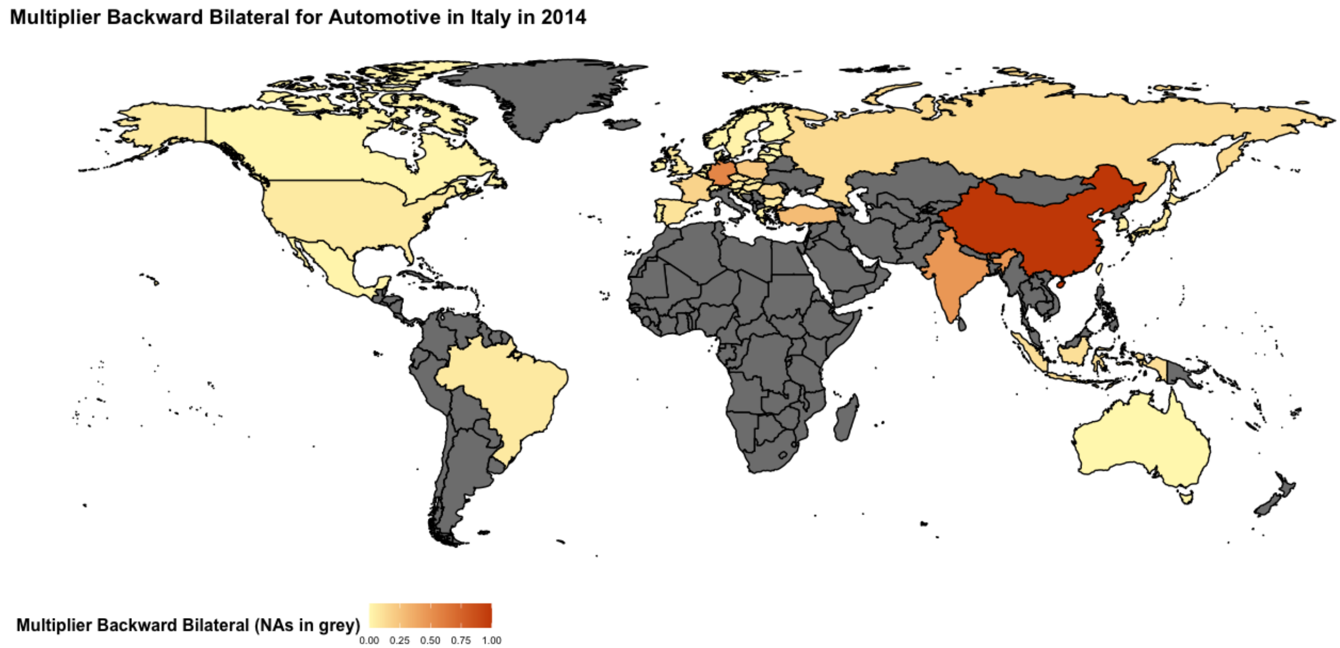

Figure 1: **Multiplier** Backward Bilaterlal: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of Italian automotive subsystem.

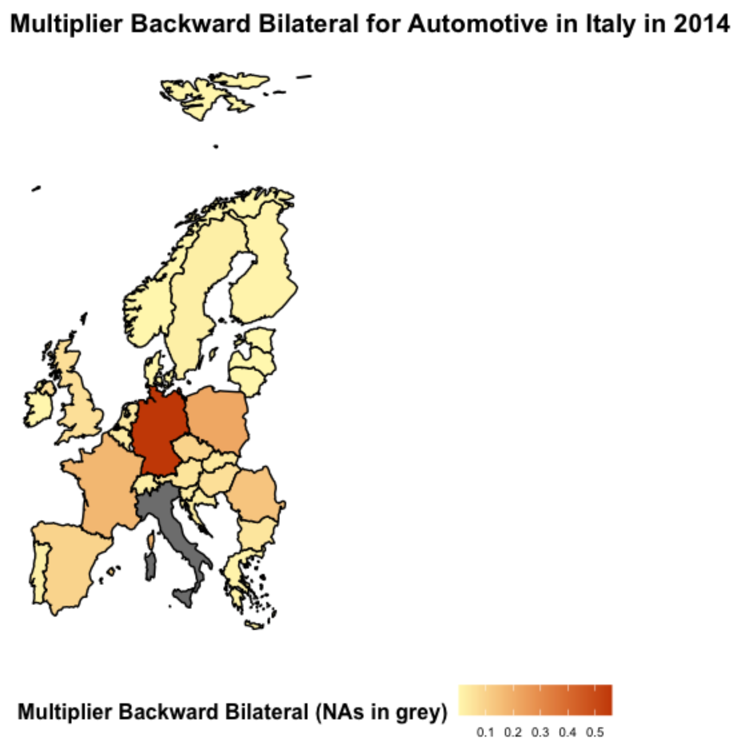

Figure 2: **Multiplier** Backward Bilaterlal: employees activated in 2014 in the European countries in order to produce 1 mn USD of final commodity of Italian automotive subsystem.

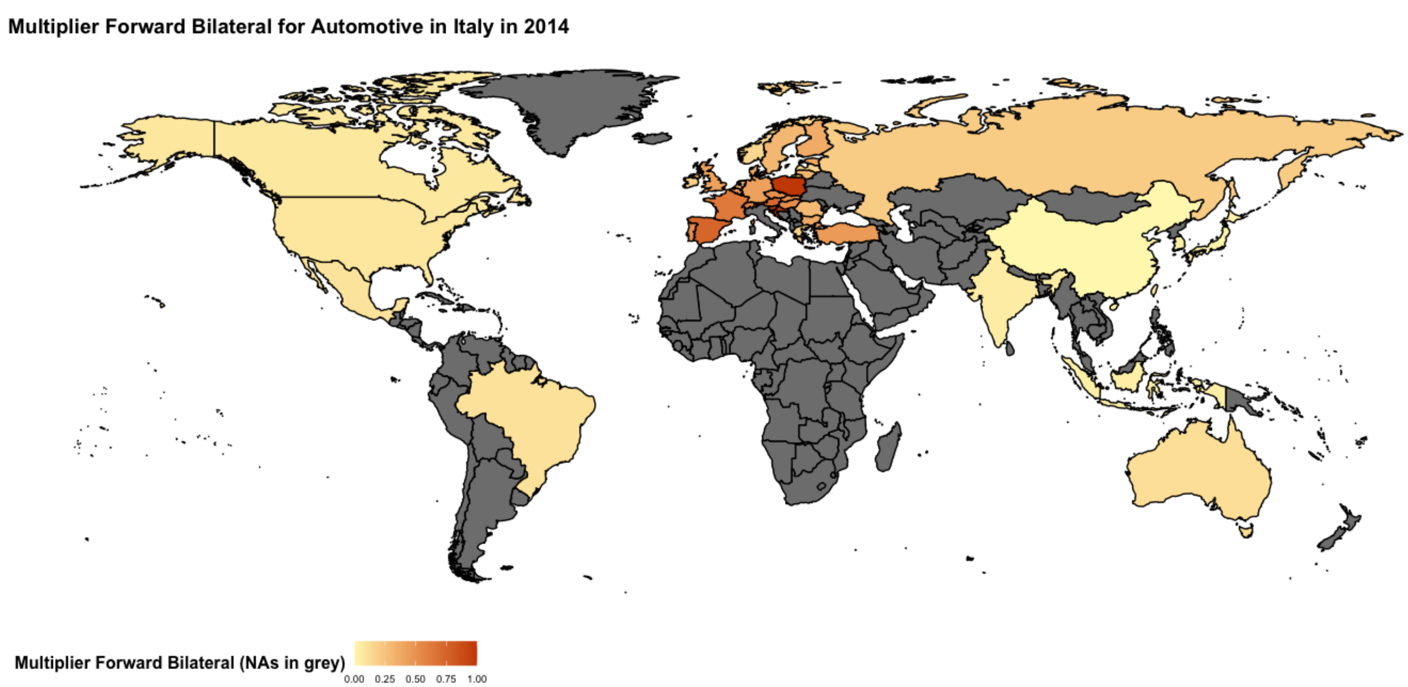

Figure 3: **Multiplier** Forward Bilaterlal: employess provided in 2014 to the (43-1) WIOD countries by Italian automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

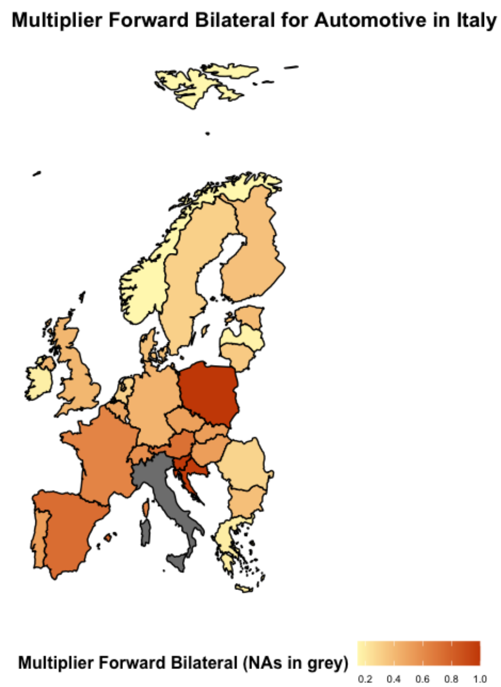

Figure 4: **Multiplier** Forward Bilaterlal: employess provided in 2014 to the European countries by Italian automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

Coming to the main indicator, we plot the ranking for the top 20 country-subsystem, in 2014 again for BNLD in effective (Figure 5) and multiplier (Figure 6) values. One clear difference detected between effective and multiplier versions of BNLD is that in the former there is more heterogeneity in terms of countries in the top 20 of the ranking (developed vs. developing, big vs small), while in the latter only small less relevant economies are presenting highest values (as Cyprus, Estonia, Ireland, Luxembourg, Malta). These countries register huge bilateral net labour dependence in multiplier values which could be explained by a lack of a proper industrial sector, thus importing lots of inputs from abroad that embodies labour (and thus knowledge following our reasoning). Figure 5 tells us also that displaying values in effective terms leads to a dominant presence of automotive and pharmaceutical subsystems, which both register a size effect in GVCs. However, nor German or US subsystems are present here, meaning that these countries accounts for less dependence from foreign labour.

We also show the ranking within four countries of interest (China, Germany, Italy and USA) again both for effective (Figures 7 and 8) and multiplier (Figures 9 and 10) values and normalized in [0,1]. Here we highlight the Pavitt class of belonging in order to appreciate also the technological dimension of bilateral net labour dependence.[9] For instance, in Figure 10 by looking at BNLD multiplier ranking for Italian subsystem we detect a more prominent role for upstream Pavitt (SB and SS) with respect to other countries. This might hint to a weak positioning in the international division of labour also in terms of strategic high-tech productions. This is in line with recent findings on Italy (Cresti and Virgillito, 2022).

Thirdly, we present the time trend of BNLD in multiplier (light blue line) and effective (red line) values for Pharmaceutical (Figure 11) and Automotive (Figure 12) in the usual four selected

[9]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, revised by Bogliacino and Pianta (2010, 2016) to account for services, 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 provides 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 the design of artefacts and in the customization.
- Scale and Information Intensive (e.g. Automotive), in which innovation capabilities arise from the 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 and services and consumer durables.
- 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.

