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The Automotive Supply Chain in Europe: An Input-Output Analysis of Value Added and Employment Composition.

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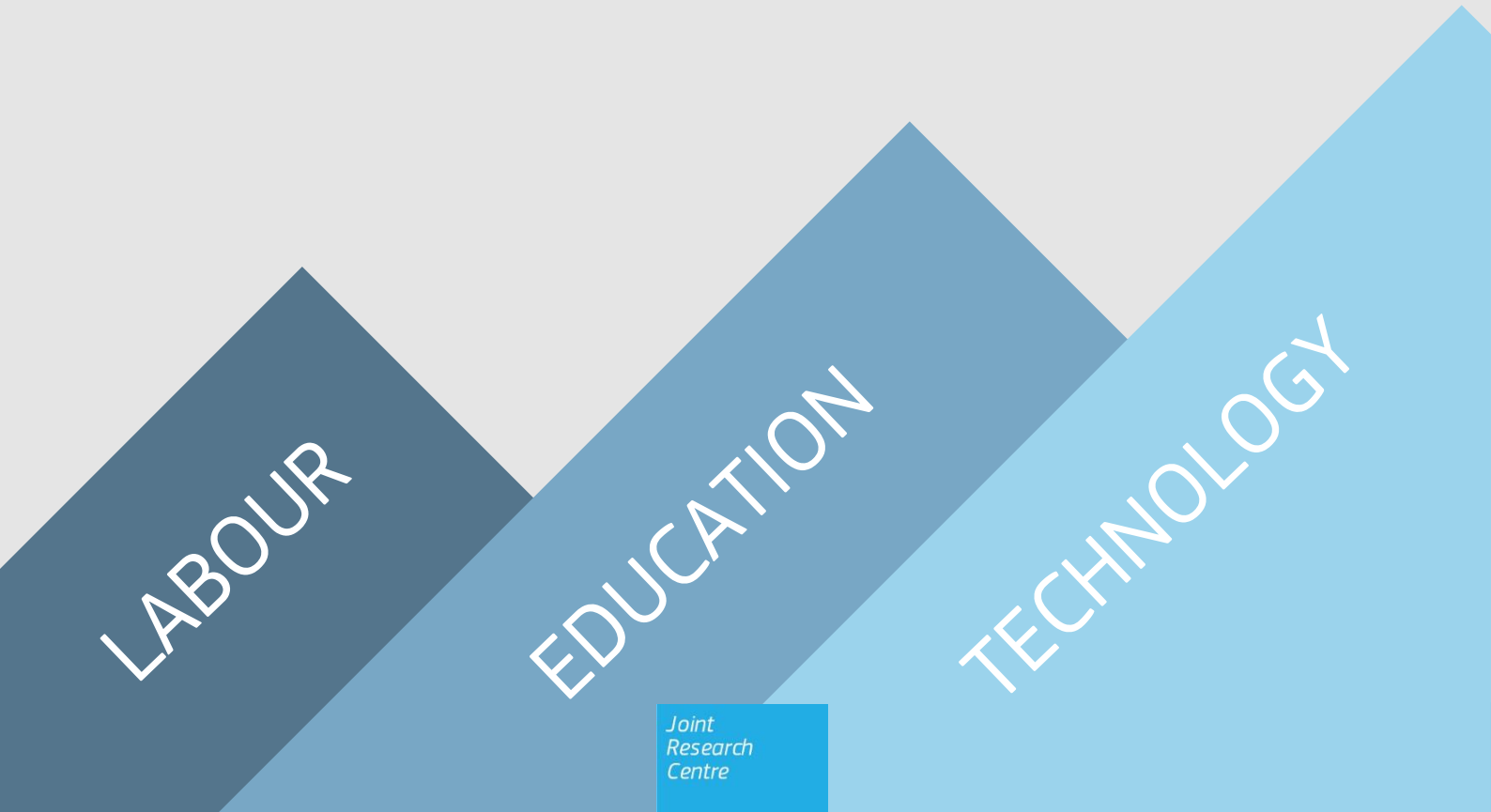

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The Automotive Supply Chain in Europe: An Input-Output Analysis of Value Added and Employment Composition.

Marta Fana (Joint Research Centre - Seville), Davide Villani (The Open University; Goldsmiths College – University of London)

Abstract

This paper studies the automotive supply chain in four European countries (Germany, France, UK and Italy). First, employing WIOD data (Timmer *et al.*, 2015) processed via Trade-SCAN (Román *et al.*, 2019), we decompose the domestic and imported inputs of production, focusing on the region and industry of origin of the contribution to show how the configuration of the automotive supply chain evolved between 2000 and 2014. The analysis focuses on the four dimensions, i.e. employment, value added, profits and labour compensation, to assess the evolution of the costs of production of the domestic and imported segments of the supply chain. We show that the imported component increases its costs in all countries except Germany, where domestic costs increase faster than imported ones. Notably, this trend can be imputed to the faster increase of the profit component of value added, rather than labour compensation. Second, we decompose the employment participating in the supply chain according to its occupational structure combining input-output data with labour Force Survey data. This analysis shows that there is a generalised upgrading trend in the occupational composition of the automotive supply chain which involves both domestic and imported labour.

Keywords: Automotive supply chain, Input-Output Analysis, Trade-SCAN, Occupational Structure.

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Contents

Introduction

The automotive sector[1] is one of the key manufacturing industries in Europe. To have a glance of this importance it suffices to consider that it still represents the first sector in terms of intra-European exports and the second one in terms of extra-European exports (EUROSTAT, 2020a, 2020b). In 2014, the industry directly employed more than 2 million workers in Europe and more than 6 million once considering the indirect links (Villani and Fana, 2020). Given the high potential fragmentation of the different steps conforming the productive process, the automotive industry has been heavily involved in the process of outsourcing and offshoring (Sturgeon, Van Biesebroeck and Gereffi, 2008).

The objective of this paper is twofold: first, it maps the process of outsourcing and offshoring of the automotive supply chain analysing the geographical and technological dimension as well as the evolution of costs of production of the domestic and imported inputs. We analyse the supply chain involved in the final production of the automotive industry in four countries (France, Germany, Italy and the UK) between 2000 and 2014. So far, although different studies dealt with the process of offshoring in the European automotive sector (Chiappini, 2012; Garbellini, 2014; Timmer *et al.*, 2015; Grodzicki and Skrzypek, 2020a), none of them focuses simultaneously on the geographical and technological dimensions of such process. This paper addresses these issues, mapping the geographical fragmentation of the supply chain and the technological contribution of the regions participating in it. We find that, until 2007, the automotive supply chain reoriented primarily towards China and that in the in the aftermaths of the global financial crisis this trend stopped, and European countries gained more importance. Moreover, differently from most of the studies on offshoring, that focus either on the value added component or on employment, our paper explores both the physical dimension of offshoring (employment embodied in imports) and the distribution of income (imported value added and its components, wages and profits).

The second contribution of this paper concerns the analysis of the trends in the occupational structure along the automotive supply chain. Different studies decompose the employment involved in GVC according to different labour supply attributes of the labour force, such as gender (Schaffer, 2008) and skills (Timmer *et al.*, 2015). To the best of our knowledge, however, no studies have focused on the demand side of labour employed in the supply chain, investigating the occupational distribution of the labour force participating to the supply chain. This paper addresses this aspect by decomposing the employment structure of each industry participating in the automotive supply chain into occupations, according to the International Standard Classification of Occupations (ISCO). This decomposition allows to characterise the process of offshoring, establishing what occupational profiles are more involved in the supply chain and how these evolve in time.

In the empirical analysis, we employ the a tool of the European Commission, Trade-SCAN (Trade-Supply Chain Analysis) (Román *et al.*, 2019) which employs data from World Input-Output Database (Timmer *et al.*, 2015). One crucial characteristics of this tool is that it allows a detailed quantification of the different steps involved in the supply chain avoiding double counting (Arto, Dietzenbacher and Rueda-Cantuche, 2019).

The paper is organised as follows. After this introduction, section 2 reviews the relevant literature on the process of offshoring in the automotive supply chain with a special emphasis to the European experience. Section 3 describes the methodology followed in the empirical analysis. Results are presented in section 4. Finally, section 5 discusses the main implications of the paper.

[1] Sector is here used as synonym of industry and not as institutional sectors as in the National Accounts.

Literature review

The contribution of this paper covers two main areas of research. The first one relates to the literature on outsourcing and offshoring and, especially, the reconfiguration of the European automotive supply chain. The second contribution concerns the assessment of the occupational structure involved in the automotive supply chain in the four countries analysed in the paper.

As noted by the literature, there is not a uniform definition of terms such as outsourcing and offshoring (Olsen, 2006; Hatzichronoglou, 2007). Many studies refer to the work of Feenstra and Hanson (1996) where outsourcing refers exclusively to foreign inputs embodied in total costs. In this paper we adopt a more general approach. Here, outsourcing can be thought as "outside procurement both for generic goods and services" (Williamson, 2008, p. 10). The unit of analysis can be the firm or, as in our case, an industry. This process of "outside procurement" can take place within a country or involve third countries. In the latter case, we refer to offshoring of production. Hence, from this classification it is possible to classify the supply chain into four different categories, distinguishing between the country of origin (domestic or a third country) and the industry of creation of intermediate inputs, whether within the same industry of analysis (i.e. automotive) or a different one (Table 1).

Table 1. Typology of intermediate goods by industry of origin and location of production.

		Industry of production of intermediate inputs	
		Within the same industry	Outside the industry
Location of production	Domestic	Production within the industry and country	Domestic outsourcing
	Foreign (offshoring)	Production outside the country but within the same industry	Production outside the country and outside the industry

Source: Adapted from OECD (2004)

Research on offshoring and trade in intermediates inputs have flourished in the last decades and different indicators measuring the level of offshoring have been developed (for an overview see Amador and Cabral, 2016). At the industry level, indicators of offshoring usually relate the foreign (i.e. imported) content that is embodied in different dimensions of analysis, such as total inputs (Feenstra and Hanson, 1999), output (Egger and Egger, 2003) and exports (Hummels, Ishii and Yi, 2001; Johnson and Noguera, 2012).

