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Armando Rungi*

Abstract

In this methodological paper, we introduce a conceptual and empirical framework that can inform on the position of European firms along Global Value Chains (GVCs). After taking stock of the most relevant scholarly works, we discuss how important it is to switch to a network perspective to account for the sophisticated coordination of webs of producers across national borders. Then, we show how a combination of firm-level data and I-O tables can be usefully employed to understand: i) the generation and distribution of economic value among interested stakeholders, ii) the organization of GVCs by multinational enterprises, iii) the propensity to retain economic value domestically, and iv) the co-location of production stages in geographical proximity. For our purpose, we introduce a case study on the global automotive industry, and we show some interesting stylized facts. Finally, we argue that firm-level evidence is crucial for the design of evidence-based policies within the Internal Market in the context of an ever-increasing global interdependence.

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1 A network perspective

1.1 From supply chains to production networks

Global Value Chains (GVCs) have become a dominant feature of the Internal Market, as they encompass an increasing fragmentation of production processes both across EU Members and with the rest of the world (ECB, 2019). Thanks to decreasing trade barriers, the production of a good or service is sliced in different elementary tasks carried out wherever the necessary skills and materials are available at a competitive cost and quality. The result is an increasing division of labor that comes together with a rising interdependence of firms, industries, and countries at a global level. Thus, modern economies can be represented as webs of producers that exchange intermediate inputs within and across national borders, and we may have a combination of both spider-like and snake-like configurations of supply networks (Baldwin and Venables, 2013), depending on the technological peculiarities of their production processes.

Yet, economic theory usually exemplifies GVCs by assuming the existence of linear technological sequences of productive tasks, i.e., the 'chain,' oriented on upstream-downstream segments[1] (Costinot et al., 2012; Antràs and Chor, 2013; Alfaro et al., 2019; Antràs and de Gortari, 2020).

Therefore, in line with theoretical models, linear position metrics are constructed from U.S. I-O tables, the Downstreamness/Upstreamness (Alfaro et al., 2019; Antràs and Chor, 2018; Antràs and Chor, 2013; Antras et al., 2012), and they have been used in combination with firm-level financial accounts to test the organization of GVCs and their value generation by matching with firms' industry affiliations (Del Prete and Rungi, 2020; Alfaro et al., 2019;

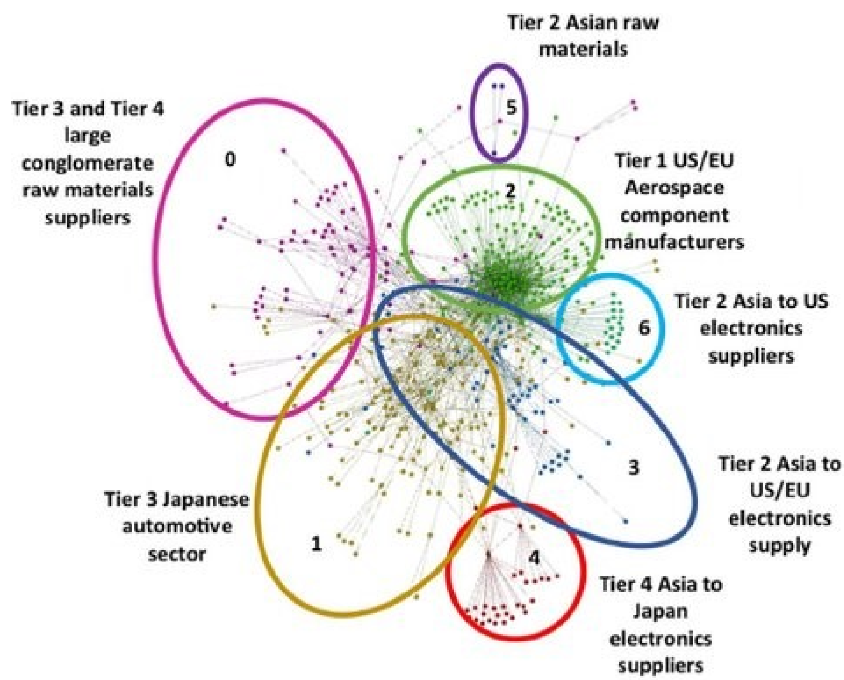
[1]We register some ambiguity in economics literature about the distinction between a supply chain and a value chain. Our opinion is that the term supply chain should be used when the interest falls on understanding the organization of buyer-supplier relationships, whereas the term value chain should be used when one is more interested in tracking the generation and distribution of economic value. Obviously, there are many cases when one is interested in how both problems correlate, as for example in following Section 2.4.

Rungi and Del Prete, 2018; Del Prete and Rungi, 2017). Eventually, Rungi et al. (2020) demonstrate how both a theoretical and an empirical representation of GVCs as production networks more usefully catches the recursive nature of many technological processes, when some intermediate inputs are needed at different stages before completion.