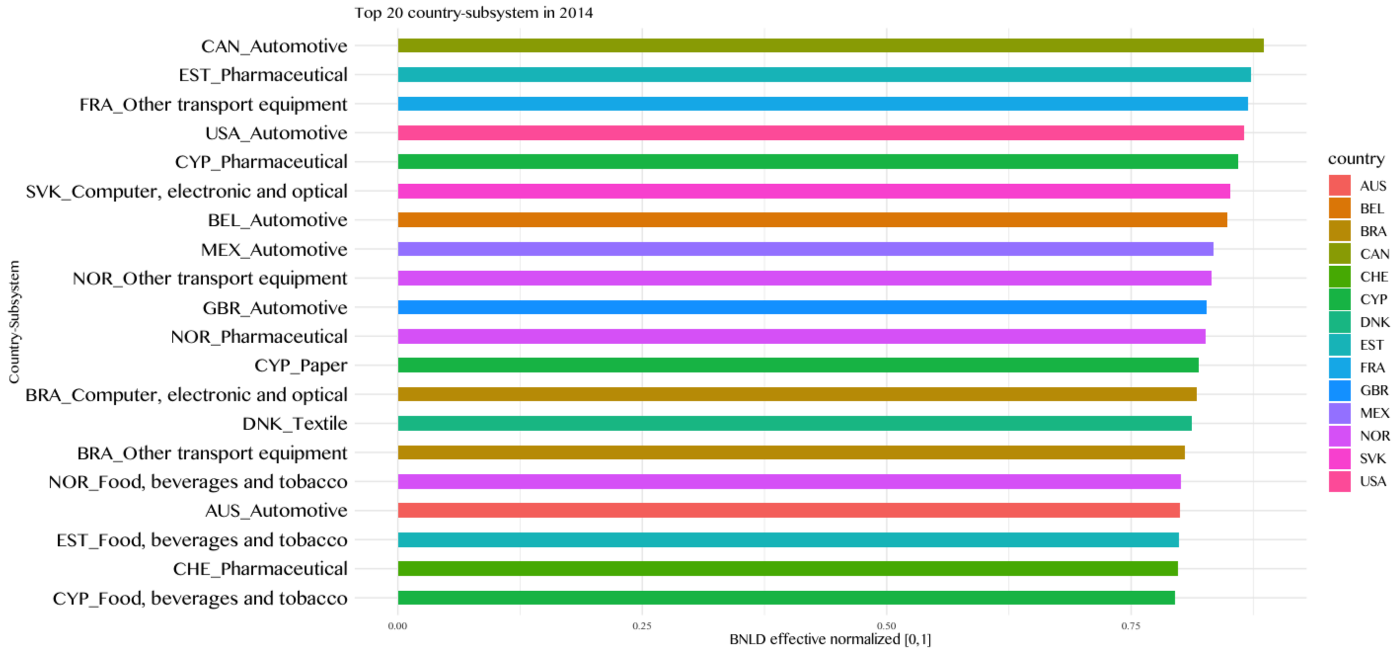

Figure 5: Top 20 in BNLD **effective** normalized in [0,1]

countries (China, Germany, Italy and USA). We focused on Pharmaceutical and Automotive as they have shown a considerable size effect in supply chains. BNLD multiplier (blue line) seems to show a general increase in trend in all countries excluding China, hence a positive dynamics for Bilateral Net Labour Dependence, which entails being more dependent from labour abroad. On the contrary, effective BNLD displays heterogeneous trends, with an overall decline untill 2008 and then a slight rise. These more fluctuating dynamics might be driven by varying final demands that triggers subsequent demand for labour.

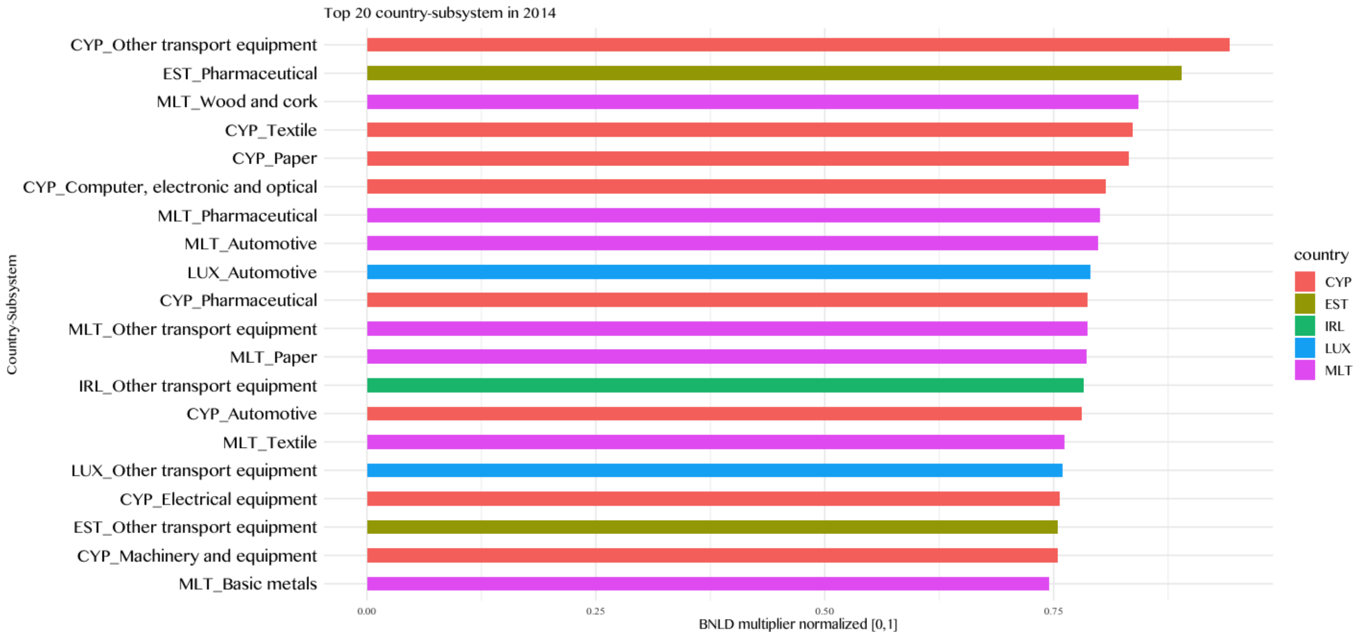

Figure 6: Top 20 in BNLD **multiplier** normalized in [0,1]

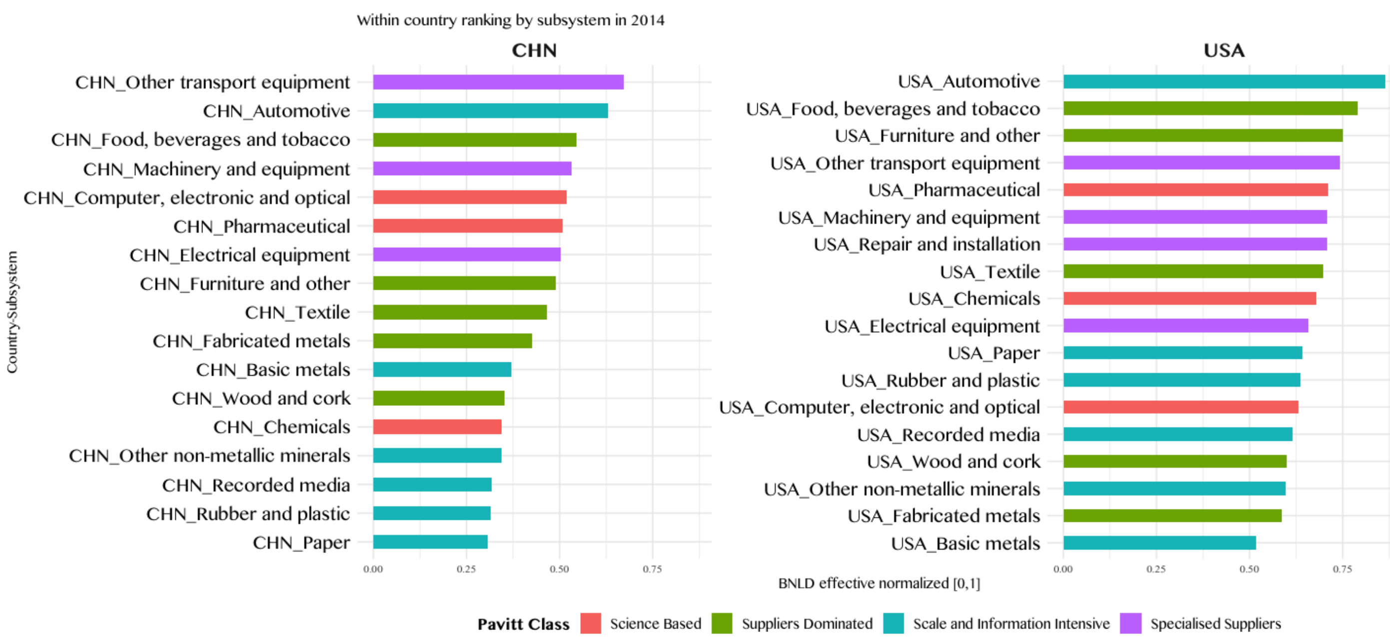

Figure 7: Ranking in BNLD **effective** normalized in [0,1] in China and Usa. Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD).

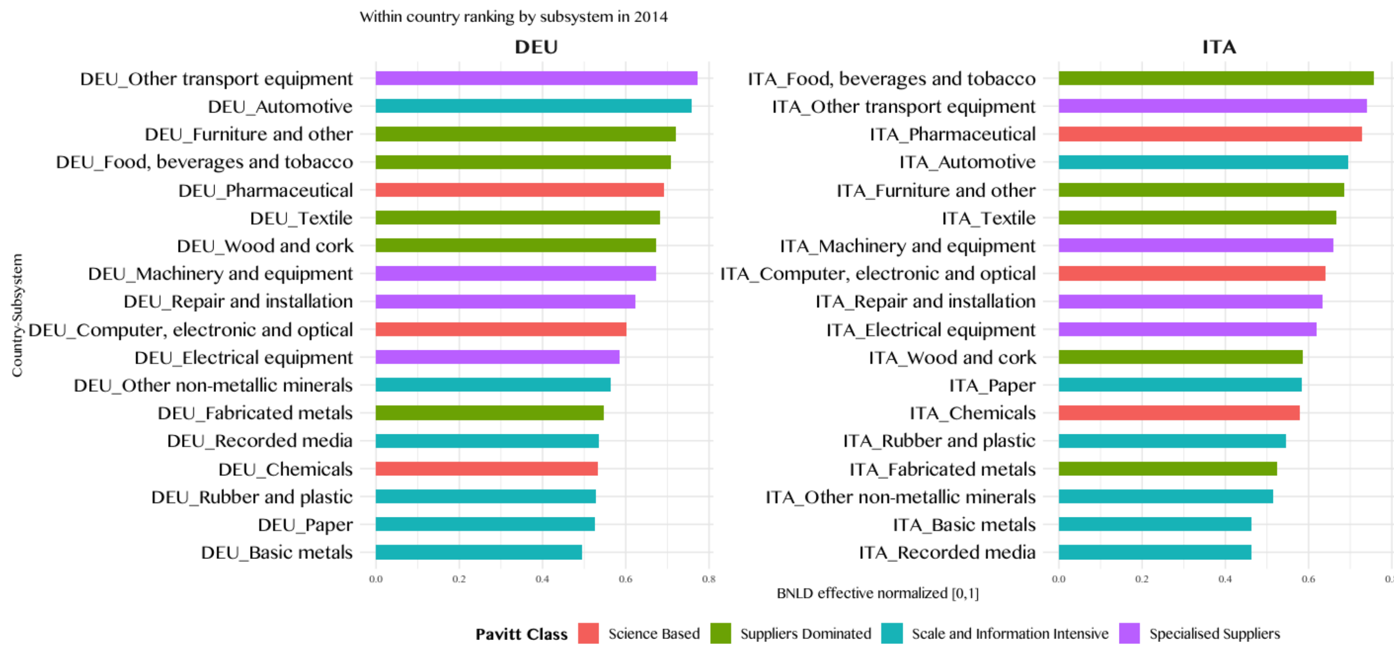

Figure 8: Ranking in BNLD **effective** normalized in [0,1] in Germany and Italy. Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD).