With respect to the literature that deals with the process of outsourcing and offshoring in the automotive industry in Europe it is worth distinguishing between those contributions that explore the micro-firm-level perspective, from those that focus on the industry level. Within the first group of contributions, different authors have studied how car producers in the four countries analysed in this paper have followed different organisational strategies of the supply chain. Even though outsourcing is a common feature of contemporary production processes, there are important differences across countries in the modalities of implementation and its implications for the local economy. For example, some authors highlight that German automakers mainly offshored the intermediate phases of production, keeping domestically the final stages of production while in France the automotive industry experienced a significant reallocation of all stages of production (Celi *et al.*, 2018). In Italy, the major car producer, FCA (ex-FIAT), promoted a strong process of offshoring that was reflected in a sharp decline in the number of cars produced in Italy (Balcet and Ietto-Gillies, 2019). The high

degree of integration is also a crucial aspect of the British car manufacturing, as testified by the increasing reliance on foreign markets, via imported inputs of production and as destination of final sell. However, in the case of the UK the higher process of integration has not implied the reduction of total output, which, on the contrary, is experiencing a slow but growing trend (KPMG, 2014).

A key element of the process of offshoring of the automotive industry in Europe is the growing participation of Eastern European (EE) countries. In these countries, the exports of the automotive sector grew rapidly and represented more than 20% of total exports at the end of the 2000s (Warda, 2013). Pavlínek and Ženka (2011) show that the employment in the Czech automotive components industry grew more than five times between 1995 and 2007 and its exports increased by fifteen times during the same period. Within this context, German producers, whose imported inputs from EE countries grew considerably in the second half of the 1990s (Nunnenkamp, 2006), are often indicated as the main clients of EE supply of parts and components, although all the countries analysed in this paper have increased the imports from this region (Jürgens and Krzywdzinski, 2009; Chiappini, 2012).

The strand of literature that employs input-output tables has highlighted the growth of the process of offshoring. Chiappini (2012) combines industry-level data with firm-level analysis to assess the process of offshoring of the automobile industry in France, Germany and Italy. The author measures the imported content of exports of the automotive industry and reveals that the share of imported inputs increased between 1995 and 2007, with the French and German automotive industries that embodied the highest share of imported inputs, followed by Italy. This author, however, base his analysis only on the participation of direct inputs. This type of approach does not capture the "real" origin of value added, that is where the value added embodied in the imported intermediate output is originated. Other studies, however, overcome this limitation. Garbellini (2014) performs a disaggregation of the imported vertically integrated labour of the twelve activities according to the industry of origin of imported intermediate inputs between 1995 and 2008 and measures the degree of offshoring employing three indicators. With respect to the automotive industry, her findings reveal that services have the highest and slightly growing participation in total inputs (approximately 40% of the total). Timmer et al. (2015) expand the focus by including also the US, China and Japan. They show that, between 1995 and 2011, the European countries studied in their paper (Germany, France and the UK) account for a higher share of imported value added compared to the Asian and American counterparts. Recent research has enlarged the aim of the discussion by analysing vertically integrated unit labour costs (VIULC) in the European automotive industry (Grodzicki & Skrzypek, 2020). This study offers very useful insights regarding the evolution of VIULC in Europe distinguishing between the contribution of different groups of countries to the evolution of the aggregate indicator.

Overall, the existing evidence indicate that offshoring has been relevant in the European automotive sector, with a rising role played by EE countries. However, to the best of our knowledge, none of the existing studies simultaneously focuses on the process of outsourcing (domestic and foreign) accounting for the geographical *and* technological origin of the inputs of production involved. In this respect, one of the objectives of the paper is to map the process of outsourcing and offshoring of the automotive industry in four major European car producers (Germany, France, Italy and the UK). As part of this objective, an additional novelty of this research is that we study the process of offshoring exploring two dimensions of analysis. The first one involves physical magnitudes, in our case the human labour (i.e. the number of workers) needed (directly and indirectly) in the production of final outputs. The second one relates to the income dimension (value added and its components, i.e. labour compensation and profits). The multidimensionality of our analysis represents an important contribution to the field. Most of the research on offshoring focuses on the latter dimension, value added (e.g. Koopman et al., 2014; Los et al., 2015; Mcgregor, 2010). However, these measures of offshoring are vulnerable to distributive changes which are independent from the technical requirements in use along the supply chain. For example, a labour market reform that reduces the cost of labour would impact on the value added content but not necessarily on the physical dimension of offshoring (i.e. the employment composition). Similarly, the process of offshoring in countries with lower wages (and value added) may offer an underestimated picture of the extent of the offshoring process in terms of the employment participation.

Authors rooted in the classical-Keynesian approach have highlighted that labour costs are only one part of total costs. Costs of production are equal to value added (profits plus labour compensation) and the cost of intermediate inputs of production (Pasinetti, 1977, 1981; Zambelli, Fredholm and Venkatachalam, 2017). Intermediate inputs (and the intermediate inputs of intermediate inputs and so on) can be decomposed into wages and profits, so that total costs of production can be ultimately considered equal to the sum of the summation of wages and profits embodied in all stages of production (Shaikh, 2016, chap. 9). Therefore, the combination of the decomposition of the supply chain in terms of employment and value added allows to determine if there are relevant differences in the cost structures (and its evolution) within the supply chains of the four countries analysed and permits to establish how functional income distribution along the whole supply chain changes in time.

The second main aspect that this paper contributes to concerns the study of the occupational structure of the automotive supply chain. Existing input-output studies explore the employment structure in terms of gender (Schaffer and Stahmer, 2006; Schaffer, 2008), skills (Timmer *et al.*, 2013, 2015; Ludwig and Brautzsch, 2014) or a mix of these two dimensions (Duarte, Sarasa and Serrano, 2019). These studies offer useful insights regarding the employment in a certain region/industry. The recent literature on the topic has paid attention to the "offshorability" of specific tasks, defined as units of work activity that produce output (Autor, 2013). The relationship between division of labour and "offshorability" is therefore explained by the Routine Biased Technical Change hypothesis, according to which the likelihood to be offshored depends mostly on the intensity of routine tasks involved in a specific occupation and, more importantly, on the technical feasibility to performs tasks remotely. Building on different works (Autor & Dorn, 2013; Autor et al., 2015; Blinder & Krueger, 2013), Goos et al., (2014) test this hypothesis concluding that routine intensity and offshorability of tasks are strongly and positively correlated. Accordingly, this relationship would explain the polarisation of occupations of domestic employment. However, several researches challenge the idea of occupational polarisation in Europe, claiming that the last two decades have been characterised by a pattern of generalised upgrading, although important heterogeneity between countries and regions (Fernández-Macías, 2012; Hurley et al., 2019; Oesch & Piccitto, 2019). Moreover, the link between routine and upgrading/polarisation is not deterministic since routine is not an attribute of tasks content (i.e. the technical and material transformation of inputs into outputs) but rather a specific method of work institutionally and historically contingent (Fernández-Macías and Hurley, 2017).

To the best of our knowledge, none of the existing input-output studies dig into changes in the occupational structure of the supply chain. Our paper contributes to fill this gap linking occupational data at the European level to input-output figures on the employment embodied in the domestic and imported intermediate inputs for the automotive production.

Research approach and methodology

As highlighted in the previous section, there have been numerous indicators of offshoring developed in the last twenty years. One recent development in input-output and trade flows analysis involves the possibility of decomposing gross trade accounting for double-counted terms, which is the content of trade that crosses the border more than once (Johnson, 2014, 2018; Koopman, Wang and Wei, 2014).

Despite these considerable progresses, Arto et al. (2019) highlight that most of the standard measures of offshoring have not been able to decompose simultaneously the bilateral trade content measured at the border and to fully take into consideration the different countries and industries that participate in the global values chain. In this paper, we follow their contribution to decompose the

automotive supply chain, quantifying the value added and labour embodied in the final exports[2] of the automotive industry according to their country and industry of origin.

Following Arto et al. (2019), it can be shown that the foreign value added and the domestic value added embodied in final exports of the producer country *r* can be obtained as follows[3]:

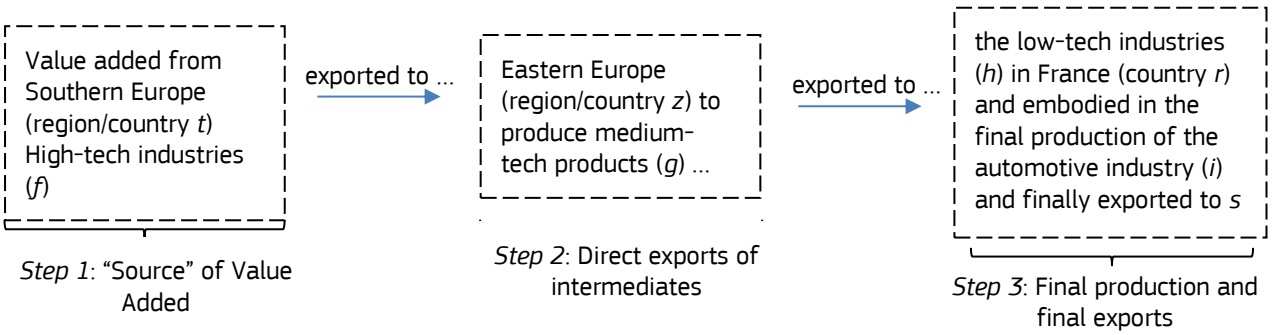
$$\mathbf{f}_{\text{final}}^{\text{rs}} = \sum_{\text{z}\neq\text{r,t}\neq\text{r}} [(\mathbf{v}^{\text{t}})^{\text{T}}\mathbf{C}^{(\text{r})\text{tz}}\mathbf{A}^{\text{zr}}\mathbf{L}^{\text{rr}}]\mathbf{y}^{\text{rs}} \quad (1)$$

$$\mathbf{d}_{\text{final}}^{\text{rs}} = [(\mathbf{v}^{\text{r}})^{\text{T}}\mathbf{L}^{\text{rr}}]\mathbf{y}^{\text{rs}} \quad (2)$$

Where $\mathbf{f}_{\text{final}}^{\text{rs}}$ and $\mathbf{d}_{\text{final}}^{\text{rs}}$ are, respectively, the vector of foreign and domestic value added embodied in the final exports from country *r* to country *s* with $r \neq s$. The term $\mathbf{v}^{\text{t}}$ indicates the vector of value added coefficients in country *t*, $\mathbf{C}^{(\text{r})\text{tz}}$ is the Leontief inverse transaction matrix for countries *t* , with $t \neq r$, and *z* where the transaction flows involving country *r* have been omitted (see Appendix 1 for details). The term $\mathbf{A}^{\text{zr}}$ is the multi-regional matrix of technical coefficients indicating the intermediate inputs from country *z* required for the production in country *r*. The term $\mathbf{v}^{\text{r}}$ is the domestic vector of value added coefficients and matrix $\mathbf{L}^{\text{rr}}$ is the domestic Leontief matrix (for country *r*) indicating the direct and indirect output of industry *i* that are needed to produce one unit of final demand of industry *j* in country *r*. Finally, $\mathbf{y}^{\text{rs}}$ is the vector of exports of final goods (i.e. the vector of final demand of country *s* from country $r \neq s$). Equation 1 allows capturing the process of offshoring distinguishing between the geographical and technological components, while equation 2 permits to decompose the domestic contribution to the production of final goods, enabling the quantification of the process of domestic outsourcing.