To get a sense of the relevance of a network approach, please consider the supply network of an Airbus, which we report in Figure 1, as sourced from Brintrup et al. (2017). Each node represents a supplier and each edge is an input shipment. The graph includes only suppliers up to a 4-th tier relationship. Still, we can see how dense the network can be and how some suppliers are more relevant than others because they deliver their inputs to several suppliers or suppliers, i.e., they are more *central* in the production process of an Airbus. Eventually, an exercise of community detection[2] on the graph in Figure 1 underlines how suppliers and shipments gather by industry and geography.

[2]One of the most important features of network structures is the existence of community structures, which can be detected by algorithms that start aggregating nodes by looking at how they interact. For a multidisciplinary review, see Javed et al. (2018).

Figure 1: The supply network of AirBus



Note: The Figure is sourced from Brintrup et al. (2017), who elaborate on original transaction data from the Bloomberg database and detect communities of suppliers that gather by geography and industry. The network includes only up to a 4th tier of supply relationships, hence excluding more upstream suppliers.

Eventually, the main advantage to switch from chains to networks is that we can understand better how non-linearities in technology and market structures can play a role in:

1. the organization of production within and across countries, when suppliers can either integrate under the coordination of a unique parent company or they engage in supply contracts among independent parties;

2. transmitting shocks within and across national borders, because their final impact depends on the topology of buyer-supplier relationship, which can either buffer or magnify initial distortions.

In the next paragraphs, we introduce the primitives of a theoretical setup in Rungi et al. (2020) that clarifies how both problems can be related. Therefore, we show how firm-level data and I-O tables can be usefully exploited to understand the network position of firms in GVCs, and how important it could be for a number of policy areas.

However, we believe it is important to clarify us a problem of definitions, which are often ambiguous in both economic literature and policy reports. In the following analyses, we will prefer making a difference between a supply chain (or a supply network) and a value chain (or a value network). In fact, we define a supply chain (network) as an ordered series of production stages that are required to finalize a product or a service that is sold to consumers. Basically, a supply chain takes shape from the technological organization of the production process, i.e. which elementary production tasks are necessary for the completion of a product or a service, and how they should be combined in a sequence before reaching the final consumers. Obviously, a supply chain (or network) becomes global when production tasks are performed in more than one country. Instead, when we refer to a GVC, we want to underline how we are interested in the economic value that is generated along a (global) supply chain (or network) by firms that compensate labor and capital services. In this context, a firm participates in a GVC if it produces at least one stage of the entire technological process, and a GVC is eventually a network of firms that trade inputs, whether they are physical or intangible inputs. Importantly, at each stage a firm adds some value in a cumulative process along the GVC that stops only with the final delivery of products or services. From an aggregate perspective, the value produced by firms adds to countries' GDPs. Hence, based on the locations where tasks are performed, the value added along GVCs can contribute to the growth potential of different countries.

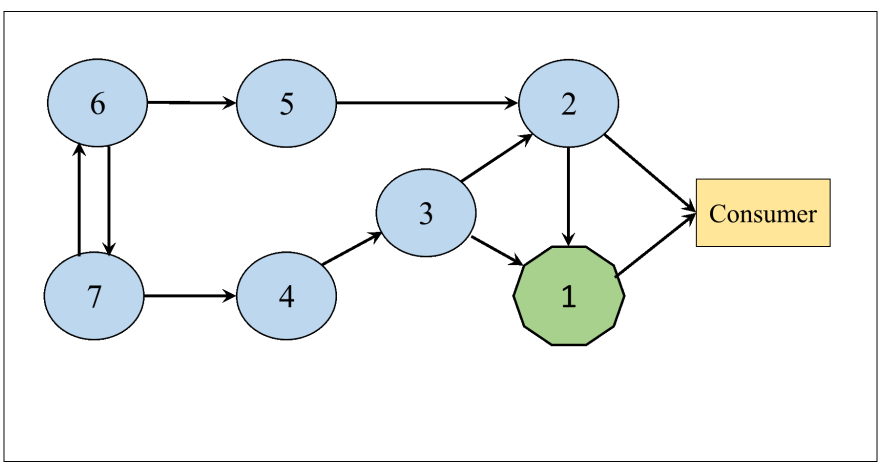
1.2 Ranking inputs

We start by introducing a fictional production network to provide the intuition for a network approach to evaluate the technological relevance of an input in a production process. In Figure 2, nodes indicate firms (production stages) and directed links indicate input deliveries (market transactions). A failure by a supplier 4 to deliver an appropriate input to firm 3 creates a friction that affects the entire GVC, as the shock for the missing delivery is at least partially passed further downstream to firm 1 and firm 2, which both use input 3 in their production. For example, one can think of either a price shock or a disruption of the logistics that can endanger the regular operations of the GVCs. Eventually, if we focus specifically on firm 1, we find that it can be hit by the same shock coming from firm 4 but:

- through a supply path firm 4 → firm 3 → firm 2 → firm 1;
- and through another supply path firm 4 → firm 3 → firm 1.