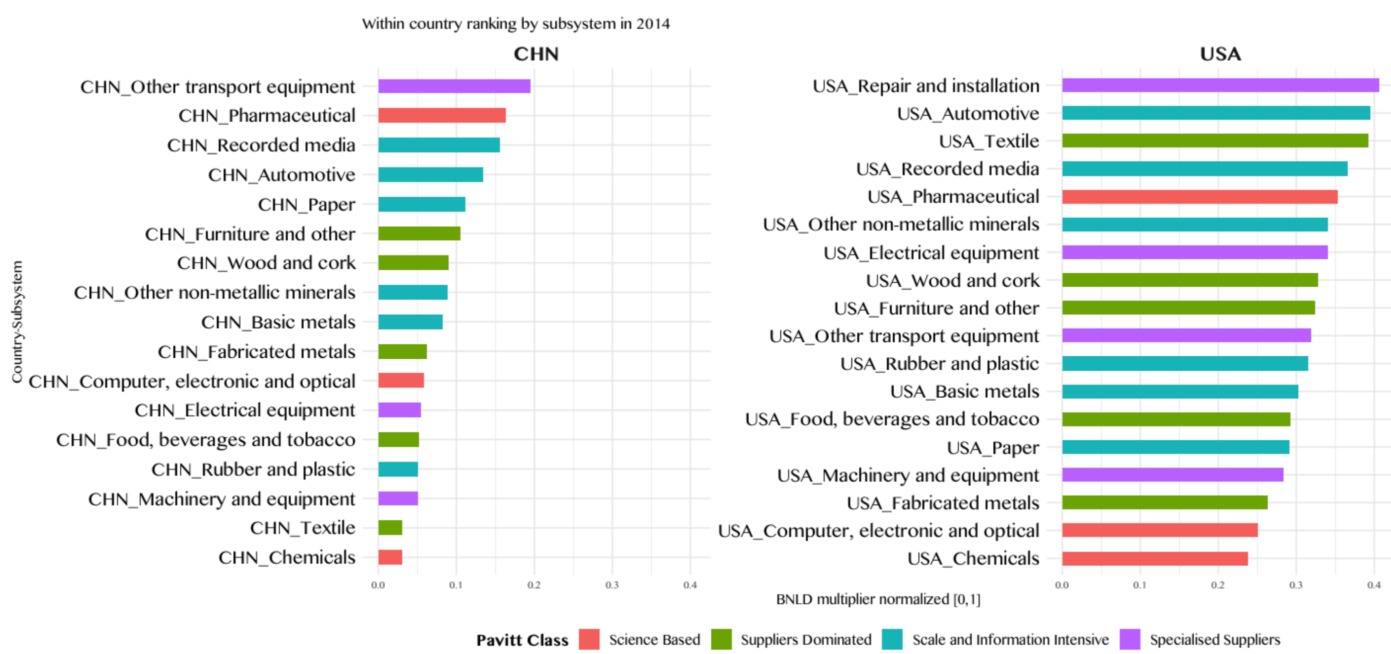

Figure 9: Ranking in BNLD **multiplier** normalized in [0,1] in China and Usa. Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD).

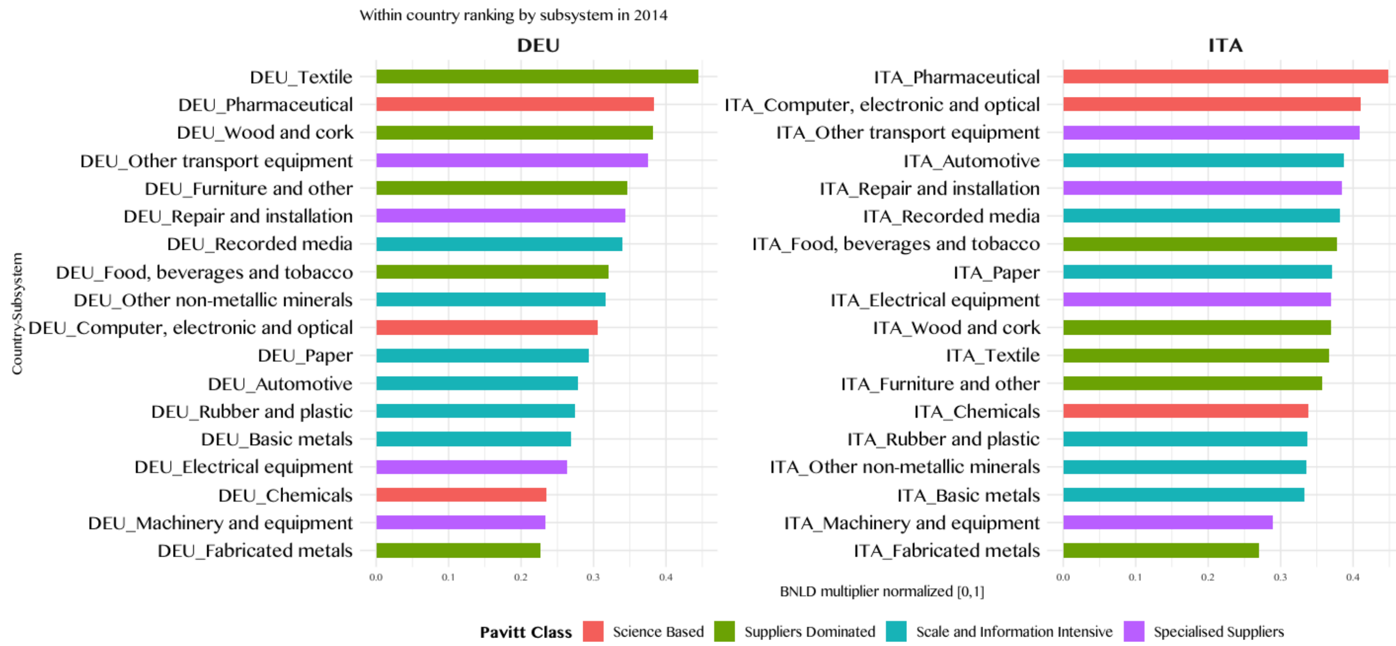

Figure 10: Ranking in BNLD **multiplier** normalized in [0,1] in Germany and Italy. Pavitt classes are: Science Based (SB), Specialised Suppliers (SS), Scale and Information Intensive (SII) and Suppliers Dominated (SD).

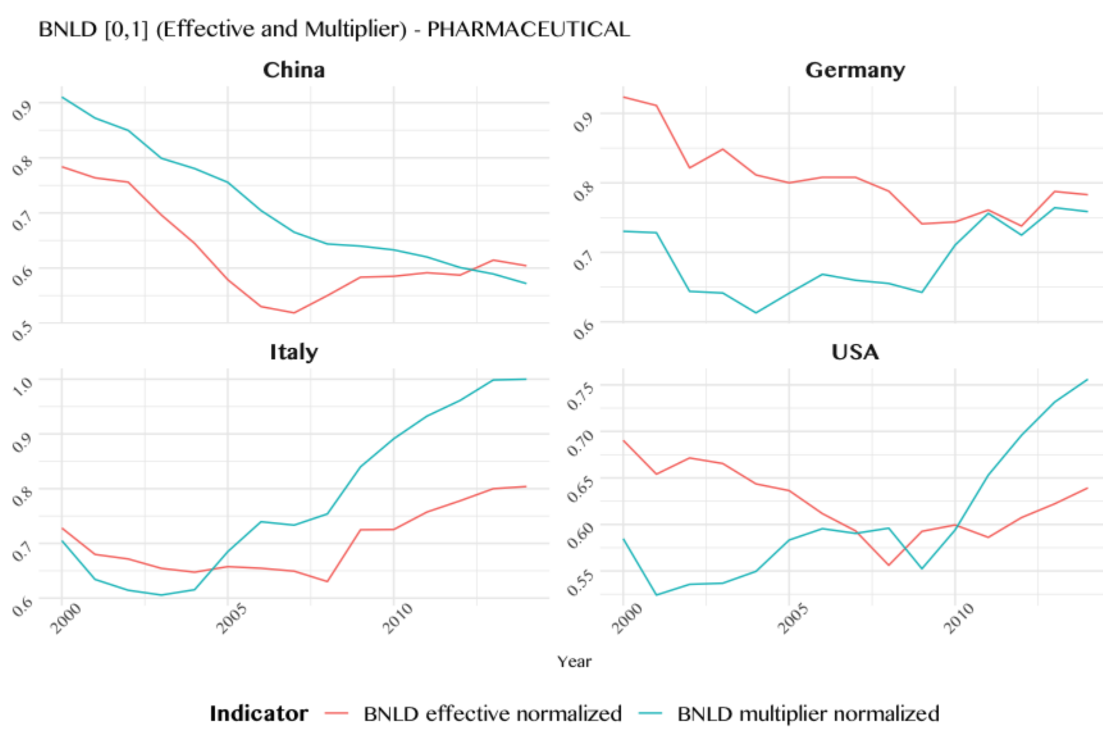

Figure 11: Trend in BNLD normalized [0,1] (multiplier and effective) for Pharmaceutical in selected countries.

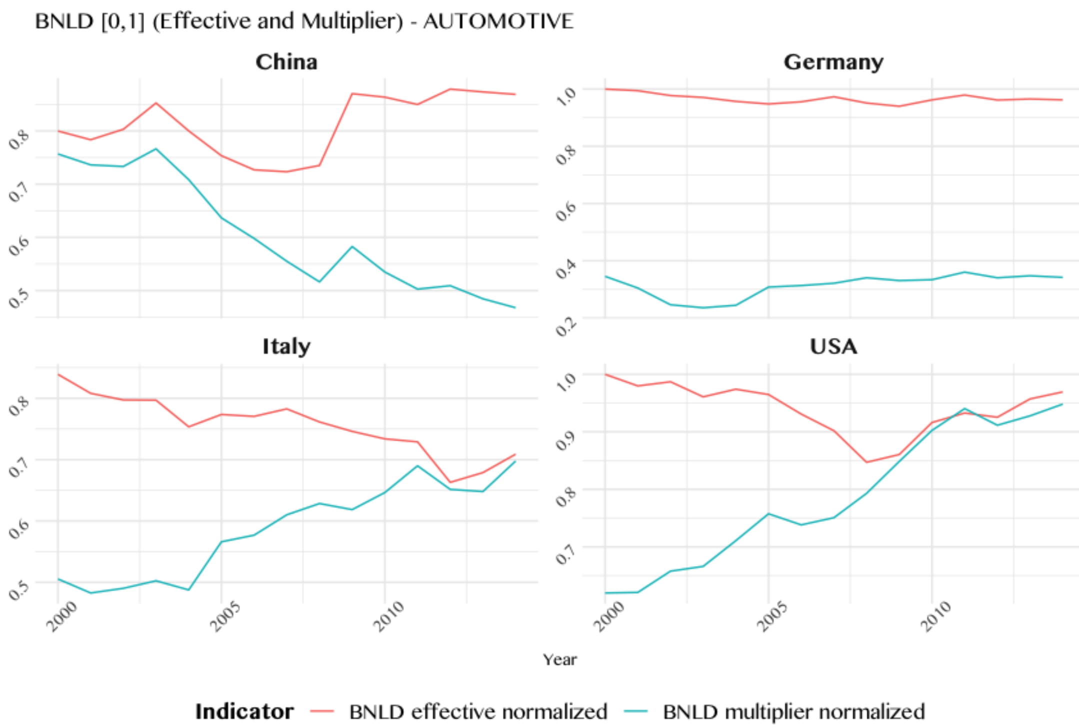

Figure 12: Trend in BNLD normalized [0,1] (multiplier and effective) for Automotive in selected countries

5 Econometric specification and estimation technique

The literature has addressed the productivity-GVCs participation nexus by means of a simple econometric specification, with producivity in levels, explanatory variables lagged, a battery of fixed effects and various controls, mainly related to capital intensity and intangible assets. We build upon these insights and propose our specification with $BNLD^{Mult}$ as main explanatory variable. Focusing on WIOD and SEA databases, a list of possible variables can be found in Table 1. In appendices, Tables 6 and 7 show correlation matrix and descriptive statistics of the variables used so far.