Each element $v_f^t c_{fg}^{(r)tz} a_{gh}^{zr} l_{hi}^{rr} y_i^{rs}$ in equation 1 represents the value added from industry *f* in country *t* embodied in the intermediate inputs of industry *g* in country *z*, to the industry *h* in country *r* that is embodied in the final production of industry *i* (which, in our case, corresponds to the automotive industry) in the producer country *r* which is exported to country *s*. To simplify this complex nomenclature, we can conceive equation 1 as a process involving three stages, that can be resumed in the following exemplifying diagram (Figure 1).

Figure 1. Simplified scheme of the steps involved in the analysis



[2] Trade-SCAN allows to quantify also the amount of employment and value added embodied in the exports in intermediate goods. Since our focus is only on the production of final goods, we omit equations regarding exports in intermediates.

[3] For an extended formulation of equation 1 and 2 see the Appendix 1. Upper case bold letters indicate matrices, lower case bold letter vectors. The superscript $^{\text{T}}$ indicates transposed terms.

In the same fashion, each element $v_h^r l_{hi}^{rr} y_i^{rs}$ in equation 2 (representing the exports of domestic value added) is the value added originated in industry *h* of country *r* which is then embodied in the final exports of industry *i* to country *r* to country *s*. In our case, *r* represents the producer country and *i* is the automotive industry.

In the forthcoming analysis we will identify the first stage of transactions (industries *f* and region *t*) as where the "real" contribution of value added and employment originates (henceforth, we will refer to this component as the "source" or "sourced" value added and employment), while the second stage (region *z* and industry *g*) identifies the direct partner supplying intermediate imports to the producer country (*r*), regardless the origin of value added and employment. In the upcoming empirical analysis, we will refer to the source imported contribution, unless explicitly stated.

By substituting the vector of value added coefficients in equation 1 and 2 ($\mathbf{v}$) for the vector of employment coefficients (or the vector of direct labour compensation coefficients) it is possible to estimate the amount of labour (or labour compensation) that is imported or domestically needed for the production of $\mathbf{y}^{\mathrm{rs}}$.

There are different important considerations that derive from the above formulations. First, the presence of matrix $\mathbf{C}^{(\mathrm{r})\mathrm{tz}}$ avoids double counting (i.e. domestic value added exported to other countries and then embodied in imported inputs) of the value added from country *r* which is exclusively accounted for in equation 2. This is because the matrix of intermediate transaction matrix of country *r* has not been included in the computation of matrix $\mathbf{C}^{(\mathrm{r})\mathrm{tz}}$ (see Appendix 1 for details). Second, the decomposition of equation 1 allows to identify the source (geographical and in terms of industry) of value added and distinguish it from the most immediate origin of intermediate inputs, that is the country/industry that directly exports intermediate inputs. For example, it is possible to quantify how much of the Eastern European value added imported by Germany for the final production of automobiles is created in Eastern Europe or if it is value imported from elsewhere by Eastern European countries and then embodied in the exports of intermediate inputs to Germany. This point is important as it allows to identify where value is originated, and not only the most direct transactions.

Data obtained from Trade-SCAN refer exclusively to the amount of value added (employment embodied and labour compensation) in final exports of the automotive industry. To estimate the total amount (consumed domestically and exported) of value added, employment and labour compensation involved in the supply chain we estimated the share of exports in final production using WIOD data. Multiplying the inverse of this share for $\mathbf{f}_{\mathrm{final}}^{\mathrm{rs}}$ and $\mathbf{d}_{\mathrm{final}}^{\mathrm{rs}}$ we obtain the amount of value added (employment and labour compensation) embodied in total final production. Formally, this is:

$$\mathbf{f}_{\mathrm{final}}^{\mathrm{rs}} * \left(\frac{y_i^r}{\sum y_i^{rs}}\right) = \mathbf{f}_{\mathrm{final}}^{\mathrm{r}} \tag{3}$$

$$\mathbf{d}_{\mathrm{final}}^{\mathrm{rs}} * \left(\frac{y_i^r}{\sum y_i^{rs}}\right) = \mathbf{d}_{\mathrm{final}}^{\mathrm{r}} \tag{4}$$

Where y^r is the total final production in the automotive industry (*i*) in country *r* and $\sum y^{rs}$ represents the total final exports of the automotive industry from country *r* to country *s* (for r ≠ s). The terms $\mathbf{f}_{\mathrm{final}}^{\mathrm{r}}$ and $\mathbf{d}_{\mathrm{final}}^{\mathrm{r}}$ are the imported and domestic total amount of value added (employment or labour compensation).

The analysis deriving from equations 1 and 2 allows to address our first research object, i.e. the mapping of the process of outsourcing and offshoring of the automotive supply chain. To address the second research objective, we analyse employment in each industry and region according to their occupational structure.

In order to do so, we adopt the following procedure. First, using EU27-LFS data at NACE 2 digit for each country, we are able to define the occupational structure at the ISCO 1-digit level. For each

country this match results into a job – occupation sector pair- matrix capturing both the horizontal and vertical division of labour. We employ this job matrix to compute the share of each occupation over total employment by sector and then merge it to WIOD employment data at the industry level. More specifically, we quantify the number of workers in each occupation and industry by pre-multiplying equations 1 and 2 by EU-LFS ISCO08 one-digit shares. In doing so, we assume that the employment structure of each economic sector at the country level is identical to the one producing intermediate goods to be exported to the automotive sector of the four producers. One limitation of this estimations is that this procedure can be run only for European countries since the occupational breakdown is not available for the rest of the countries. Despite this limitation, this methodology still allows to provide an occupational profile of most of the workers embodied in the European automotive supply chain. This type of analysis allows us to contribute to the debate related to shifts in employment structures along value chains at the European level.

The empirical analysis is performed employing TRADE-Scan (Román *et al.*, 2019), an analytical tool developed by the European Joint Research Centre (JRC) using data from the World Input-Output Database (Timmer *et al.*, 2015). The WIOD database (2016 release) is composed of multi-regional input-output matrices (MRIO) containing information about 43 countries and one Rest of the World region and 56 industries. Data on occupations are obtained from EU-LFS (Eurostat). We employ the 1 digit classification which consists in nine different categories of occupations (excluding Armed Force).

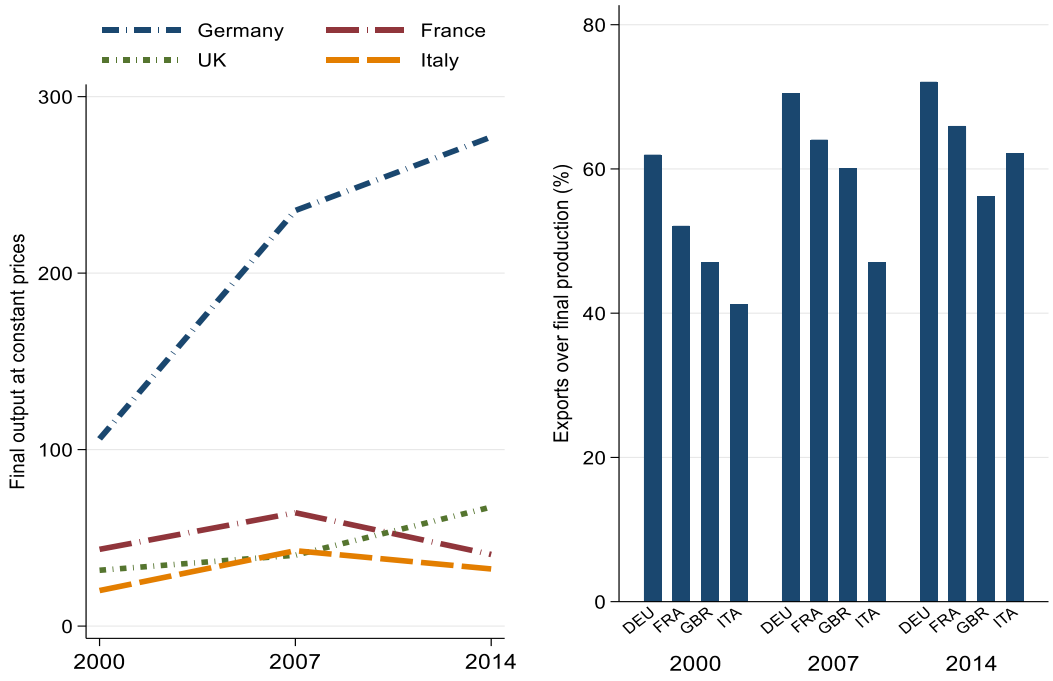
For simplicity, we group countries into five groups in addition to the domestic (producer) economy: Central Europe (CE), Eastern Europe (EE), Southern Europe, China and Rest of the World (ROW). Industries are grouped into five groups according to their technological level: automotive, High-Tech (HT), Mid-Tech (MT), Low-Tech (LT) and the remaining industries (primary industries + services), Other Sectors (OS).[4]

Results

We start this section by analysing the evolution of net output in the automotive industry in the four countries (Figure 2). What appears immediately is the difference between Germany and the rest of countries. German automakers increase their net output almost three times between 2000 and 2014, whilst production in the other countries is approximately one fifth of the German one. In the UK output increases approximately 50% during the period, while in Italy it expands until 2007 and reduces in the aftermaths of the global financial crisis to similar levels as 2000. Finally, France has a similar pattern than Italy, with an even stronger reduction in output. This pattern reflects the different strategies followed by car makers in these countries (Celi *et al.*, 2018; Balcet and Ietto-Gillies, 2019), aimed at displacing only part of the supply chain (Germany) or the whole supply chain (France and Italy). The right panel of Figure 2 shows the increasing role of foreign demand. In all countries the share of final output exported grows, absorbing most of the final production. With no surprise, Germany is the country that exports the highest share of production, followed by the other countries.