More in general, we expect that any downstream firm will be more affected by a distortion hitting an upstream supplier if: i) firms in the economy rely on more deliveries of (direct and indirect) inputs; ii) the network is more connected, in the sense that there are more supply paths through which shocks can run across several production stages. In a nutshell, the technological centrality of some inputs can have an important role in magnifying the impact shocks in presence of complex production networks (see also Acemoglu et al. (2012), Carvalho (2014), Baqaee and Farhi (2018), and Carvalho and Tahbaz-Salehi (2019)).

Figure 2: A fictional supply network, source: Rungi et al. (2020)



Therefore, from our perspective, the basic unit of observation is a path connecting any two nodes. Any two countries, industries, and firms can be connected by more than one path.

In turn, paths can include different sequences of countries, industries, and firms. From our point of view, the most useful notion of network position we should look at in this case is the *eigenvector* centrality, whose main intuition is that a node is more important if other important nodes point to it.

In this framework, a (direct or indirect) input should rank higher because:

1. it is more requested to produce other (direct or indirect) inputs;
2. it is more requested to produce other highly requested inputs.

Thus, one could figure out a nested production function[3] of a generic downstream producer i operating in a sector k, who considers the deliveries by any generic upstream supplier j operating in a sector h:

$$y(k,i) = \zeta_k \ell(k,i)^{\beta_k} \left(\prod_{h=1}^{M} \left[\sum_{j=1}^{M_h} \left[\tau_h^{-1} x(k,i,h,j) \right]^{\frac{\varepsilon_h - 1}{\varepsilon_h}} \right]^{\frac{\varepsilon_h}{\varepsilon_h - 1} g_{hk}} \right)^{\alpha_k}. \tag{1}$$

where α_k is the amount of budget spent on intermediate inputs by the downstream producer k and β_k is the amount of budget spent on labor. Inside brackets, every g_{hk} is the amount of an h-th intermediate input from upstream. A term $\zeta_k = \beta_k^{-\beta_k} \prod_{h=1}^{N} g_{hk}^{-\alpha_k g_{hk}}$ is needed to simplify computations. Since we assume a Cobb-Douglas production function with constant returns to scale, we have $\alpha_k + \beta_k = 1$, and $\sum_h g_{hk} = 1$. The term ϵ_h is the elasticity of substitution in the generic upstream market, and naturally $x(k,i,h,j)$ is the quantity of the generic intermediate input needed downstream.

Eventually, the matrix $\mathbf{G} = (g_{hk})_{h,k}$ defines the sector level technology, i.e., the actual supply network of the economy, which can be directly inferred from Input-Output tables. See Section 1.4 for further discussion and a calibration from the theory.

Crucially, a parameter $\tau_h \geq 1$ in (1) introduces the general idea of a friction on an

[3]For more details, please see Rungi et al. (2020), of which we report here an excerpt to provide intuition of the advantages of looking beyond linear sequences. In turn, Rungi et al. (2020) build upon the work of Grassi (2017) and Grassi and Sauvagnat (2019).

upstream market, say a logistic problem during a pandemic shock. When $\tau_h > 1$, we can figure out how the h-th input can be used less efficiently in the production process, and such a shock has consequences on all downstream producers.

In fact, following Rungi et al. (2020), we define the value of an Input Rank as the impact that such a distortion has on the marginal costs of a (direct or indirect) downstream buyer, i.e., the derivative (in logs):

$$\frac{\partial \log \lambda(k,i)}{\partial \log \tau_h} = \mathbf{e}_k' \left[\mathbf{I} - \mathbf{AG}'\right]^{-1} \mathbf{e}_h = \mathbf{e}_h' \left[\mathbf{I} - \mathbf{GA}\right]^{-1} \mathbf{e}_k \tag{2}$$

where $\lambda(k,i)$ denotes the marginal cost of production of a firm i in sector k, $\mathbf{e}_k$ is the k-th unit vector, $\mathbf{A}$ is the diagonal matrix that collects sector specific intermediate inputs' cost shares, $\{\alpha_k\}_{k=1}^{M}$, and $\mathbf{G}$ is the industry-level technology already introduced before.

Briefly, from this perspective, a shock can cascade through the supply structure and have an impact on the marginal costs of the downstream producer, which becomes all the more crucial if that upstream supplier is more *central* because her inputs are required by more producers in the network.

In the end of the day, the downstream impact of any shock is:

1. higher if a supplier is more *central*, because it delivers to other intermediate suppliers that use the same input in their production processes, as retrieved from its position in the entire economy $\mathbf{G}$;

2. higher if intermediate suppliers buy more of that specific intermediate input, i.e. the cost shares $\{g_{h1}\}$ for an input $h1$ are higher than cost shares of an input $h2$ in the economy represented by $\mathbf{G}$;

3. higher if the overall intensity at which intermediate inputs vs. labor inputs are employed is also higher, as retrieved from $\{\alpha_k\}_{k=1}^{M}$;

4. higher if the elasticity of substitution in the upstream market, ϵ_h is lower, i.e., there are less competitive pressures in the upstream market.