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

Table 1: List of possible country-sector variables. The sectoral availability is always at two digit manufacturing industries. See Table 8 in the appendix.

Since we find that labour productivity is highly persistent through time, we include the lagged version on the right-hand-side of the equation and alternatively we shift it on the left-hand-side thus estimating also the first difference. As a result, preliminary specifications could take the following form with dependent variable in levels and in first differences:

$$LP_{i,t} = \alpha LP_{i,t-1} + \beta_1 BNLD^{Mult}_{i,t-1} + \beta_2 KE_{i,t-1} + \beta_3 FD_{i,t-1} + \beta_4 W_{i,t-1} + \varepsilon_i + \delta_t + \mu_{i,t}, \quad \text{where } t = 2000,...,2014,\ i = 1,...,612 \tag{7}$$

And:

$$\Delta LP_{i,t} = \alpha + \beta_1 BNLD^{Mult}_{i,t-1} + \beta_2 KE_{i,t} + \beta_3 FD_{i,t} + \beta_4 W_{i,t} + \varepsilon_i + \delta_t + \mu_{i,t}, \quad \text{where } t = 2000,...,2014,\ i = 1,...,612 \tag{8}$$

Where $LP_{i,t}$ is labour productivity (gross output over number of persons engaged) in levels, ΔLP is labour productivity in differences, $BNLD^{Mult}$ (normalized to stay within [0,1]) is our main explanatory variable, KE is capital per employee, FD is final demand and W is average wage. All variables are expressed in log terms. Time dummies and country-industry fixed effects are included as well. In both equations we expect a negative relationship of lagged $BNLD^{Mult}$

with LP or ΔLP proxing a dependence positioning in the international division of labour.

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 and in particular 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). An easy solution entails lagging the explanatory variables, as we do. However, looking at Figure 6 we can see that the sectors most dependent from foreign labour are not specifically the most productive ones. Hence we might suffer less from this bias. The omitted variable bias is often tackled by including a battery of fixed effects and by adding control variables related to capital investments and stock, while wages and final demand are usually not included. Education, R&D, intangibles and interaction terms are often included as well (Tsakanikas et al., 2020). Moreover, as we add the lagged dependent variable in eq (7), another form of endogeneity might occur. In this case usual solutions lead to IV or SYS-GMM. Concerning multicollinearity issue, we have run Variance Inflation Factors (VIF) analysis, in addition to standard correlation matrix (see Table 6). VIF test detected possible multicollinearity in lagged labour productivity and in lagged average wage, which show also a considerable correlation coefficient between the two. Removing average wage (as we want to keep lagged productivity in order to capture the persistent dynamics of the dependent variable) lead to Variance Inflation Factors always lower than 5, which make us more confident of the robustness of the estimation. We kept average wage as a control in the estimation results we present, but bearing in mind this issue.

Table 2 and 3 display Fixed Effect estimations with dependent variable in levels (LP_t) and lagged dependent among regressors (LP_{t-1}) and in differences (ΔLP_{t-1}). In both cases FE (1) to FE (8) represent possible baseline specifications with $BNLD^{Mult}$ always as main explanatory variable and varying the three controls to check if the sign and significance of main explanatory variable are kept. China, Brazil, Indonesia, India, Mexico, Cyprus, Malta, Russia and Luxembourg represent possible outliers (especially small economies and China) are removed from the sample and included again only in FE (9) as a check. $BNLD$ multiplier is always detected with a significant negative coefficient as expected and the result is confirmed in various checks. In the regression in levels, the magnitude of its coefficient is quiet stable, ranging from -0.624 to -0.766, with average wage (W) as the control that reduces $BNLD$ coefficient most. On the contrary, capital per employee (KE) seems not to influence $BNLD$ coefficient. We perform Likelihood-ratio test and Wald test to assess the relevance of each explanatory variable. The former highlights that only KE seems not to improve the model when added in FE (2). The latter confirms this result bu also seems to suggest that adding FD in FE (5) and in FE (3) is also not really improving the estimation. Concerning the regression in difference, the coefficient of $BNLD$ is ranging from -0.728 to -1.052. Again, $BNLD$ coefficient is mostly reduced when W is included. In this specification nor the Likelihood-ratio test or the Wald test are suggesting to exclude any specific variable.

In Table 2 KE and FD are detected with positive signs, although only KE is significant and only in FE (7), hinting to a role for short-term demand in a Kaldor-Verdoorn flavor (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) and it is generally significant. $BNLD$ is always negative and significant. On the contrary when dependent variable is in differences (Table 3), coefficients of KE, FD and W are detected with negative values and larger significance, hinting to a possible anchoring effect to growth rate of labour productivity.

Table 2: 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)
$BNLD_{t-1}^{Mult[0,1]}$	-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) excludes developing or small countries and China. FE (9) includes all WIOD countries

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

Table 3: 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)
$BNLD_{t-1}^{Mult[0,1]}$	-1.032*** (0.200)	-0.867*** (0.186)	-0.895*** (0.185)	-0.746*** (0.166)	-1.052*** (0.204)	-0.728*** (0.170)	-0.732*** (0.172)	-0.744*** (0.165)	-1.001*** (0.148)
KE_{t-1}		-0.153*** (0.0117)	-0.143*** (0.0113)	-0.0409*** (0.0149)			-0.0478*** (0.0158)		-0.0875*** (0.0183)
FD_{t-1}			-0.0279*** (0.0104)	-0.0177* (0.0106)	-0.0505*** (0.0102)			-0.0194* (0.0109)	-0.0181** (0.00893)
W_{t-1}				-0.202*** (0.0224)		-0.241*** (0.0149)	-0.198*** (0.0208)	-0.239*** (0.0148)	-0.101*** (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

6 Concluding remarks

This work, although at a preliminary stage, seeks to contribute in an original way to the literature investigating the link between GVCs participation and productivity. The gap identified in the literature is twofold: i) the global fragmentation of labour is a neglected dimension, while we argue that it is crucial as workforce embodies knowledge, thus offshoring labour might result in a loss of productive capacity eventually detrimental for country and sectoral performances; ii) the bilateral interdependencies are ignored, while we know that, although we refer to global chains, trade takes mainly place between specific countries. Our contribution tries to fill this gap by proposing an indicator of Bilateral Net Labour Dependence, aimed at capturing asymmetric positioning of country-sector in in the international division of labour (and thus of knowledge). The descriptive evidence provided seems to offer a picture of this measure as able to show such weak positions both in cross-sectional and in temporal perspectives. The last part of the paper is a contribution in line with the literature of GVCs as we estimate the relationship of BNLD in multiplier terms with labour productivity. We detect a negative and significant coefficient that make us confident of the measure we constructed. However there are limitations for the analysis performed so fare and extensions to complete the paper and make it more robust and coherent.

First of all, as we are proposing a dynamic panel analysis, we might adopt a System GMM estimation in order to be on a safe side concerning the robustness and reliability of results, properly addressing endogeneity problems. Secondly, we could take again inspiration from the literature and add further controls to avoid omitted variable bias, together with some interaction term as proposed in Tsakanikas et al. (2020). We could also investigate the relationship between BNLD in *effective* terms and productivity. From the evidences shown in the appendix we could guess of a positive link, but more conceptual effort should be devoted here to disentangle the various effect of final demand and technical change. In principle, we could use it in two ways: i) as a robustness indicator in alternative to BNLD in multiplier but it displays very heterogeneous patterns among countries and sectors likely resulting in an ambiguous effect on productivity; ii) as a proxy of market positioning, thus giving emphasis to the role of final demand, but again its effect would be mixed with others.

Another improvement might come from the exploitation of Pavitt Taxonomy also in the construction of BNLD indicator, namely having labour dependence in relation to specific Pavitt classes. This could represent a way to better qualify labour (and thus the knowledge embodied). Alternatives could be to disentangle employment by occupation or to highlight the so-called functional specialization in trade. Concerning the data, it would be necessary to replicate the analysis with constant price I-O tables and variables to check the role of price dynamics, as well as try to use other database. For instance the OECD ICIO tables (2021 Release) could be useful to enlarge the time span and especially to include more developing countries (e.g. from South-East Asia), thus capturing further relevant bilateral interdependencies. Lastly, we could think of different dependent variables capturing the performance of sectors in order to have a better proxy for the loss of knowledge and capabilities as a result of delocalization of labour and disentangling the effect from mere technical progress.

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Appendices

We present here some further evidence on the measures we computed. First of all, Figure 10 and 11 present backward and forward bilateral for automotive in Italy in effective terms. Results are in line with the evidence in multiplier terms, but here the role of Germany in requiring Italian labour is emphasised due to the demand effect of German car productions. Figures 12 to 17 show instead the maps of backward and bilateral multipliers for automotive of Germany, USA and China. The specific bilateral relationships we referred to in the paper here emerge clearly.

Then we present the density distribution in 2014 for multiplier (light blue) and effective (rose) values (Figure 21), also displayed disaggregated by subsystem (Figure 22). Here BNLD is normalized to stay within the range [0,100] to better appreciate the distribution of values. Figure 24 shows the correlation between BNLD in multiplier values normalized by [0,1] (Figure 20) 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. On the contrary, as Figure 23 seems to suggest, BNLD effective could be a determinant of positive sectoral performances as it captures a 'demand-side' market positioning by giving emphasis on the effective amount of final demand. Next steps of investigation might include an analysis of the role of $BNLD^{Eff}$ for productivity. These scatter plot refer to 2005 as an example and observations are plotted by highlighting different sectoral belonging. We have removed China, Brazil, Indonesia, India, Mexico, Cypro, Malta, Russia and Luxembourg which are either outliers or developing countries that we exclude from the econometric estimation.

Lastly, we provide correlation matrix (Table 6) and descriptive statistics (Table 7) of the variables used in the econometric analysis, together with the lost of sectors (Table 8) and countries (Table 9).

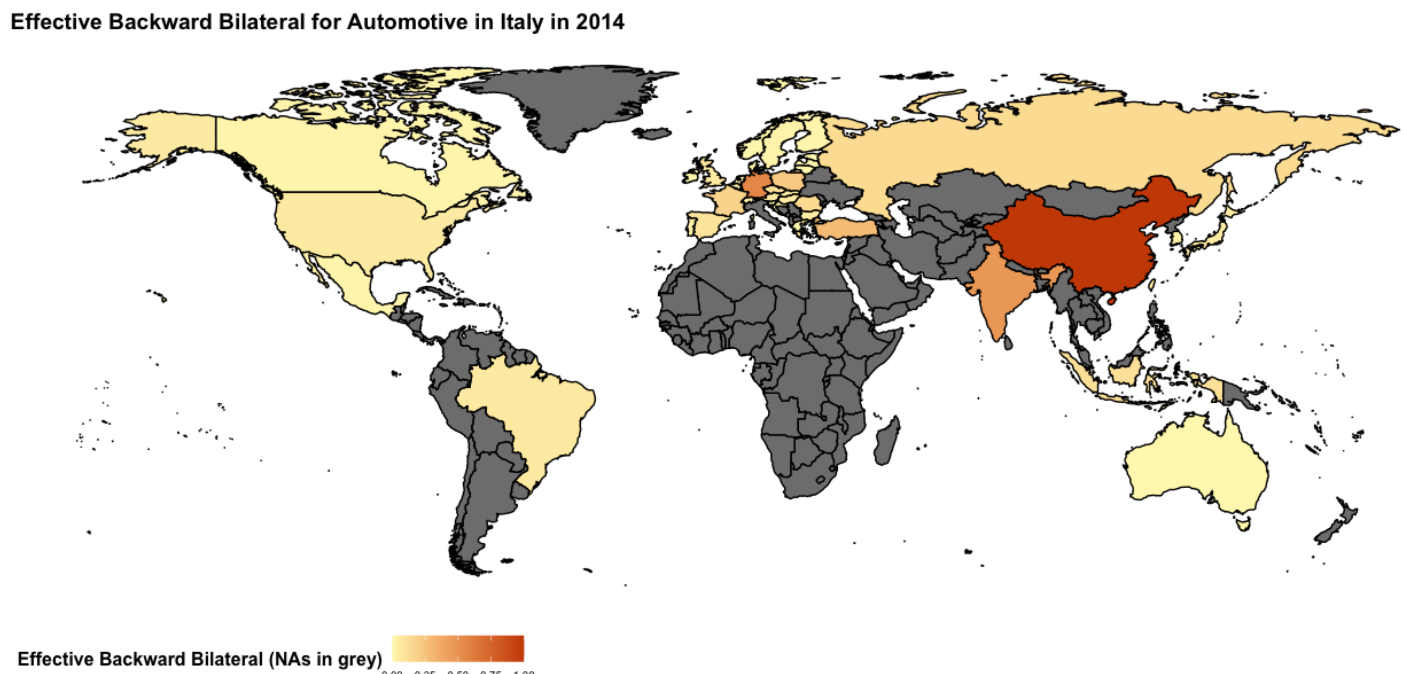

Figure 13: **Effective** Backward Bilaterlal: employees activated in 2014 in the (43-1) WIOD countries in order to produce effective amount in USD of final commodity of Italian automotive subsystem.