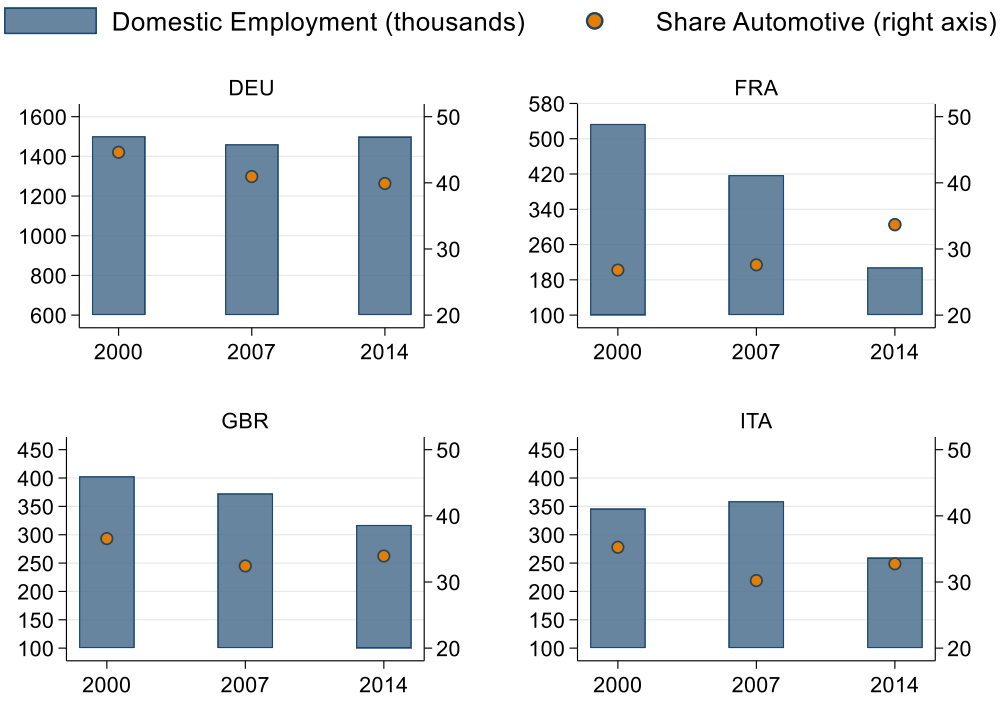
[4] See Appendix 2 for details regarding the country and industry classification.

Figure 2. Final output of the automotive industry (billions of constant US$ at 2010 values) and share of exports of total output. Source: WIOD.



Within this context, we address to one of the main questions of this paper, that is how the composition of the automotive supply chain has changed during this period. Figure 3 presents the evolution of the total (direct + indirect) domestic employment needed to produce total (domestically consumed + exported) final output and the share of domestic labour that is employed within the domestic supply chain. In 2014, all countries in the sample record a lower number of employed persons than in the 2000. This reduction is negligible in Germany and it is more accentuated in the other countries, especially in France. This trend is quite linear in France and the UK. Differently, Germany shows a mild recovery in the total employment after the global financial crisis, while in Italy the trend is the opposite, after a small expansion at the beginning of the century, total employment declines after 2007. In France, the loss of employment has been accompanied by a reduction of domestic outsourcing (reaching almost 66% of the total domestic employment), while in the other three countries domestic outsourcing grows slightly. Despite these trends, Germany is the country that accounts for the highest degree of concentration of labour within the automotive industry (40% of domestic labour in 2014).

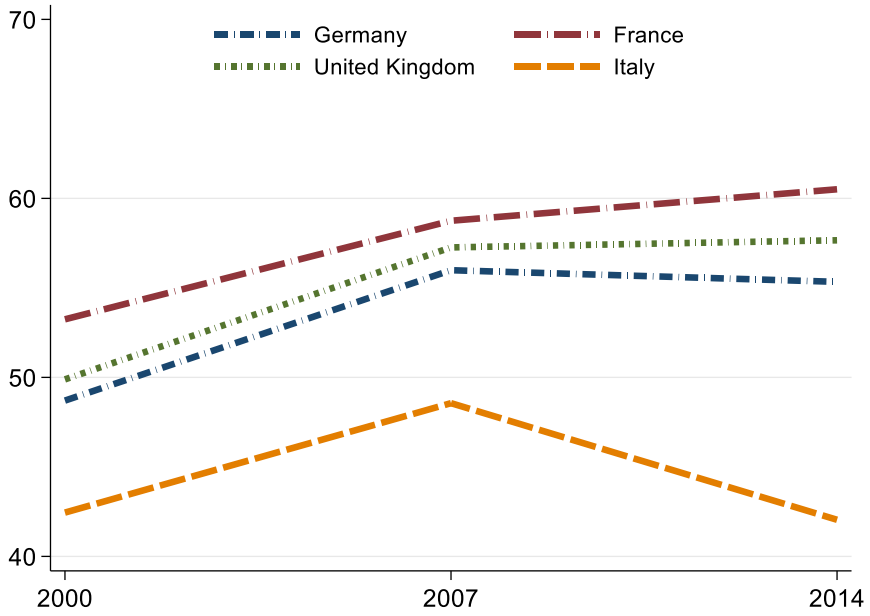
Figure 3. Number of total (total + indirect) domestic employment embodied in the production of final goods and share of employed persons in the domestic automotive sector over the total domestic employment. Source: Authors' calculations using WIOD and TRADE-Scan.



The mild growth of domestic outsourcing is also accompanied by more marked increase in offshoring. Between 2000 and 2014, the share of imported labour over total labour has increased in all countries except Italy, especially until the global financial crisis (Figure 4).[5] France is the country that accounts for the highest share of imported employment (60% of total employment), followed by the UK, Germany and Italy, which has a substantial lower share of foreign labour than the other European producers considered here. Notably, the process of offshoring has decreased in intensity after the global financial crisis. Although these data do not allow to conclude that there is significant process of reshoring took place between 2007 and 2014 (Blecker, 2016), it appears that the tendency to offshore seems to have come to an halt after the global financial crisis. Moreover, it must be bore in mind that these trends take place in a very different context. As noted in Figure 2, Germany is the only country that expands considerably the production and domestic employment during this period. In the other countries the trends in offshoring are associated to the dismantling of the domestic automotive supply testified by the stagnation or reduction of output and domestic employment.

[5] Data refer to the imported inputs from all sectors (automotive and other) contributing to the production of the automotive industry in the producer countries.

Figure 4. Share (%) of foreign employment (direct and indirect) involved in the production of the automotive industry by final producer. Source: Authors' calculations using WIOD and TRADE-Scan data.



Geographical and technological decomposition of imported employment

In this subsection of the paper, we investigate the geographic origin of foreign employment in the intermediate imports from two approaches (respectively steps 1 and 2 in Figure 1): 1) country where employment is actually generated (source) and 2) country origin of the imports (partner). The former dimension identifies where value and employment are generated, independently from the region that directly supplies it to the producer. This difference matters because measures based on direct trade may hide a changing composition in the source contribution from a certain region (Maurer and Degain, 2010). For example, the growth in the employment in the direct imports of the UK from other CE countries could be the result of an increase in the amount of labour employed in CE countries or/and increase in employment in any other region of the worlds (e.g. China) and then embodied in the direct exports from CE to the UK. According to this example, the first approach would measure the Chines employment imported by the UK regardless the country where it is directly imported from, while the second approach would quantify the employment directly imported from CE to the UK, without distinguishing the source of employment.

Table 2 shows the importance of ROW that is the region that contributes substantially more to the imports in terms of labour for all producers. Although its participation is declining over time, this region is the most important one throughout the period. Central European countries reduce their importance, considering both the direct intermediate imports and the source contribution in terms of supply of employment. This reduction is especially marked between 2000 and 2007, while there is a small rebound between 2007 and 2014. SE maintains a fairly stable participation during the period. France is the country characterised by a stronger relationship with this region, a finding that is imputable to the strong relationship between French car producers and Spain (Chiappini, 2012).

China and EE are the two regions that increase their participation at both levels of analysis and in every producer country, consistently with the literature that highlights the growth of this region in the automotive supply chain (Nunnenkamp, 2006; Pavlínek and Ženka, 2011; Warda, 2013). The participation of this group of countries in the supply chain is not equally distributed among producers.

EE is particularly important for Germany, where the employment direct imports from this region go from 19.1% in 2000 to 26.4% in 2014, and, to a lesser extent, Italy, where the share of labour from EE countries moves from 9.4% to 16.1%. This growth, however, is much more reduced when looking at the source component of imports. In this case the growth of EE employment in Germany is of 3 percentage points only (from 16.1% to 19.7%) and 4 in Italy (from 8.4% to 12.5%). As to China, the growth in the participation is more uniform across producers, and its participation is higher (during the whole period) in France and in the UK than it is in Germany and Italy. Interestingly, the growth of the source employment from China is clear until 2007, while between 2007 and 2014 the Chinese participation decreases. On the other hand, the growth of the share of employment from EE countries is faster in the second sub-period (2007-2014). These findings highlight an aspect often neglected in the literature, suggesting an important shift in the offshoring pattern. The composition of imports of intermediate inputs oriented rapidly towards China at the beginning of the 2000s, but the role played by this country decreased in the second sub-period. After the global financial crisis, the supply chains reorganise towards a greater contribution of European countries, especially EE ones.

The table also shows that the only regions whose contribution is higher when considering the "source" perspective are China and ROW. This outcome is not unexpected, since part of this result may be influenced by the proximity between producers and commercial partners. Those regions that are geographically closer to the producer countries have a higher participation as direct suppliers of inputs. However, the results of Table 2 there are important differences between direct and "source" contribution to the supply chain. A consistent part of the participation in direct supply of the European countries is the result of the re-export of labour embodied from third countries, especially China and ROW countries.

Table 2. Share of the "source" of imported employment vs. direct imported labour.