The latter two items require particular attention. What we are saying is that shocks of any nature on an upstream market can have a higher impact on downstream buyers if production processes are less labor intensive. In simple words, if we look at the fictional network of Figure 2 and there is a shock, say, at stage 4, its impact is buffered if stages 3 and 2 use more labor services than intermediate inputs. A case for competitive pressures is less evident from (2), but it is there. In a simple setting with monopolistic competition like Rungi et al. (2020), any supplier builds a markup based on the elasticity of substitution ϵ_h. Thus, a higher markup implies a higher price paid by the downstream buyers through relatively higher cost shares.

1.3 Shocks on a supply network

In this section, we briefly discuss a few shocks whose transmission could be relevant for policy making, and how they could transmit along a production network based on the simple setup we describe in the previous paragraphs. Please note that the exposition of the arguments has no pretence in terms of formal notation. It is intended as a non-exhaustive and unambitious list of possible extensions of the more basic setup introduced in Rungi et al. (2020).

Contract enforcement

The quality of a contractual environment is important for the productivity of buyer-supplier relationships. Following the empirical work conducted by World Bank (2020a), we can proxy contract enforcement as the time and cost for resolving a commercial dispute through a local courts. More in general, the efficiency of a court system has an impact on the workings of an entire economy. In our perspective, we can think of a difficulty in enforcing contracts as a shock that can be passed downstream to direct and indirect buyers, within and across national borders. If it becomes easier for a contracting party to renege on supply contracts in a market h, we can represent it as a rising τ_h, i.e. a higher wedge between the supplier and its direct buyers that cascades downstream through several production paths. In general, we can generalize the intuition by encompassing other frictions that derive from market-specific environments, as for example a rising local financial friction.

Trade policy

Although we do not explicitly model international trade in previous paragraphs, it is easy to understand how a rising trade friction can be plugged in a production network like the one introduced by Eq. (1). If a supplier and its direct buyers are located in different countries, then a rising τ_h can indicate an increasing tariff or non-tariff barrier. Such a wedge would have an impact on more downstream buyers in any sector k. Both foreign and domestic transactions will be affected by a trade policy that makes international transactions more costly, as depending on the network topology introduced in previous paragraphs.

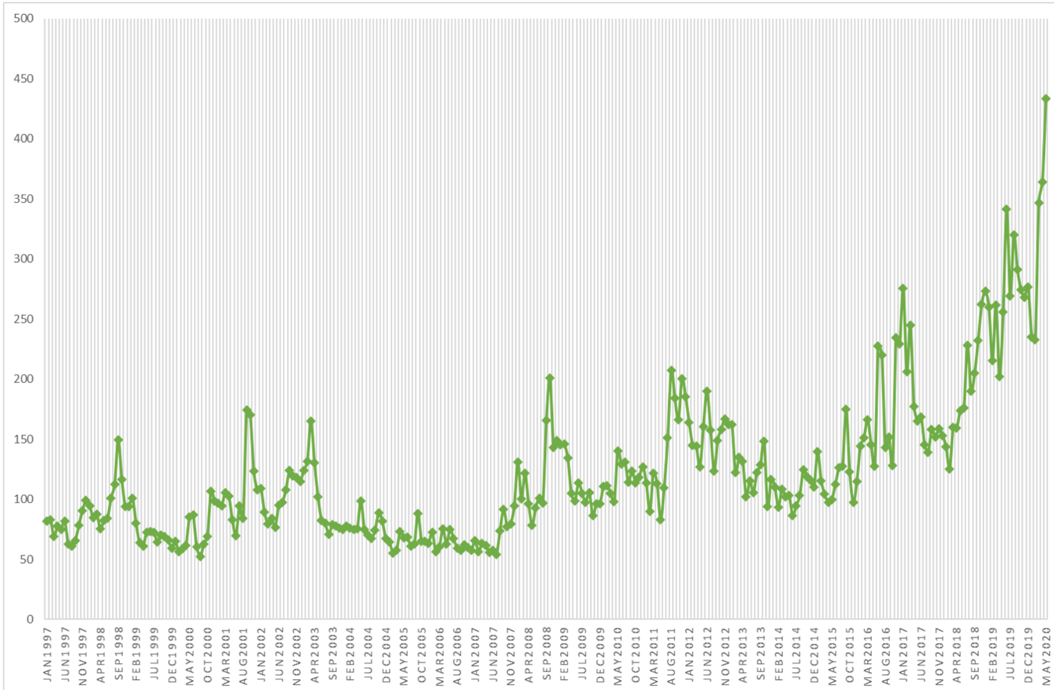
Social distancing As a measure to prevent contagion from the recent pandemic crisis, social distancing is already having an impact on the organization of production. Work from home with *smart* solutions is possible thanks to investment in information and communication technologies. Yet, we can reasonably assume that labor productivity will be lower, at least in the short and medium run, before a complete readjustment takes shape. In this case, we assume that labor-intensive industries will suffer relatively more from lower (labor) productivity. In our framework, labor intensity is the inverse of intensity in intermediate inputs, α_k. That is, social distancing will have a stronger direct impact on firms that are active in sectors where $alpha_k$ is lower. In turn, given our framework, a lower (labor) productivity will affect the entire supply network, because all input industries will deliver relatively less than before. However, more labor-intensive inputs, i.e., the ones that have a lower *alpha*, will have a higher (direct and indirect) impact on downstream buyers.