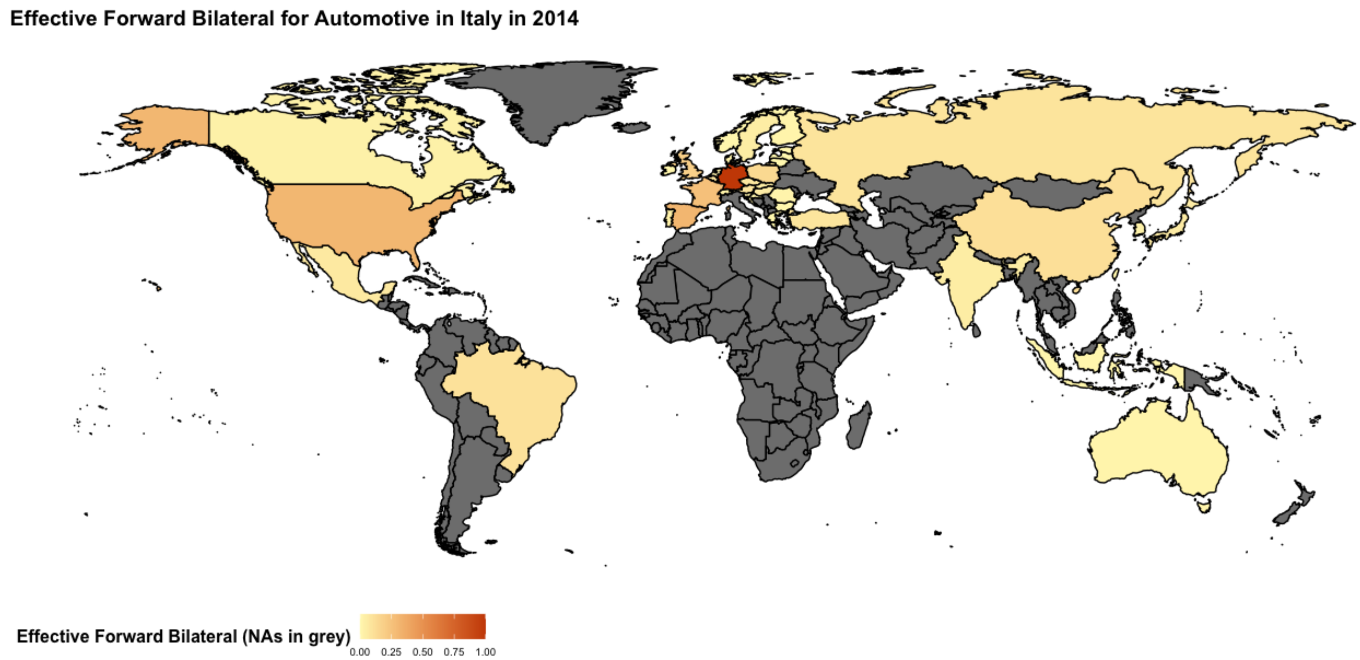

Figure 14: **Effective** Forward Bilaterlal: employess provided in 2014 to the (43-1) WIOD countries by Italian automotive industry in order to produce effective amount in USD of the various final commodities in the subsystems in the world.

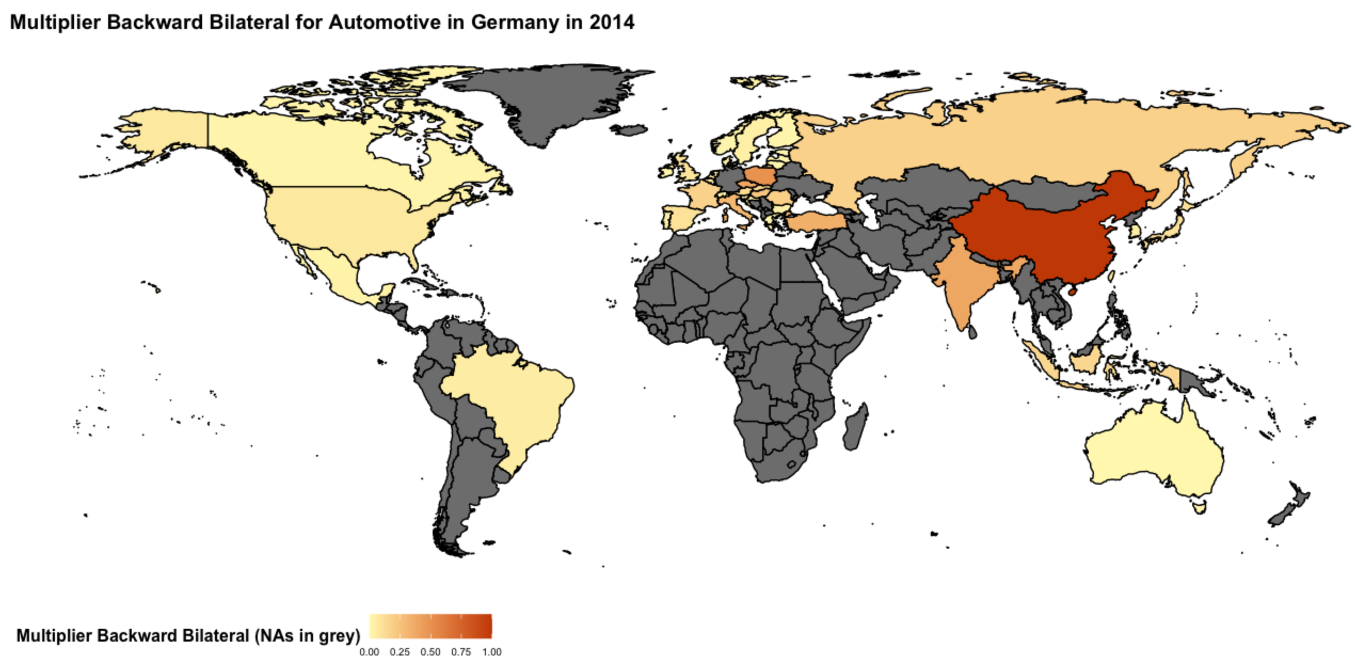

Figure 15: **Multiplier** Backward Bilaterlal: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of German automotive subsystem.

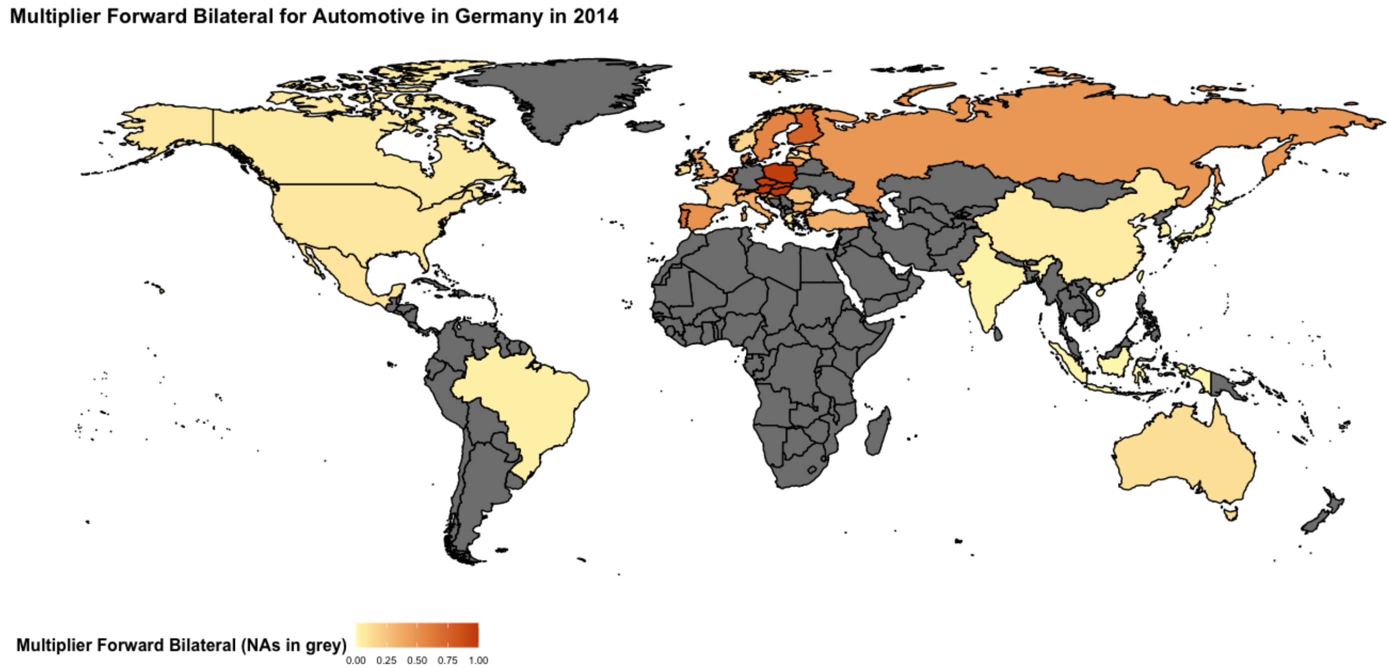

Figure 16: **Multiplier** Forward Bilaterlal: employess provided in 2014 to the (43-1) WIOD countries by German automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

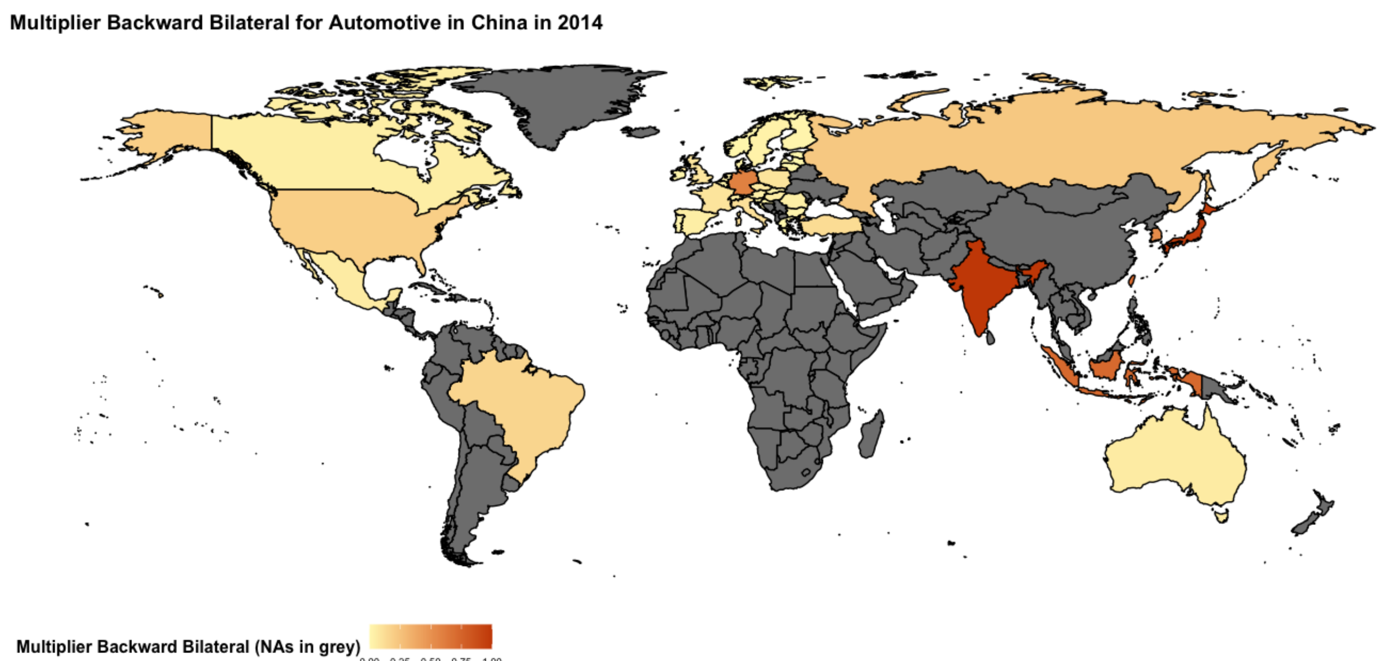

Figure 17: **Multiplier** Backward Bilaterlal: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of Chinese automotive subsystem.