	Share of foreign employment by area										Difference Direct – "Source" employment				
	Step 1: "Source" of imported employment					Step 2: Direct imported labour									
2000	CE	CHN	EE	ROW	SE	CE	CHN	EE	ROW	SE	CE	CHN	EE	ROW	SE
DEU	15.0	10.3	16.1	52.7	5.9	24.9	6.9	19.1	41.0	8.2	9.9	-3.4	3.0	-11.7	2.2
FRA	10.7	14.3	4.6	58.7	11.7	20.5	10.6	4.5	45.9	18.5	9.7	-3.7	-0.1	-12.7	6.8
GBR	9.8	12.1	3.6	69.2	5.3	18.0	8.5	3.6	62.3	7.6	8.2	-3.6	0.0	-6.9	2.3
ITA	11.3	9.6	8.4	68.4	2.3	19.5	6.4	9.4	61.4	3.3	8.2	-3.2	1.0	-7.0	0.9
2007	CE	CHN	EE	ROW	SE	CE	CHN	EE	ROW	SE	CE	CHN	EE	ROW	SE
DEU	12.5	17.9	16.2	47.7	5.7	23.5	12.1	22.4	33.9	8.1	11.0	-5.8	6.2	-13.7	2.4
FRA	7.8	22.2	6.3	54.1	9.5	17.0	16.7	7.6	42.6	16.1	9.2	-5.5	1.3	-11.5	6.5
GBR	8.4	20.0	5.4	61.1	5.2	17.3	14.6	6.8	53.5	7.8	8.9	-5.3	1.4	-7.6	2.6
ITA	9.1	19.2	9.2	60.0	2.4	16.9	14.9	11.9	52.8	3.5	7.7	-4.3	2.7	-7.2	1.1
2014	CE	CHN	EE	ROW	SE	CE	CHN	EE	ROW	SE	CE	CHN	EE	ROW	SE
DEU	12.0	16.5	19.7	45.6	6.3	20.7	10.9	26.4	33.6	8.5	8.7	-5.7	6.7	-12.0	2.2
FRA	8.1	20.6	8.7	51.4	11.2	15.8	15.2	10.6	40.1	18.3	7.7	-5.4	1.9	-11.4	7.1
GBR	8.5	21.5	6.9	57.5	5.6	17.5	16.9	8.5	48.2	8.9	9.0	-4.6	1.6	-9.2	3.2
ITA	10.0	18.6	12.5	56.4	2.5	18.1	14.4	16.1	47.5	4.0	8.1	-4.2	3.5	-8.9	1.5

Source: Authors' calculations using WIOD and TRADE-Scan data

The composition of the imported employment by technological group shifted towards non-manufacturing activities in all regions except China (Figure 5). This growth is counterbalanced by a reduction in the number of workers in the most advanced industries, High-Tech and automotive. The participation of employment from the automotive industry increased considerably only in EE, where in 2014 it almost represents 20% of the total. The number of workers employed in High-Tech sectors is steady or decreases in all regions, with the only exception of China. However, despite this process of catch-up, the absolute participation of China in these two industries in 2014 is still below that of EE and SE.

Figure 5. Share (%) of the origin of "source" employment embodied in the final production of the automotive industry by region of imports and technological group of intermediates inputs. Imports from the automotive industry only. Source: Authors' calculations using WIOD and TRADE-Scan data.

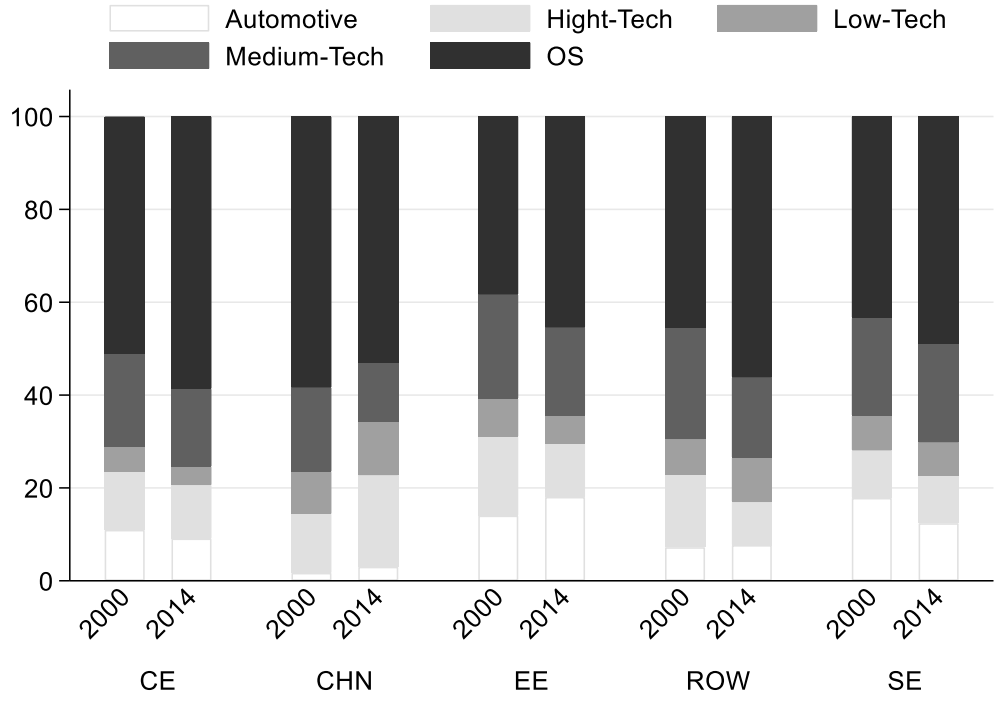


Table 3 digs into the technological composition of imported employment focusing on each final producer. Germany is the country where the offshoring process is more concentrated in the imports of labour from the automotive industry. In terms of direct imports, they represent approximately 40% of the total. France and, to a lesser extent, the UK are the countries that are more reliant on the High-Tech industry, although this share decreases in time.

The relative importance of these industries by country is confirmed also when considering on the "source" contribution of each technological group. In this case, the share of employment absorbed by manufacturing is lower than when analysing the direct relations of production. This is because much of the direct employment that is accounted by manufacturing is indirectly employed in the OS (mostly services) industries. Moreover, the share of imported "source" labour generated in the automotive and HT industries is steady or declining. The only exception is Italy, where these two sectors gain weight during the period, but their share is still lower than the other three producer countries. This implies that much of the increase of the direct imports from the automotive and HT industries is, in fact, due to the increase of employment generated in other sectors (mainly OS and, to a lower extent, LT) which is finally embodied in the automotive and HT sectors.

Table 3. Share (%) of imported employment by technological group. Direct employment and "source" employment

	Step 1: "Source" imports					Step 2: Direct imports				
2000	AUTO	HT	LT	MT	OS	AUTO	HT	LT	MT	OS
DEU	12.3	12.7	6.4	20.4	48.2	38.3	17.9	4.8	24.6	14.3
FRA	8.0	19.6	7.4	20.4	44.6	23.5	37.1	7.9	24.4	7.1
GBR	7.5	15.4	7.2	24.6	45.3	26.1	26.1	7.4	33.3	7.2
ITA	6.3	10.4	9.5	25.1	48.7	20.9	15.6	13.2	36.7	13.6
2007	AUTO	HT	LT	MT	OS	AUTO	HT	LT	MT	OS
DEU	11.7	12.4	6.2	17.6	52.1	40.4	19.2	4.1	24.6	11.6
FRA	7.0	16.6	8.9	16.7	50.7	22.8	34.1	12.0	23.7	7.4
GBR	9.1	14.1	7.3	17.8	51.7	32.8	25.5	7.2	26.6	7.9
ITA	7.1	10.3	9.8	19.5	53.4	25.3	16.3	13.3	32.0	13.0
2014	AUTO	HT	LT	MT	OS	AUTO	HT	LT	MT	OS
DEU	11.8	10.4	7.3	16.4	54.1	41.2	17.5	5.5	21.9	13.9
FRA	7.3	13.6	10.8	14.6	53.7	26.2	30.0	14.1	19.6	10.1
GBR	8.6	12.0	8.6	17.1	53.6	33.2	24.7	7.8	25.6	8.7
ITA	6.7	11.7	8.7	19.3	53.5	24.1	23.6	8.9	31.7	11.6

Source: Authors' calculations using WIOD and TRADE-Scan data

This analysis can be resumed as follows. Overall, the general picture shows that the automotive and HT industries increased their importance in direct terms, but this trend is not reflected when considering the "source" component of imports. In this case, the contribution in terms of employment of these industries is steady or declining in all final producer countries while there is a major increase is recorded in the participation of OS.

Value added, wages and profits

After presenting figures regarding the amount of employment involved in the process of outsourcing/offshoring, Table 4 completes the picture adding the income component, i.e. the share of foreign value added and labour compensation (wages) participating in the supply chain. Several relevant aspects emerge from the analysis. First, the share of foreign value added is considerably lower than the share of employment. This is no surprise, given the composition of the foreign component (see Table 2 above) that is largely dominated by countries where the value added, and wages are lower than in the four producers.

A second important consideration relates to the combined analysis of the three dimensions (employment, value added and wages). A faster increase in foreign value added (wages) than foreign employment means that the growth in offshoring is realised in countries/regions where the growth of value added (wages) is higher than in the domestic economy (see the last three columns in Table 4). This implies that, despite being cheaper than the domestic employment (identified by the lower share of foreign value added than foreign employment) the foreign component of employment is becoming relatively more expensive compared to the domestic one. From this perspective, other important findings can be highlighted. Germany is the only producer where the growth of foreign value added is below that of foreign employment. This means that in Germany the cost of the foreign components has grown less than the costs of the domestic one. This is a crucial point. The standard interpretation of German competitiveness emphasises the role played by wage moderation in this country. This is undoubtedly true, as German wages have grown less compared to the other three countries and compared to imported wages (see Table 4). However, this is only part of the story since final prices can be considered as the sum of the value added (wages + profits) embodied in all stages

of production (Shaikh, 2016, chap. 9). In Germany, the profit component of value added has grown considerably more than wages, and above the growth of the imported value added.