Market competition An increase in competitive pressures upstream has the potential to increase productivity of downstream buyers, if we believe in the framework introduced in Section 1.2. In fact, a higher elasticity of substitution in an upstream market, ϵ_h, implies a lower markup and, thus, a lower price of (direct and indirect) inputs, whose impact on the marginal costs of downstream buyers depends on the relative positions in the supply network.

Policy uncertainty Following recent works (Baker et al., 2020, 2016)[4], we believe that an important component of modern economies is policy uncertainty perceived by economic agents. To provide an idea of how important it is in recent decades, we sketch the global index following Baker et al. (2016). In fact, as a result of the recent pandemic crisis, the index of global policy uncertainty has peaked at its maximum over the last two decades, when data are available. The trend was already rising in the latest years as a consequence of global crisis, including tariff wars between USA and China. Previously, in 2008 and 2011, we can spot local peaks corresponding to a global and a European financial crisis, respectively. Yet, the global index almost doubled in just five months from the beginning of 2020.

[4] Baker et al. (2016) usefully construct a measure of policy-related economic uncertainty based on three components: i) a first component quantifies uncertainty by looking at newspaper coverage and text analysis; ii) a second component catch uncertainty by looking at expiration of tax code provisions in future years; iii) a third component looks at the disagreement among available economic forecasts. The analysis is available at a global level and for a number of single countries.

Figure 3: Global Policy Uncertainty (PPP) from January 1997 to May 2020



Note: The data are sourced from https://www.policyuncertainty.com/. The index is taken with a global coverage, considering purchasing power parity (PPP). For a description of the methodology, see Baker et al. (2016).

We presume that the impact of policy uncertainty at a global level adds on top of market-specific shocks. It is an uncertainty about the policies of the future that can decrease the propensity of economic agents to invest in the long term. hence further reducing the productivity of the global economy. A dynamic analysis of investment plans and their impact on the innovation of production processes is beyond the scope of the framework introduced in Section 1.2. Yet, we can presume that suppliers in a production network could discount uncertainty also in the short run, therefore reducing the purchases of both direct and indirect inputs.

1.4 An application: the automotive supply network

A nice feature of the framework in Section 1.2 is that it can be directly calibrated on Input-Output tables. For our purpose, we show an application to the automotive industry by using alternatively the U.S. Input-Output tables, sourced from the Bureau of Economic Analysis (BEA, 2002), and the world Input-Output tables, sourced from WIOD (Timmer et al., 2015).

On one hand, U.S. 2002 Input-Output Tables by BEA (2002) provide a finer-grained representation of the technological structure of an economy, because it disaggregates relationships among 425 industries (i.e., nodes) generating 51,768 transactions (i.e., edges) at the 6-digit of the NAICS classification. For this reason, the latter have been used in studies that go beyond the U.S. economy (Acemoglu et al., 2009; Antràs and Chor, 2013; Carvalho, 2014; Alfaro et al., 2016, 2019). The main assumption is that technological structure of supply networks is fixed in the short-medium term, i.e., we have the technological backbone of a GVC that is similar across countries.

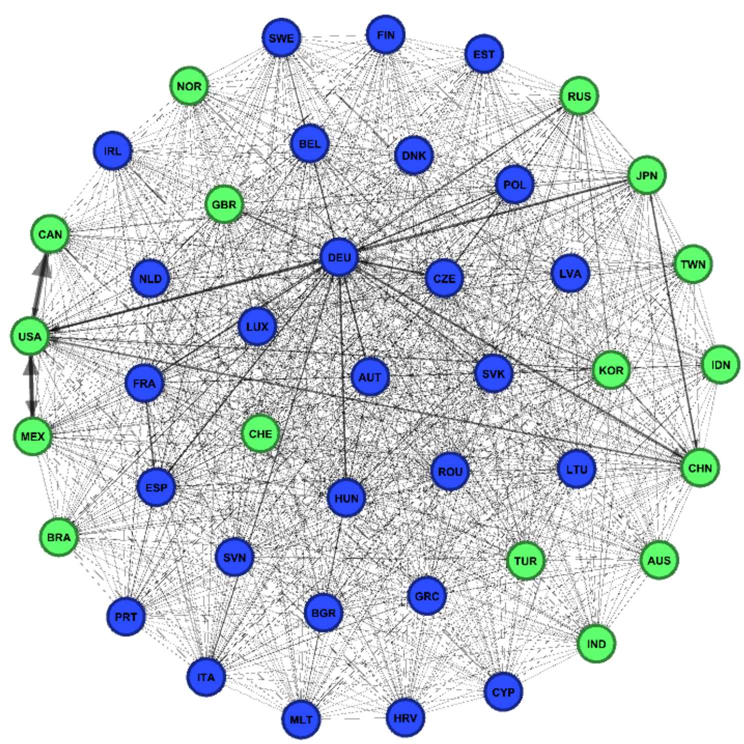
Of course, the main disadvantage is that one does not have geography in U.S. Input-Output tables. For this reason, we also look at WIOD data that include 43 countries, including a residual for the rest of the world, and 56 sectors[5]. In this case, however, the technological detail is lost because industries are reported at a 2-digit ISIC level. For example, in the case of the automotive industry, main intermediate industries producing parts and components would be classified together with final producers of cars. Geographic detail comes at the expense of technological detail. For this reason, we will adopt U.S. and multicountry I-O alternatively, depending on which aspect we are interested to look at.