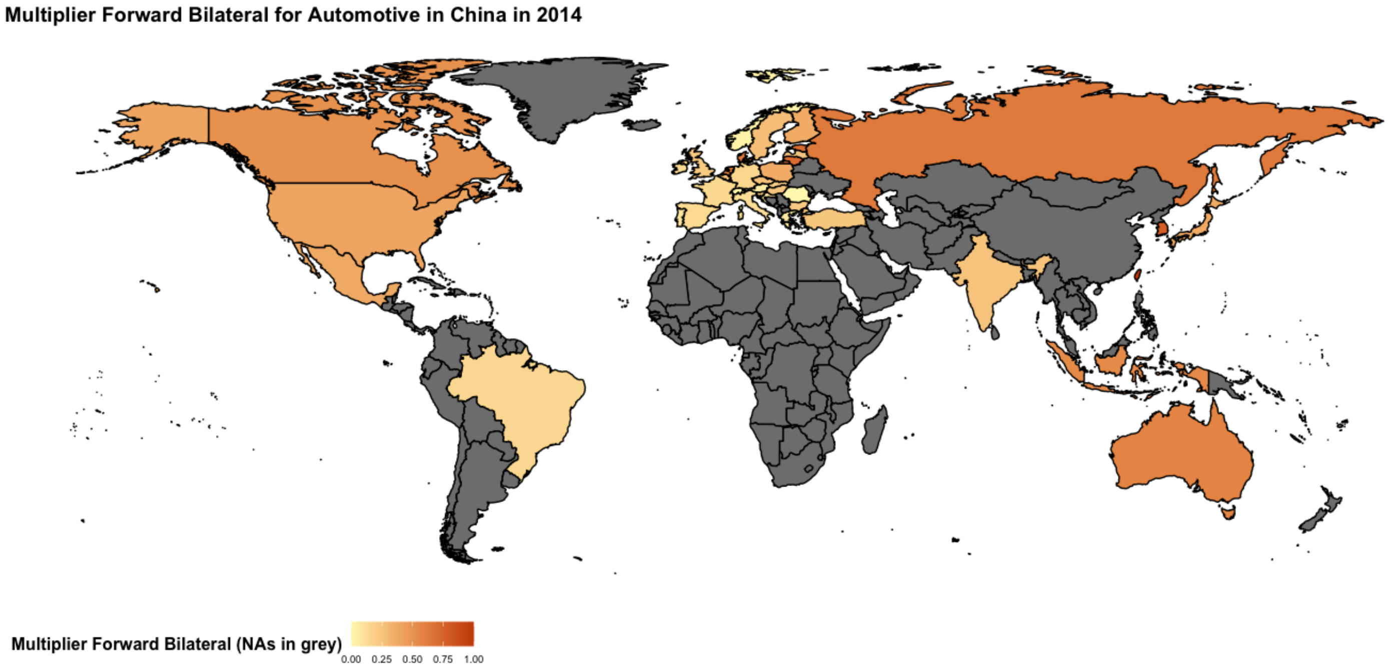

Figure 18: **Multiplier** Forward Bilaterlal: employess provided in 2014 to the (43-1) WIOD countries by Chinese automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

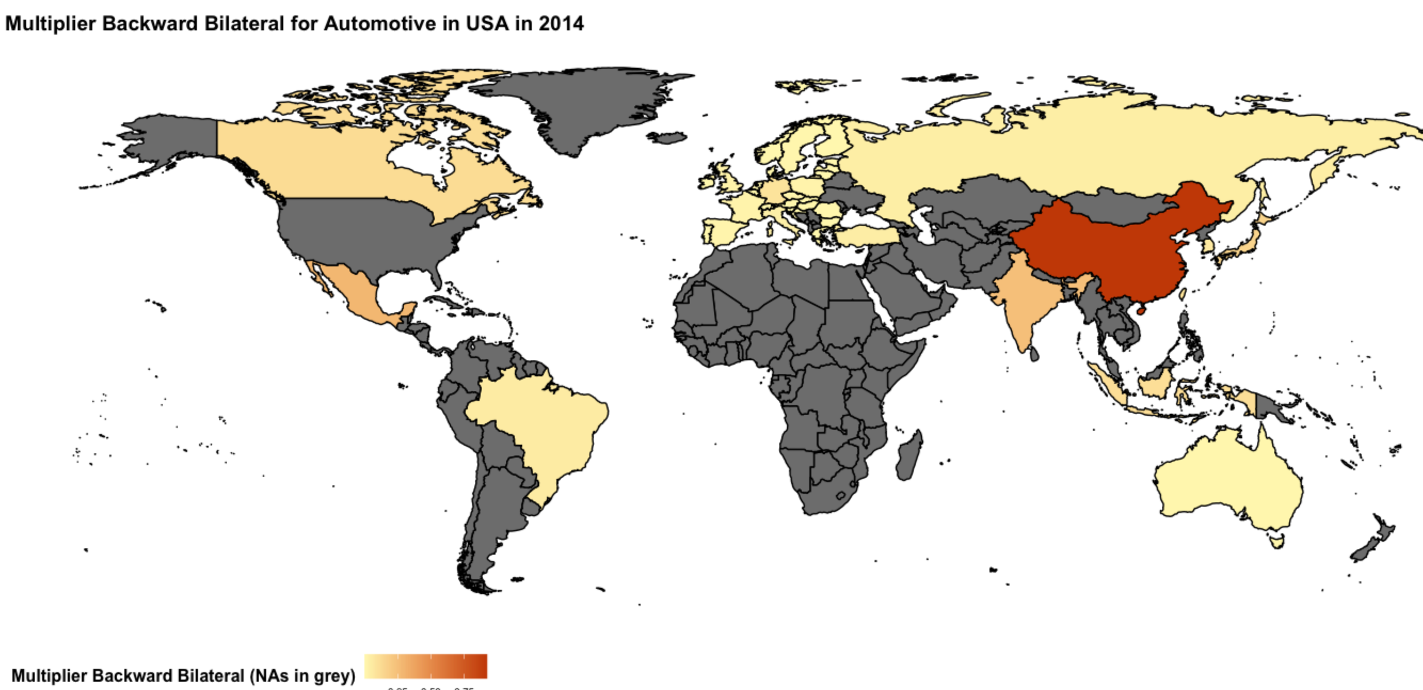

Figure 19: **Multiplier** Backward Bilaterlal: employees activated in 2014 in the (43-1) WIOD countries in order to produce 1 mn USD of final commodity of US automotive subsystem.

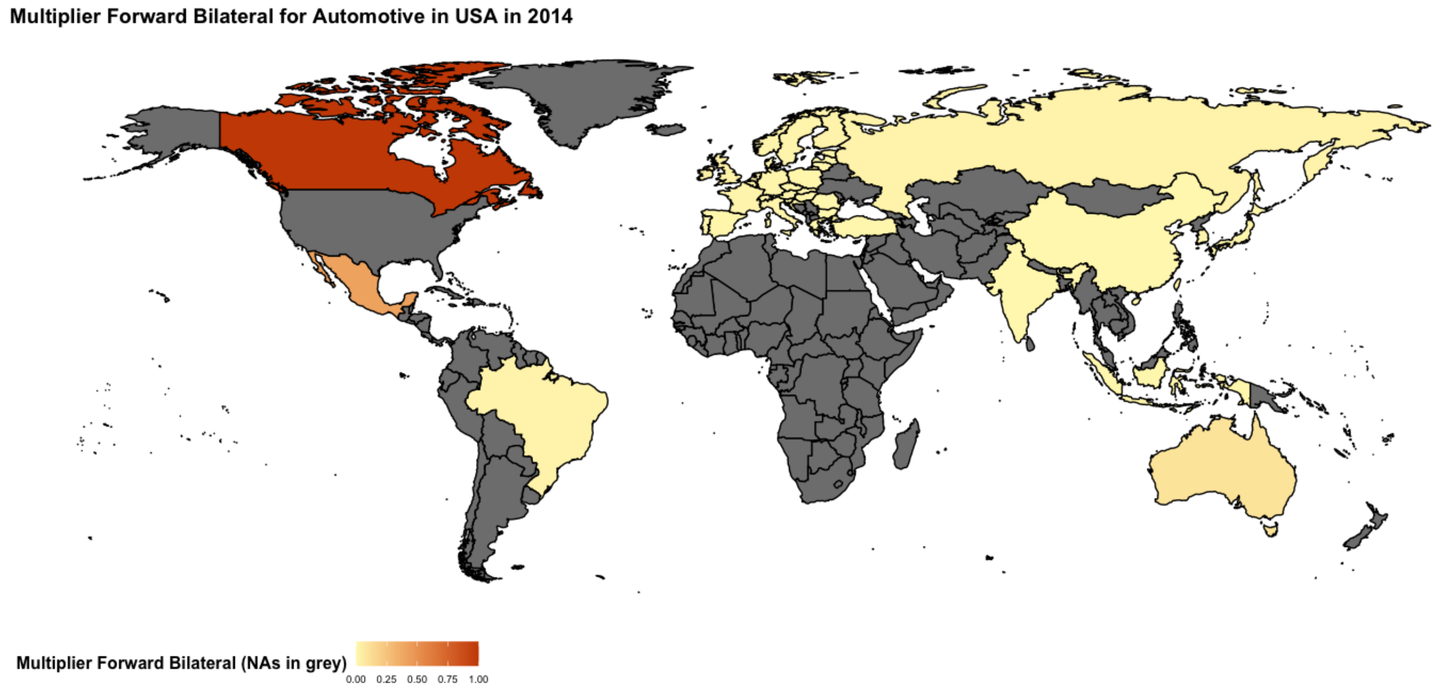

Figure 20: **Multiplier** Forward Bilaterlal: employess provided in 2014 to the (43-1) WIOD countries by US automotive industry in order to produce 1 mn USD of the various final commodities in the subsystems in the world.