In the other three countries, the situation is the opposite. In this case, the increase in foreign value added has always been above the growth of foreign employment, implying a reduction in costs of the foreign employment that has become increasingly more expensive compared to the domestic one. Furthermore, it is worth highlighting that this path is not uniform in the first and second sub-period. Between 2000 and 2007 the growth of the share of imported employment is above (or in line, in the case of the UK) that of imported value added, implying that foreign labour becomes relatively cheaper than domestic one. Part of this trend can be imputed to the higher growth of the participation of Chinese employment during this period (Table 2). In the second sub-period, the situation is the opposite and more than counterbalance the trend experienced until 2007. The increase in the share of foreign value added is higher than the growth in foreign employment. This growth of the imported costs can be partly imputed to the faster rise of countries with relatively higher wages and profits in absolute terms (such as EE countries and, to a lesser extent, CE countries) and the reduction of the imported labour from China.

Table 4 Share (%) of imported employment over total employment, imported value added over total employment, imported wages over total wages and imported profits over total profits by producer country.

		2000	2007	2014	Δ 2007 - 2000	Δ 2014 - 2007	Δ 2014 - 2000
DEU	Employment	48.7	56.0	55.3	7.3	-0.7	6.6
	VA	25.1	28.4	30.2	3.3	1.8	5.1
	Wages	20.3	24.9	26.9	4.6	2.0	6.6
	Profits	33.9	32.7	34.4	-1.2	1.6	1.6
FRA	Employment	53.2	58.8	60.5	5.6	1.7	7.3
	VA	29.6	32.2	38.2	2.6	6.0	8.6
	Wages	26.4	26.0	29.7	-0.4	3.7	3.4
	Profits	34.3	41.5	52.5	7.2	11.0	18.2
GBR	Employment	49.9	57.3	57.7	7.4	0.4	7.8
	VA	23.8	31.3	32.4	7.5	1.1	8.6
	Wages	17.8	21.0	24.3	3.2	3.3	6.5
	Profits	36.5	54.2	47.2	17.8	-7.1	10.7
ITA	Employment	42.4	48.6	42.0	6.2	-6.6	-0.4
	VA	18.9	22.8	23.9	3.9	1.1	5.0
	Wages	16.3	18.2	18.2	1.9	0.0	1.9
	Profits	22.3	28.6	32.4	6.2	3.8	10.1

Source: Authors' calculations using WIOD and TRADE-Scan data

Notably, what emerges from Table 4 is that the growth of the imported costs of production is to be attributed to the growth of profits, rather than wages. In Germany, the evolution of domestic profits has contributed to the growth of domestic value added, that is in line with the evolution of imported value added. In the other countries, where it is the imported component employment becomes relatively more expensive compared to the domestic one, the growth in the imported costs has to be imputed to the rapid increase of imported profits which exceeds the growth of imported wages. The more rapid growth of profits compared to wages is also testified in Table 5, where the increase of the imported value added over the whole period is above that of imported wages.

Table 5. Average domestic and foreign value added and wages. Absolute levels (thousands of US$) and growth (%, 2000-2014).

	Value Added							
	Domestic				**Imported**			
	Thousands of US$			Growth	Thousands of US$			Growth
	2000	2007	2014	00-14	2000	2007	2014	00-14
DEU	58.2	78.7	87.5	50.2	20.1	23.4	28.8	43.5
FRA	56.7	64.9	72.6	28.0	20.4	20.7	27.6	35.1
GBR	59.3	62.4	80.3	35.4	18.0	20.1	26.3	45.9
ITA	52.6	61	61.6	17.1	16.1	17.8	24.3	50.9
	Wages							
	Domestic				**Imported**			
	Thousands of US$			Growth	Thousands of US$			Growth
	2000	2007	2014	00-14	2000	2007	2014	00-14
DEU	40.2	45.7	51.2	27.5	10.9	12.1	15.2	39.4
FRA	35.5	42.4	52.0	46.5	11.4	10.7	14.5	27.4
GBR	43.4	49.5	58.1	33.8	9.6	10.1	13.8	43.7
ITA	30.6	35.8	39.6	29.3	8.5	8.8	12.4	46.8

Source: Authors' calculations using WIOD and TRADE-Scan data

Occupational composition and change

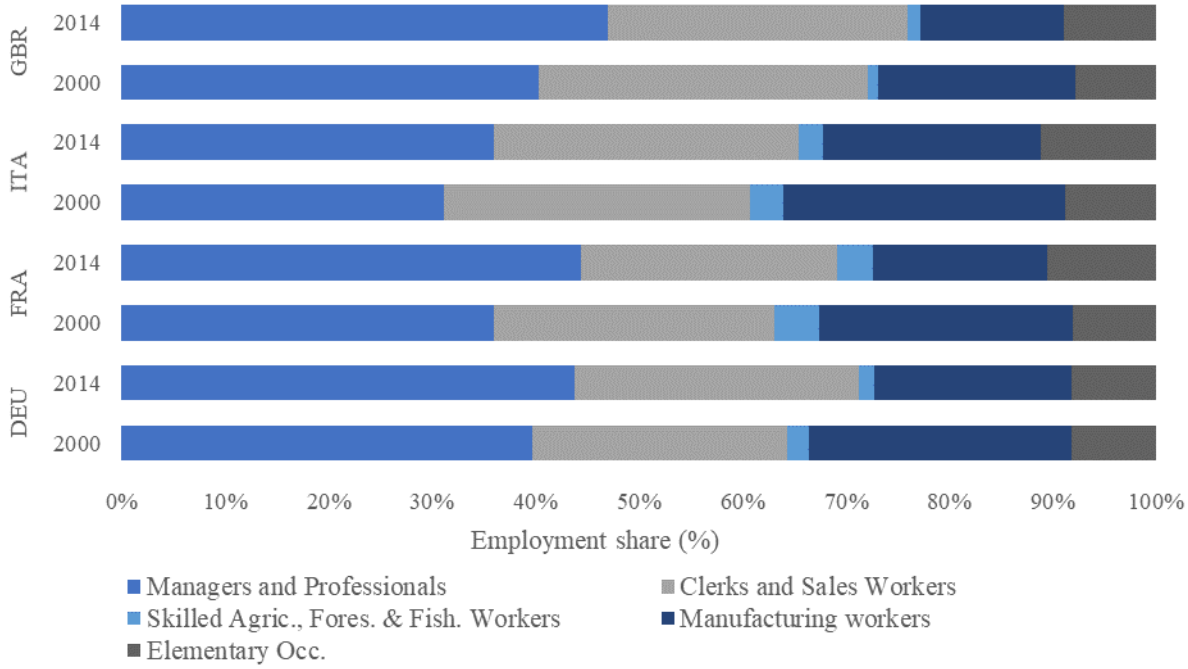
In the present section, we dig into the dynamics of occupational structures of both imported and domestic labour within the automotive value chains. The methodology described in Section 3 allows us to trace changes in the employment composition of the offshored production as well as the employment composition in the producer countries. As mentioned, the results of this section comprise European countries only, due to the lack of occupational data for China and ROW. According to the results presented below, the employment structures are characterised by a generalised increase in top occupations while middle and lower occupations display more heterogenous participation. However, heterogeneity emerges depending on the aggregation used to trace these changes.

We start by focusing on the domestic composition of labour. Figure 6 shows that, considering the total domestic employment embodied in the final production of vehicles, there is an upgrading in the occupational structure of the supply chain, in line with what has been highlighted by other authors (Oesch & Piccitto, 2019). Differences in the occupational structure across the four producer countries tend to smooth between 2000 and 2014, especially thank to the growth of the top three occupations. The only significant difference between countries concern the shares of Clerical and Sales Workers whose participation increases only in Germany.

This general trend towards occupational upgrading also is confirmed restricting the analysis to the domestic employment in the automotive industry (Figure 7). The only, expected, difference is that, when restricting the analysis to the workers from the automotive industry, the share of Manufacturing workers is more relevant. However, in this case higher heterogeneity emerges across producers. In 2014, Italy is the country with the highest share of Managers and Professionals thanks to the consistent increase in the share of Technical and Associated Professional (from 15 to 35%). These findings suggest that during the period analysed there was a reconfiguration of domestic production although domestic outsourcing is rather constant (see Figure 3), with top occupations mostly held in-house and increasing their importance. An opposite dynamic characterised domestic employment in the UK where Manufacturing workers have experienced a boost (around 10 percentage points). This aspect is interesting, because it shows that, despite the intense process of offshoring put in place by British car makers, in the UK there is a growing participation of crafts and plant machines operation

workers, which are usually believed to be the type of occupations more offshorable (because of their high routinisation of manual tasks).

Figure 6. Distribution of occupations in domestic employment by producer and year. All sectors contributing to the automotive supply chain.



A similar upgrading trend is also present when looking at the imported employment from the regions that indirectly participate to the supply chain as provider of intermediate inputs Figure 8). In 2000, CE countries are characterised by a higher share (35%) of top occupations (Manger, Professional and Technical and Associated professional) compared to EE and SE countries (where this share is almost identical, around 25%). The opposite holds for the share of workers employed as Craft & Related Trade Workers and Plant and Machine Operators whose shares, both Southern and EE countries, reached fifty percent of total employment at the beginning of the period.

This difference reduces significantly between 2000 and 2014. Data show an overall upgrade in the occupational composition across regions. Both managerial and professional occupations and clerical and sales workers occupations increase everywhere. This change is accompanied by a reduction in the so-called manual occupations, i.e. Craft & Related Trade Workers and Plant and Machine Operators. Despite this convergent trend, differences between regions persist. EE countries continue to export a higher share of Craft and Plant, Machine operators and Assemblers than SE and, especially, CE countries. This result can be partly explained by the higher participation in EE countries, compared to other regions Figure 4 of the employment in the automotive industry.

Figure 7. Distribution of occupations (only Automotive) domestic employment by producer and year (automotive industry only).