We start by representing the automotive supply networks from WIOD data in Figure 4, where countries (nodes) are indicated by ISO 3-digit codes, and transactions (edges) are

[5] Another widely used multicountry I-O tables are the ones proposed by EORA MRIO (Lenzen et al., 2013). For some references where the latter have been used, see for example World Bank (2020b). An advantage in using EORA is a higher geographic coverage, up to 190 countries. However, the technological detail is very poor, since it aggregates all the national details within 26 industries.

weighted considering the amount of flows. Please note that, by excluding industries different from the automotive, we are also excluding suppliers that do participate to the value chain (better, network) of the automotive sector. For sake of a clear visualization, we select only the sub-graph made of nodes and edges indicating flows of parts and components from within the automotive manufacturing, and crossing national borders. Interestingly, we observe a strong integration in North-America, on one side, and in the European Union, on the other side. Both trade areas exchange intermediate inputs two-ways with partners in Asia.

Figure 4: Global automotive network, source: author's elaboration from WIOD data

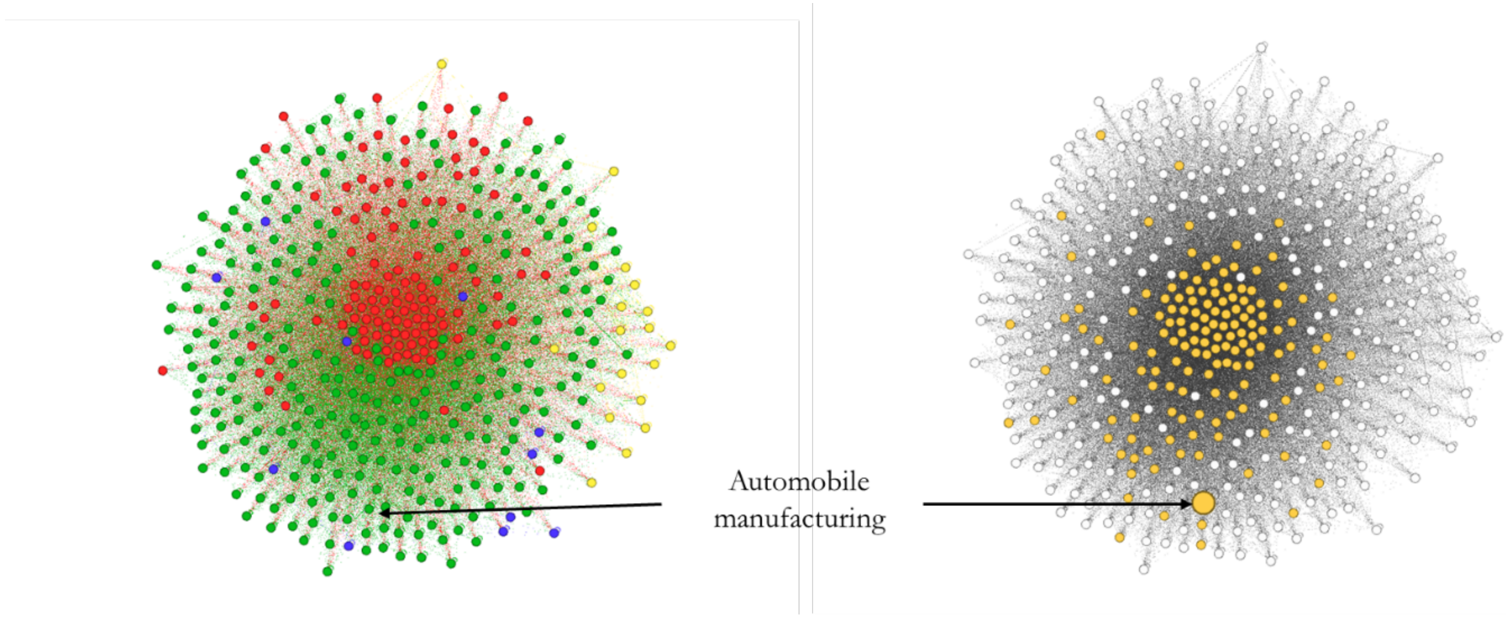


Note: The data are sourced from WIOD for year 2014, as this is the latest available year. Nodes and edges are organized by a force-directed layout, following Fruchterman and Reingold (1991) and using GEPHI software.