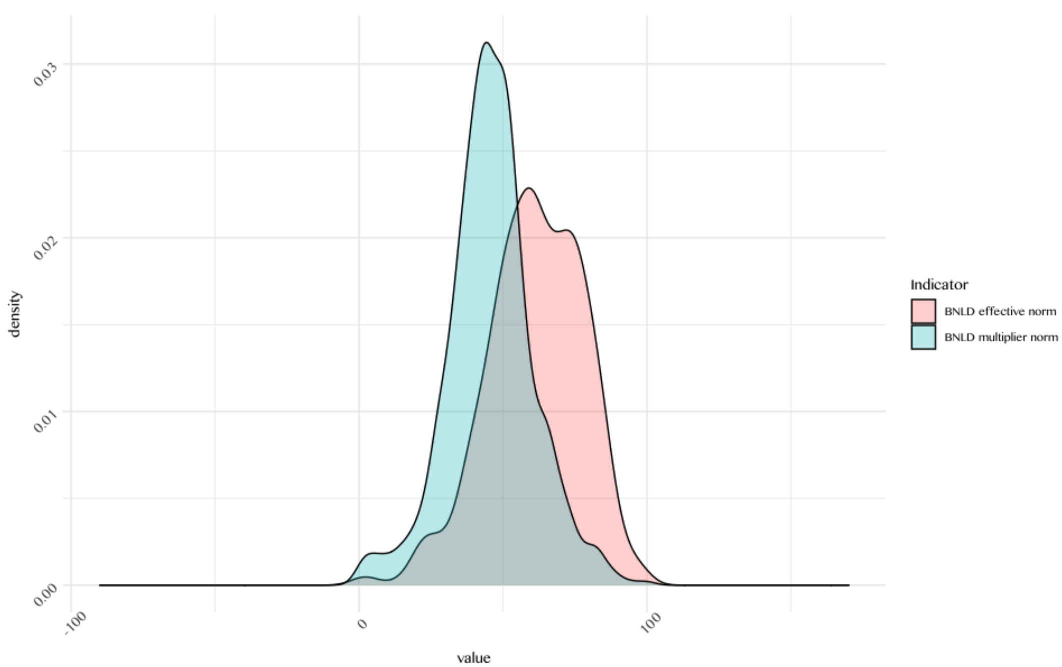

Figure 21: BNLD density distribution in 2014: multiplier (light blue) and effective (rose). BNLD normalized in [0,100] to better appreciate the distribution.

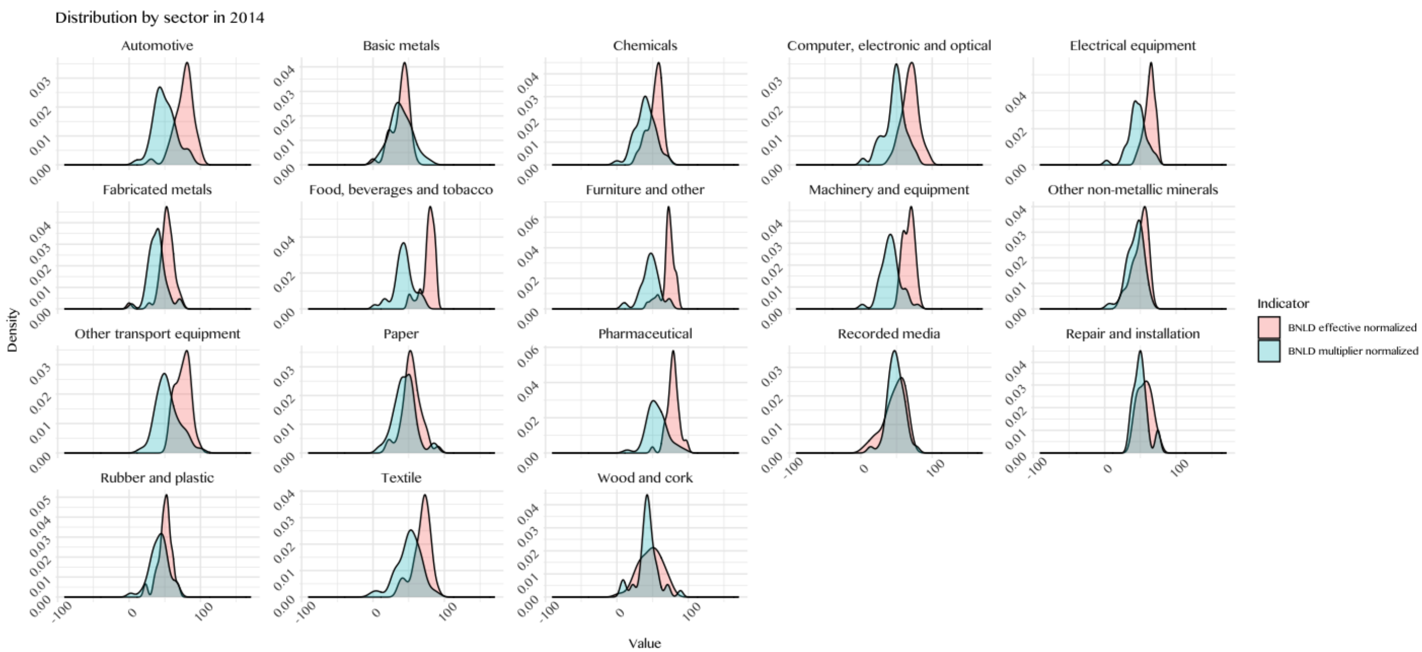

Figure 22: BNLD density distribution in 2014: multiplier (light blue) and effective (rose). BNLD normalized in [0,100] to better appreciate the distribution.

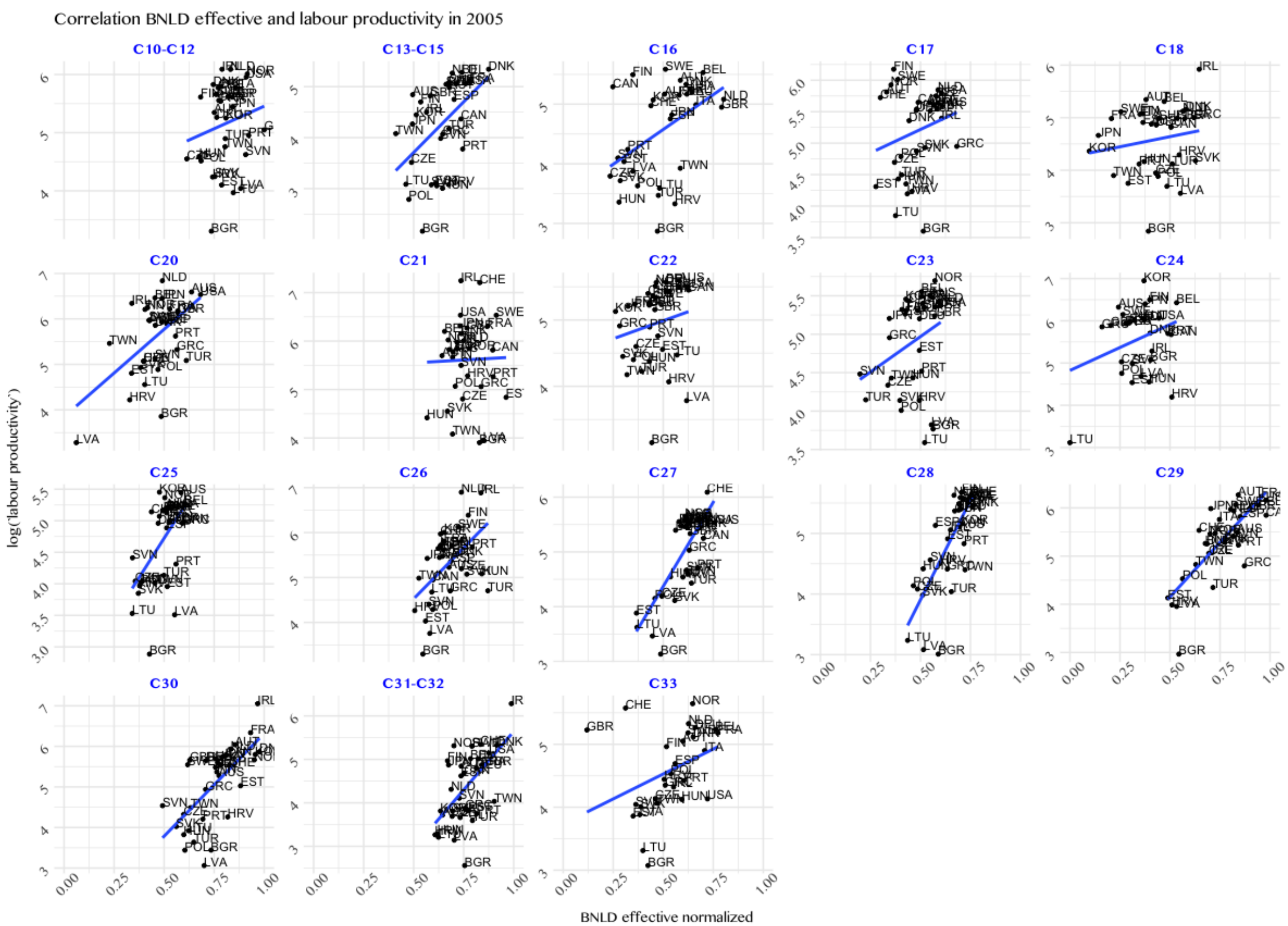

Figure 23: Scatter plot BNLD [0,1] (**effective**) and labour productivity by industry code in 2005

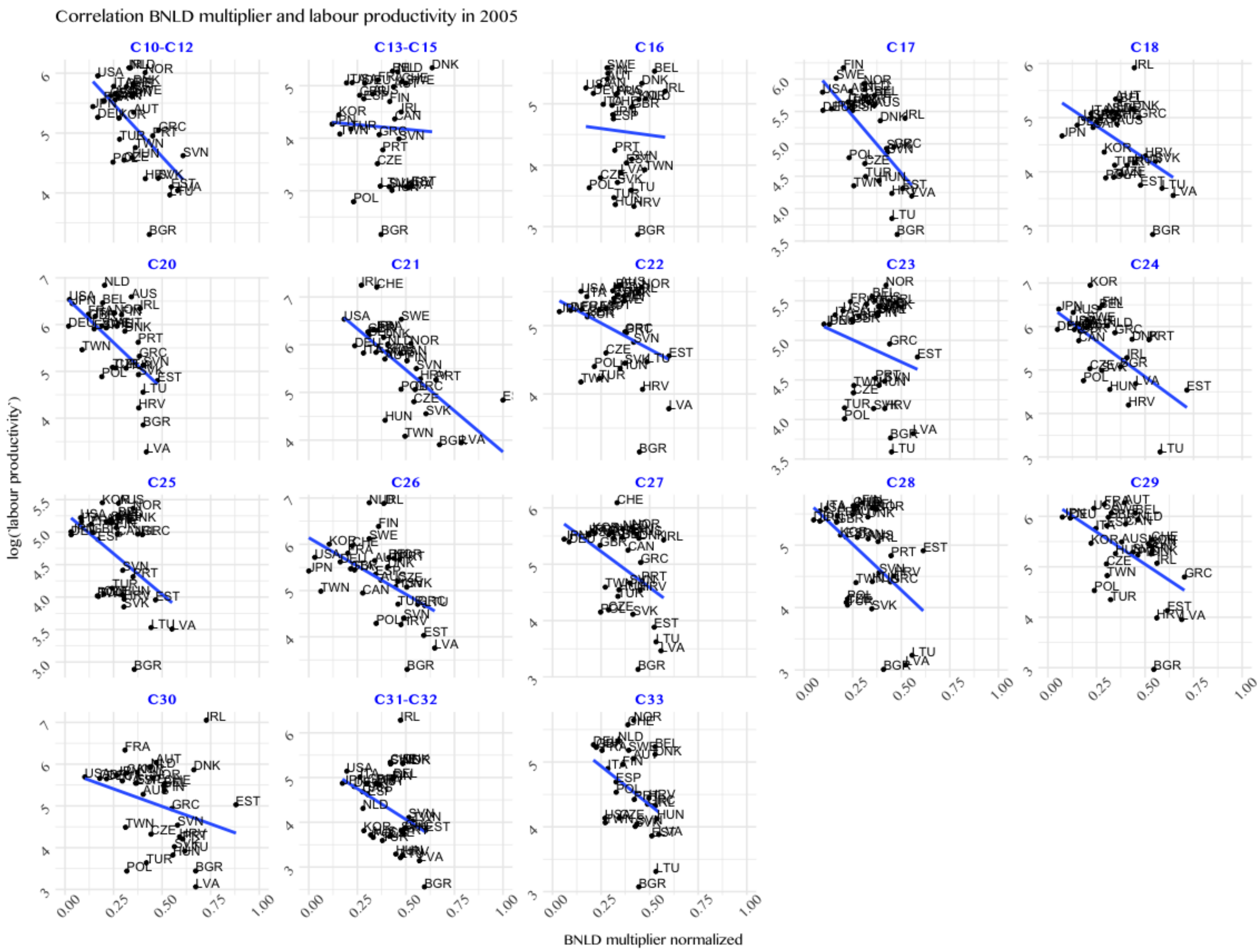

Figure 24: Scatter plot BNLD [0,1] (**multiplier**) and labour productivity by industry code in 2005