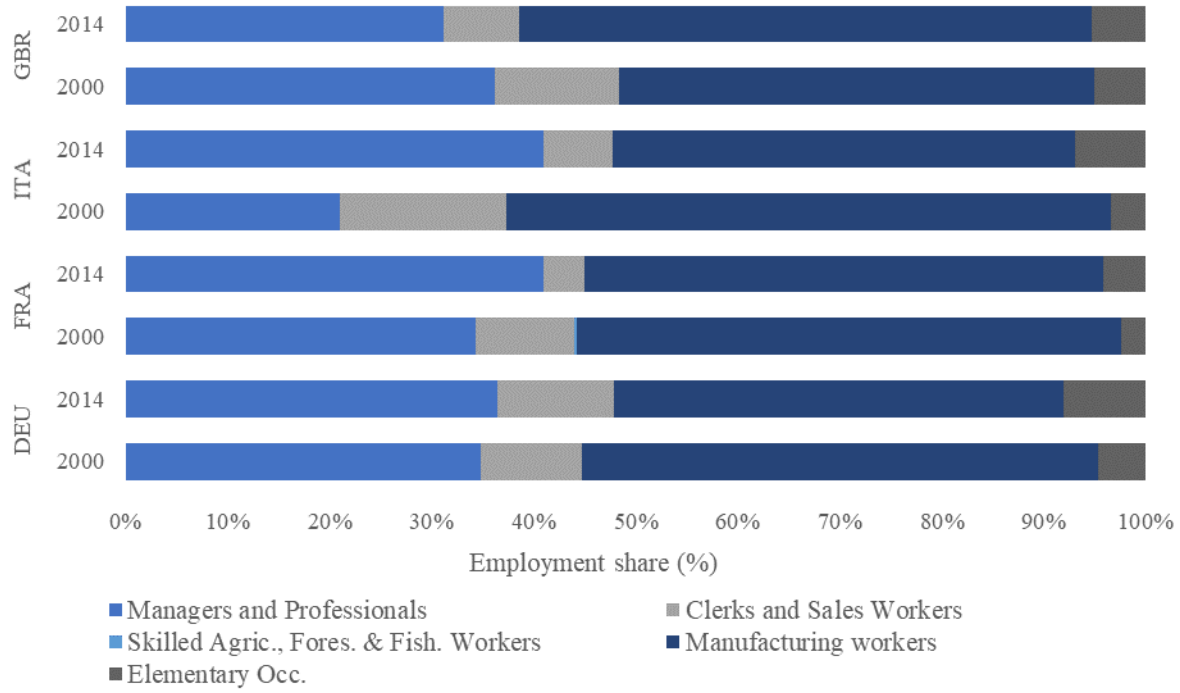
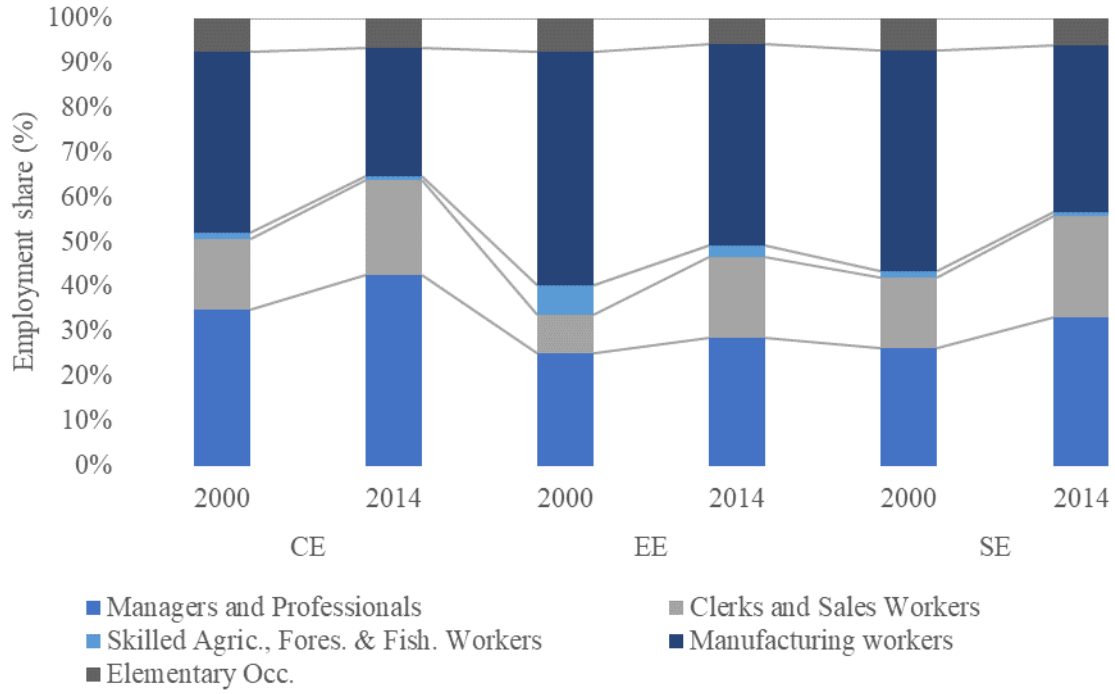


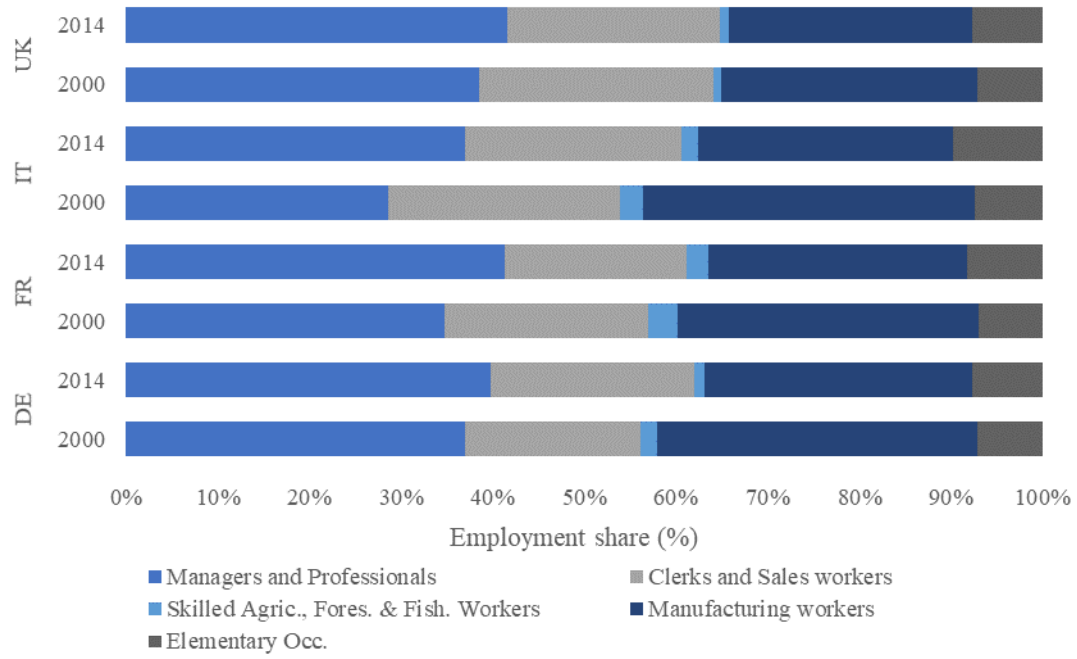
Figure 8. Distribution of employment across occupations by foreign region and year (independently of the producer country).



Finally, the total effect on the employment composition (Figure 9) of the supply chain (i.e. domestic + imported occupational composition) depends on the mix in terms of sectors and countries supplying intermediates input to producer countries (Table 2-Table 3). Overall, the share of top occupations (Managers, Professionals and Associate Professionals) increases in all countries, while the positive change among both Clerical Support Workers and Trades and Sale Workers is relatively higher in Italy at the end of the period with respect to the other producers.

Overall, despite some differences across producers, our findings show that there is a generalised increase at the top of the occupational ranking (mirrored by a simultaneous decrease at its bottom) of imported labour. This evidence has two important underpinnings: first, patterns of occupational upgrading characterise embodied labour in the production of intermediate inputs. A notable exception is represented by the UK, where so-called manual occupations in the automotive industry increased, despite the increase in offshoring. Second, the intensification of offshoring is not associated with the rise of occupations characterised by more manual and routine tasks as defined by Goos et al. (2014) in countries producing intermediate inputs: both the shares of Craft Workers and Plant and Machine Operators decline over time.

Figure 9. Distribution of imported and domestic employment across occupations by producer and year.



In summary, our empirical exercise shows that European employment embodied in the automotive supply chain follows a similar qualitative pattern of occupational upgrading, in line with most recent literature on occupational change over time (Fernández-Macías, 2012; Hurley et al., 2019; Oesch & Piccitto, 2019). Extending our analysis at the global level could reach different conclusion if labour imported from China and ROW has a higher participation of manual occupations. Nevertheless, it is still relevant to recall the trends in the regional composition of the supply chain. As shown in Table 3, the automotive supply chains in the analysed producer countries becomes more "European" between 2000 and 2014. This higher participation of European countries in the supply chain went in the hand with higher participation of professional and managerial occupations.

At present, our evidence shows that although imported labour is characterised by higher (and cheaper) share of manual workers, differences in employment structures of imported and domestic labour reduced over time.

A further step in the analysis of changes in labour demand along value chains should therefore investigate if, within a similar qualitative trend, actual differences in traded work activities emerge (that is whether the composition of the task contents embodied in imported employment, as well as organisational methods of production change significantly within the same occupation). The two aspects characterising labour process should be jointly studied to explain what lies behind the increase in Technical and Associated Professional, not only in the domestic production but also its offshored component. According to Fernandez-Macias et al. (2016), these workers are characterised by a high intensity of intellectual tasks and a low content of supervision and reduced routinized processes. Hence, routine intensity seems not to be the only determinant driver of offshorability, as claimed by Goos et al. (2014) unless it is proven that imported labour is more routinized than domestic one at the top of the occupational ranking. A specular argument applies to Plant and Machine Operators whose labour process is organised around codified standards and procedures (i.e. highly routinized) with low level of workers' autonomy. However, their weight over total imported employment has decreased during the period, challenging a deterministic link between offshorability and routine. Differences in tasks content and methods of work within the same job (occupation-by-sector pair) represent a crucial research area of inquiry for future research which explores the relationship between task, routine and offshorability.