For visualization of networks, we adopt GEPHI, an open access graph platform introduced by Bastian M. (2009). The platform makes available many graphical layouts for networks, mainly to organize nodes and edges following some algorithms that locate nodes and relative edges depending on the peculiarities of the network structure. In the case of Figure 4, we picked the Fruchterman and Reingold (1991) force-directed layout, because it organizes any two nodes considering their attractive force based on the information on weighted exchanges (edges) of inputs. As a result, the more central node is Germany, because it integrates strongly with other main partners of the European Union that are at close geographical distance. In fact, all neighbors (Austria, Luxembourg, Czech Republic, Poland, Denmark, Belgium, United Kindgom, Netherlands) are present in a closer ring around Germany. On the other hand, Germany exchanges many intermediate automotive inputs across the Atlantic with the United States, and in the Far East with China and Japan. Interestingly, however, the strongest ties are among partners of the former NAFTA (now called USMCA: United States, Mexico, and Canada Agreement).

From our point of view, the technological centrality of upstream markets is more important than geographic centrality. Therefore, we switch in Figure 5 to BEA (2002) data. They allow us to spot the Automobile Manufacturing (code: 336111) after looking at the entire economy. The visualization by GEPHI is performed picking another alternative force-directed layout, i.e., the Force Atlas rev. 2 (Jacomy et al., 2014). In fact, we find the Automotive Manufacturing located on the outskirts of the graph mainly because it is an industry that delivers to final consumers. Instead, at the center of the graph, we find input industries that are more technologically *central* because they deliver to other industries. On the right, we report services industries in red, manufacturing industries in green, and primary industries in blue.

Figure 5: The automotive supply network from U.S. Input-Output tables



Note: The data are sourced from BEA (2002). Nodes and edges are organized by a force-directed layout, following Jacomy et al. (2014) and using GEPHI software. On the left, services industries (in red), manufacturing industries (in green), and primary industries (in blu). On the right, only top direct inputs of the Automobile Manufacturing (code: 336111) are reported if their direct requirements are above the median.

An important characteristic of modern economies, which we visualize on the left of Figure 5, is the relevance of services inputs. The most central, for example, are Research and Development, and Wholesale trade, which are both important for the innovation and the logistics organization, respectively, of virtually any industry in the rest of the economy. If we look at the right graph of Figure 5, we find a colored selection for the top direct inputs of the Automotive Manufacturing, i.e., the direct inputs whose I-O coefficients are above the median if we consider all input industries of the sector.

Please note, however, that both Figures 4 and 5 provide us an idea of *global centrality* by visualizing nodes from the inside out of the graphs, but what we may be interested is a measure of *local centrality.* The latter would consider the relative position of each supplier *vis á vis* any root node, where the final downstream customer is.

For this purpose, we can look at the Input Rank we can build from the theoretical framework, $\upsilon_k = \mathbf{e}_h' [\mathbf{I} - \mathbf{GA}]^{-1} \mathbf{e}_k$, which we briefly introduced in Section 1.2. If we fix sector k to be the Automobile Manufacturing (I-O NAICS code 336111), what we need is just the I-O table to represent matrix $\mathbf{G}$, and the entries of a diagonal matrix $\mathbf{A}$ computed as a ratio between the total use of intermediate inputs of each representative firm in a sector h at the numerator and the gross output of the same industry at the denominator. The unitary vector $\mathbf{e}_h$ will have a unique entry equal to one when k is the Automotive Manufacturing. Therefore, in Table 1, we report the top20 (direct and indirect) inputs that are most relevant for the root industry.

Clearly, the first most technologically relevant input industry for the production process of the Automobile Manufacturing is the industry itself with a value .103[6]. Indeed, despite the 6-digit disaggregation of the industry, we cannot exclude that some intermediate parts and components are produced in the Automobile Manufacturing, and they are sourced from

[6]Please note that, by construction, the sum of the Input Rank values of all direct and indirect inputs will sum up to one. From this perspective, we can interpret Input Rank values as percentage values, i.e., the percent marginal impact that a distortion on that specific upstream markets h will have on the downstream buyer in the root industry k.

within the industry to assemble final cars destined to consumers[7].