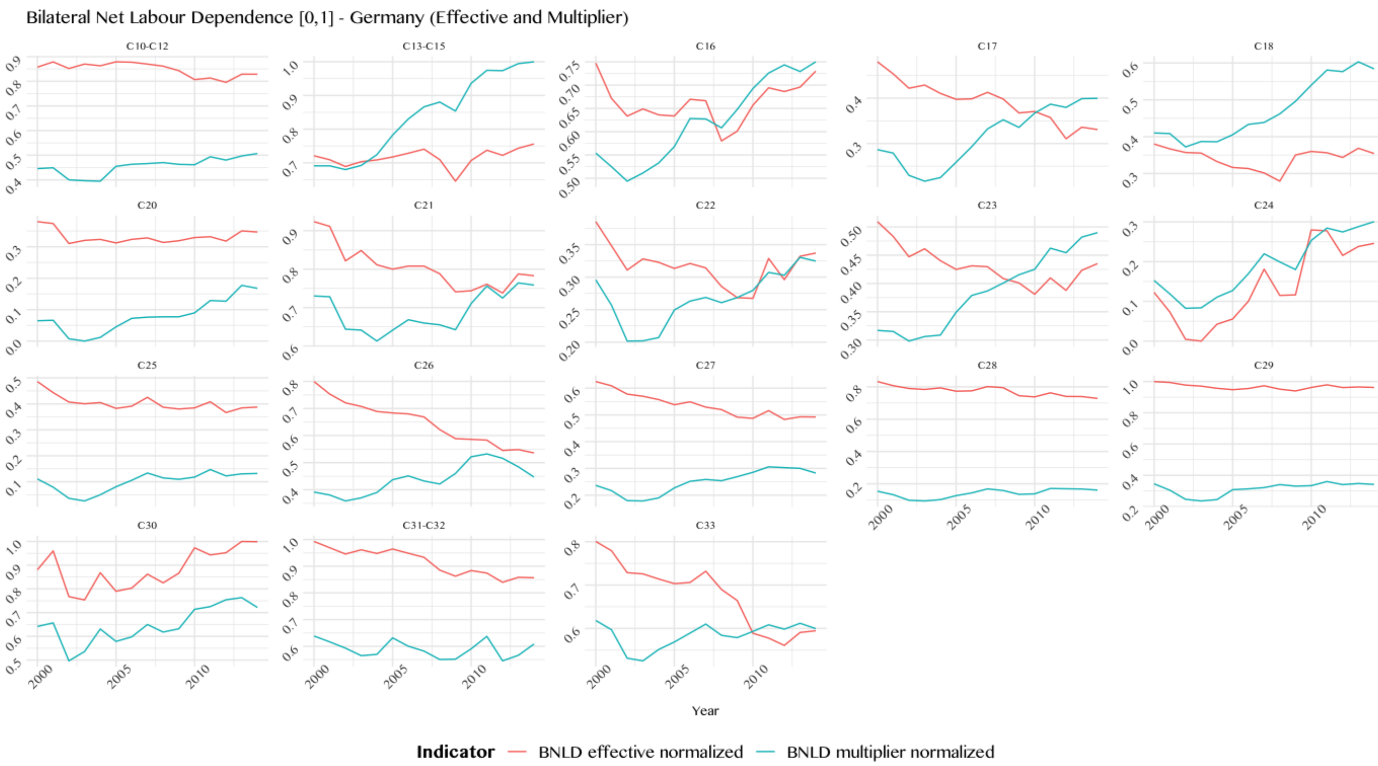

Figure 25: Trend in BNLD normalized [0,1] (multiplier and effective) for Germany.

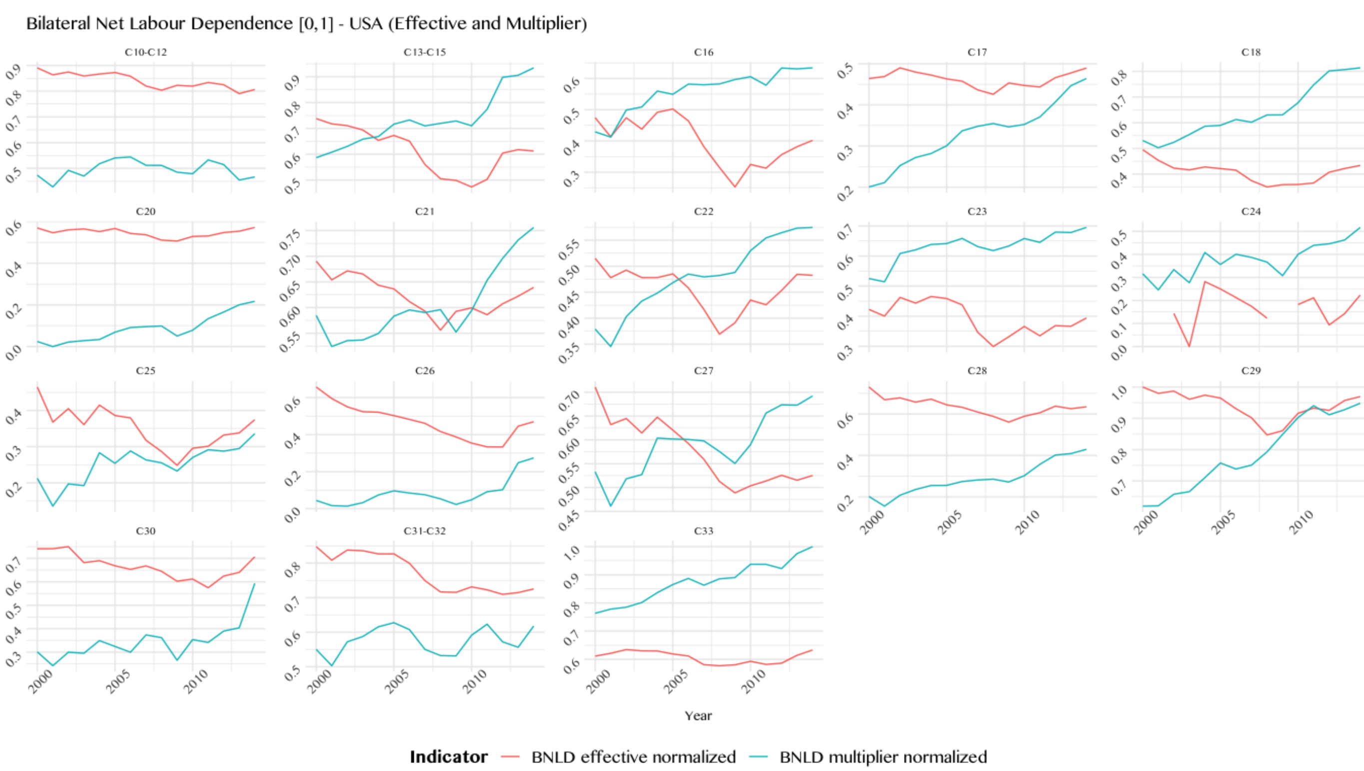

Figure 26: Trend in BNLD normalized [0,1] (multiplier and effective) for USA.

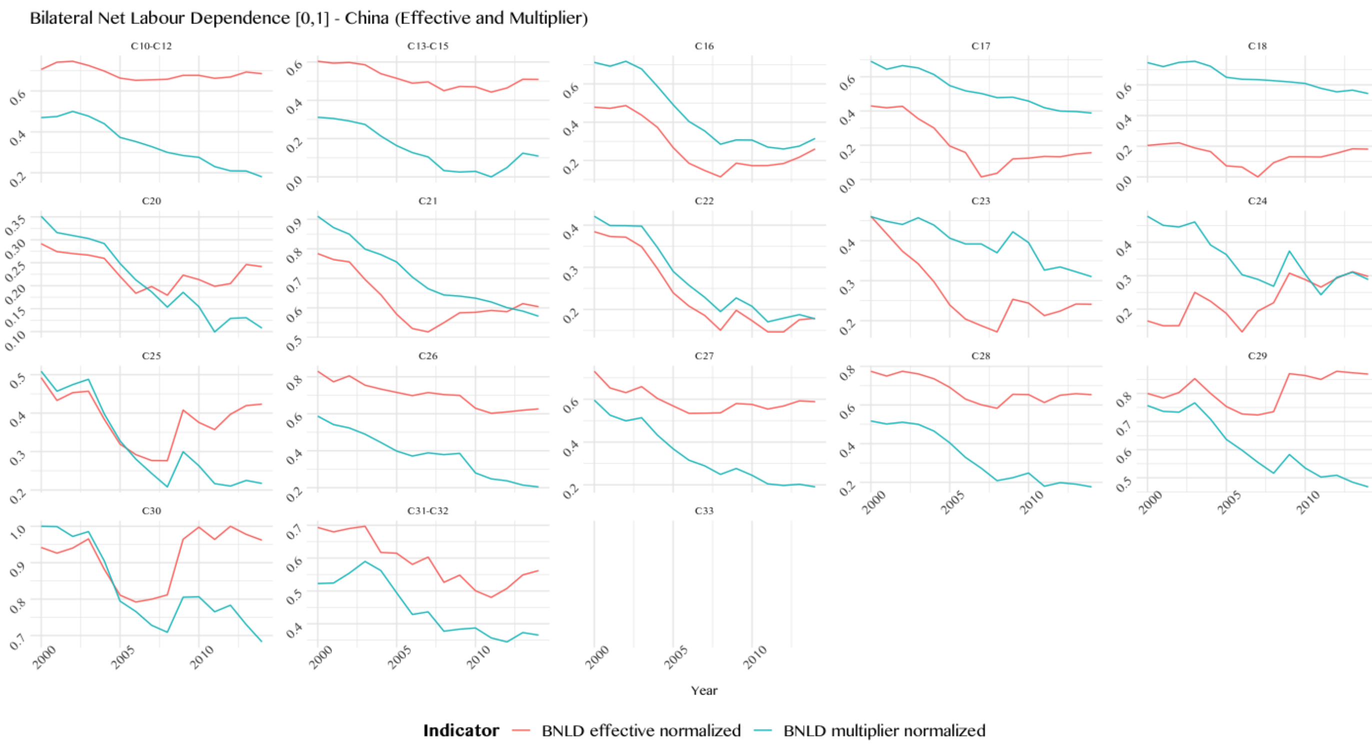

Figure 27: Trend in BNLD normalized [0,1] (multiplier and effective) for China.

Variables	LP_t	LP_{t-1}		KE_{t-1}	FD_{t-1}	W_{t-1}	$BNLD_{t-1}^{Mult[0,1]}$	$BNLD_{t-1}^{Eff[0,1]}$
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 Multipler [0,1] ($BNLD^{Mult[0,1]}$)	-0.285	-0.286	-0.248	-0.591	-0.278	1.000		
Lagged BNLD Effective [0,1] ($BNLD^{Eff[0,1]}$)	0.221	0.223	0.119	0.545	0.191	0.236	1.000	

Spearman rho = 0.236

Table 6: 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 Multipler [0,1] ($BNLD^{Mult[0,1]}$)	9088	.439	.099	.184	.936
BNLD Effective [0,1] ($BNLD^{Eff[0,1]}$)	8775	.611	.112	0	.938

Table 7: Descriptive statistics

Code	Industry descriptions	Pavitt Class
	Manufacturing	
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 8: 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 9: List of 34 countries