Conclusions

This paper studied the supply chain of the automotive industry of four European producers of final goods. In line with the existing literature (Chiappini, 2012; Garbellini, 2014; Timmer *et al.*, 2015), the paper evidences the relevance of the imports which constitute a considerable part of total inputs. At the same time, other elements, that have usually been overlooked by the literature, emerge from this analysis. The tendency to offshore activities changes after the global financial crisis, both in absolute terms and in its geographical composition. The participation of non-European countries is still considerable, although declining over the period (between 2007 and 2014 from China). This has been mirrored by the growth of the share of production realised in Europe whose participation increases after 2007, especially because of the rising participation of EE countries which is especially marked in the German and Italian supply chain. The participation of EE countries is not predominant in the French and British supply chain where the imported employment from EE countries is similar to that from CE countries (and lower than the imported employment from SE countries in the case of France) In this respect, our findings provide new light to the involvement of these countries in the supply chain. The analysis also shows that figures on the direct imports of intermediates tend to overestimate the European participation, which is lower when considering exclusively the "source" employment. This means that a consistent share of Extra-European employment is not embodied in the direct imports from extra-European countries, but it is embodied in the direct imports of intermediate from European partners.

Moreover, the joint analysis of the employment and income dimension reveals that the imported component (except for Germany) is reducing its costs compared to the domestic component. Despite at the end of the period there is still a considerable absolute cost advantage in the imported components of the supply chain, this difference reduces during the period analysed. In Germany, the gap between domestic and imported cost of labour has not reduced (despite the growing degree of offshoring) because of the rapid growth of the domestic value added during this period. Importantly, this trend is due to the growth of profits generated along the German supply chain, while the growth of domestic wages is the lowest recorded in the sample. The growth of profits is also responsible for the growth in costs of the imported components in the other producer countries, which is testified by the lower (higher) growth of the share of imported wages (value added) compared to imported

employment. This evidence should put emphasis on an often neglected component of costs (profits) which also impact on price formation. In this study we have highlighted that neglecting the role played by profits in the formation of costs lead to radically different interpretations regarding the evolution of costs of production and its functional distribution.

The second main contribution of this paper is the joint analysis of the dynamics of overall employment embodied in each phase of the production process along the value chain and its occupational distribution, that was realised linking EU-LFS data to WIOD data. Our findings involve two important aspect. First, despite some differences persist across regions, the European value chain related to the automotive sector confirms a structural pattern of upgrading (Hurley et al., 2019) both across producer (apart from the UK) countries and across "importing" regions. In particular, the share of top occupations such as professionals and, more importantly, Technical and Associated Professionals, increased, while the opposite trend applies to the share of Craft and Plant & Machine Operators and Assemblers. Second, our findings question the hypothesis according to which offshoring is strongly and positively related to the degree of routine embodied in work activities as defined and claimed by Goos et al., (2014). If this was the case, the share of jobs characterised by higher routine, like Plant and Machine operators, should have increased instead of decreasing in countries producing intermediate inputs. Hence, routine intensity does not appear to be a strong determinant of offhsorability unless it is proven, *ceteris paribus*, that imported labour is more routinized than domestic one. At present, these conclusions cannot be drawn, due to data availability. Hence, the relationship between offshoring, tasks content and methods of work is an open and pivotal research question to be further explored. In order to accomplish this ambitious project, detailed and robust data on the tasks profile at the national level should be made available. Given the high heterogeneity between countries, using aggregate data or imposing data from one country to other national contexts, would potentially bias the results as routine and work organisational practices are not a technical and/or deterministic attribute but institutional and historically contingent characteristics of the mode of production.

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Appendix 1

This appendix is based on Arto et al. (Arto et al., 2019) and presents in detail the decomposition of equations 1 and 2.

We depart from the standard MRIO framework, where **x** is the multi-regional vector of total output, **Y** is the multi-regional matrix of final demand, **Z** is the multi-regional matrix of intermediate transactions. The multi-regional matrix of direct production coefficients is **A**, and **B** is the multi-regional Leontief matrix ($\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$). The matrix **C** is the Leontief matrix where all rows and columns from country r have been removed from the matrix of production coefficients:

$$\mathbf{C}^{(\mathrm{r})} = (\mathbf{I} - \mathbf{A}^{(\mathrm{r})})^{-1}$$

This matrix is crucial to avoid double counting. By removing the rows and columns that involve domestic transaction, this matrix ensures that the computation of foreign contribution does not include any domestic component that is exported and then re-imported.

Total exports of country *r* to country *s* ($\mathbf{e}^{\mathrm{rs}}$) can be expressed as the sum of the exports of intermediate and final goods and services. That is:

$$\mathbf{e}^{\mathrm{rs}} = \mathbf{Z}^{\mathrm{rs}}\mathbf{i} + \mathbf{y}^{\mathrm{rs}}, \qquad \forall\ r \neq s \tag{1A}$$

Where $\mathbf{Z}^{\mathrm{rs}}$ is the matrix of intermediate transactions, $\mathbf{i}$ is the summation vector of appropriate length and $\mathbf{y}^{\mathrm{rs}}$ is the vector of foreign final demand, corresponding to the exports of final goods and services from country *r* to country *s* (for $r \neq s$).

Focusing on the final exports only, the vector $\mathbf{y}^{\mathrm{rs}}$ can be expressed in terms of value added contributions as:

$$\mathbf{y}^{\mathrm{rs}} = \sum_{t} [(\mathbf{v}^{\mathrm{t}})^{\mathrm{T}}\mathbf{B}^{\mathrm{tr}}]\mathbf{y}^{\mathrm{rs}}, \qquad \forall\ r \neq s \tag{2A}$$

This is because $\sum_t [(\mathbf{v}^{\mathrm{t}})^{\mathrm{T}}\mathbf{B}^{\mathrm{tr}}]$ is equal to the identity matrix **I** (for a proof see Arto et al., 2019b, Appendix 1).

The total value added in the final exports of country *r* to country *s* can be further decomposed between the domestic value added and the foreign (imported):

$$\mathbf{y}^{\mathrm{rs}} = \underbrace{[(\mathbf{v}^{\mathrm{r}})^{\mathrm{T}}\mathbf{B}^{\mathrm{rr}}]\mathbf{y}^{\mathrm{rs}}}_{I} + \underbrace{\sum_{t \neq r} [(\mathbf{v}^{\mathrm{t}})^{\mathrm{T}}\mathbf{B}^{\mathrm{tr}}]\mathbf{y}^{\mathrm{rs}}}_{II}, \qquad \forall\ r \neq s \tag{3A}$$

Where *I* is the domestic value added that is embodied in the final exports of country *r* to country *s* and *II* is the imported component embodied in final exports.

Finally, it is possible to distinguish the productive chains that are entirely domestic from those that have passed at least once from a foreign country. Similarly, it is possible to distinguish between those chains whose value added that is exclusively foreign and from those that have passed through country *r* (the domestic country) at least once.

$$\mathbf{y}^{rs} = \underbrace{[(\mathbf{v}^{r})^{T}(\mathbf{B}^{rr} - \mathbf{L}^{rr})]\mathbf{y}^{rs}}_{a} + \underbrace{[(\mathbf{v}^{r})^{T}\mathbf{L}^{rr}]\mathbf{y}^{rs}}_{b} + \underbrace{\sum_{z \neq r, t \neq r} [(\mathbf{v}^{t})^{T}\mathbf{B}^{tz} - \mathbf{C}^{(r)tz})\mathbf{A}^{zr}\mathbf{L}^{rr}]\mathbf{y}^{rs}}_{c} + \underbrace{\sum_{z \neq r,\ t \neq r} [(\mathbf{v}^{t})^{T}\mathbf{C}^{(r)tz}\mathbf{A}^{zr}\mathbf{L}^{rr}]\mathbf{y}^{rs}}_{d}, \forall\ r \neq s \quad \text{4A}$$

Where *a* + *b* = *I* and *c* + *d* = *II*. The terms *a* and *c* are the domestic and foreign components of the value chain that embodies value added of country *r* that has crossed at least once the border. These terms are the double counted terms that are accounted into standard statistics of gross trade flows. The terms *a* and *c* correspond to, respectively, the entirely domestic and entirely foreign components that are embodied in the final exports from country *r* to country *s*. That is, $a = \mathbf{d}^{rs}_{final}$ and *c* = $\mathbf{f}^{rs}_{final}$ that are presented in section 3 of the paper.

Appendix 2

Table A1. Country classification

Region	WIOD Countries (code)
Central European (CE) countries	Austria (AUT) Belgium (BEL) Switzerland (CHE) Germany (DEU) Denmark (DNK) Finland (FIN) France (FRA) United Kingdom (GBR) Luxemburg (LUX) Netherlands (NDL) Norway (NOR) Ireland (IRL) Sweden (SWE)
China (CHN)	China (CHN)
Eastern European (EE) countries	Bulgaria (BGR) Czech Republic (CZE) Hungary (HUN) Slovenia (SLO) Slovak Republic (SVK) Poland (POL) Romania (ROU)
Rest of the World (ROW)	Australia (AUS) Brazil (BRA) Canada (CAN) Cyprus (CYP) Estonia (EST) Croatia (HRV) India (IND) Indonesia (IDN) Japan (JPN) South Korea (KOR) Lithuania (LTU) Latvia (LVA) Mexico (MEX) Malta (MLT) Russia (RUS) Turkey (TUR) Taiwan (TWN) USA (USA) Rest of the World (ROW)
Southern European (SE) countries	Spain (ESP) Greece (GRC) Italy (ITA) Portugal (PRT)

Table A2. Industry classification

Group of Industry	ISIC Rev. 4 Code	Industry
Automotive	C29	Manufacture of motor vehicles, trailers and semi-trailers
Low-Tech (LT)	C10-C12	Manufacture of food products, beverages and tobacco products
	C13-C15	Manufacture of textiles, wearing apparel and leather products
	C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	C17	Manufacture of paper and paper products
	C18	Manufacture of Printing and reproduction of recorded media
	C31_C32	Manufacture of furniture; other manufacturing
Med-Tech (MT)	C22	Manufacture of rubber and plastic products
	C23	Manufacture of other non-metallic mineral products
	C24	Manufacture of basic metals
	C25	Manufacture of fabricated metal products, except machinery and equipment
	C30	Manufacture of other transport equipment
High-Tech (HT)	C20	Manufacture of chemicals and chemical products
	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
	C26	Manufacture of computer, electronic and optical products
	C27	Manufacture of electrical equipment
	C28	Manufacture of machinery and equipment n.e.c.
Other Sectors (OS)		Remaining industries

Source: Adapted from -Rueda and Verger (2016)

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