Table 1: Top 20 inputs for Automobile Manufacturing (code: 336111

Abs. Rank	I-O code	Industry name	Input Rank
1	336111	Automobile Manufacturing	.102631
2	336300	Motor Vehicle Parts Manufacturing	.056081
3	420000	Wholesale Trade	.011838
4	550000	Management of Companies and Enterprises	.011031
5	531000	Real Estate	.009647
6	331110	Iron and Steel Mills and Ferroalloy Manufacturing	.008335
7	211000	Oil and Gas Extraction	.007206
8	533000	Lessors of Non-financial Intangible Assets	.005214
9	221100	Electric Power Generation, Transmission, and Distribution	.005164
10	324110	Petroleum Refineries	.004916
11	484000	Truck Transportation	.004421
12	325190	Other Basic Organical Chemical Manufacturing	.004088
13	517000	Telecommunications	.004024
14	541800	Advertising and Related Services	.003968
15	334413	Semiconductor and Related Device Manufacturing	.003706
16	52A000	Monetary Authorities and Depository Credit Intermediation	.003572
17	221200	Natural Gas Distribution	.002947
18	325211	Plastics Material and Resin Manufacturing	.002804
19	32619A	Other Plastics Product Manufacturing	.002680
20	325110	Petrochemical Manufacturing	.002569

Note: Input Rank vector is computed following Rungi et al. (2020) for each using industry among 425 industries classified at the 6-digit in the U.S. BEA 2002 tables.

It is no surprise that the second most relevant input industry is the Motor Vehicle Parts Manufacturing (code 336300), for which we already have a high direct requirement coefficient in I-O tables. Less intuitive is the ranking of following input industries. As observed in Figure 5, services industries play a central role in the entire economy. In the specific case of the automotive industry, Wholesale Trade services are important for the overall connectivity of the supply logistics, because they are asked to deliver most of the tangible inputs that circulate in the production network. Then, what automotive companies derive from the industry for the Management of Companies and Enterprises (code 550000) are essentially headquarters services[8], in an industry that heavily relies on complex forms of

[7] This is a general characteristics of I-O table, whatever root industry we pick. The heavy weight of the diagonal in a I-O table and its consequences for scholars that want to measure sourcing strategies had been already documented by Alfaro and Charlton (2009).

[8] Following the original definition included in BLS (2018), we know that the sector comprises *'i) companies*

corporate governance. Of course, Real Estate (code 531000) services are much important in a heavy industry where plants for components and final goods are an essential prerequisite for production. Interestingly, Lessors of Non-financial Intangible Assets are custodians of intellectual property rights (patents, brands, engineering designs), from which a great source of competitive advantage is expected. Further down in the ranking, we find energy, financial services and other manufacturing inputs.

Please note how, in terms of magnitude, there is a huge dispersion across the distribution of the Input Rank. The impact of a distortion coming from the market for Motor Vehicle Parts (code 336300) is, at the margin, about eleven times higher than a distortion coming from Electric Power Generation (code 221100), which is in turn twice bigger than a marginal impact of a shock coming from Petrochemical Manufacturing (code: 325110).

2 The Smile Curve and value retention

2.1 Who's smiling now?

The generation and distribution of economic value by firms has gained little attention so far. Most empirical studies focus on the upgrade and downgrade of countries and industries along GVCs once looking at metrics that catch the average position in terms of value added content in trade by extrapolating from multi-country input-output tables[9]. Yet, the firm-level value added is a simple albeit useful indicator that has been relatively neglected[10] but it could be useful for the design of evidence-based policies, because it allows:

that hold financial activities (securities or other equity interests) in other companies for the purpose of a corporate control to influence management decisions; ii) companies that professionally administer, oversee, and manage other companies through strategic or organizational planning and decision making.'.

[9] This is the approach taken by many international organizations, including the OECD (2018), the World Bank (2020b), and the UNCTAD (2019). For seminal references on the decomposition of trade in value added to avoid multiple counting, see Koopman et al. (2014) and Koopman et al. (2010). The original problem is to eliminate a multiple accounting of the value of inputs from gross trade available from customs data when GVCs cross several national borders.

[10] A notable exception is the ongoing effort by R. and K. (2019)

1. measuring the distribution of surplus among factors of production (labor and capital) from participation to GVCs;
2. catching the share of economic value that is retained from GVCs in an industry, a country or a region.
3. more in general, assessing the heterogeneity of firms within a country, an industry or a region;

Trivially, by definition, the value added of a firm is the difference between the sales and the costs of the intermediate inputs that have been used in production. Broadly speaking, if we sum up value generated by firms, we have an aggregate for the gross product of a country, industry, or region[11].

Thus, what does it mean if a firm is able to add more value than another after selling its production and paying materials and services? There are two possible non-mutually exclusive reasons:

(a) A firm is able to generate more value because its products sell better if compared to competitors, i.e., they have a higher innovative content and/or are perceived as of a higher quality.

(b) A firm is able to retain some monopolistic rents from the market, unconditional on the quality or innovation content of its products.

More than often, we can have a combination of both (a) and (b). In fact, depending on the underlying market conditions, we could compare the notion of firm-level value added with the theoretical notion of markup, which is the difference between the selling price of a good and its cost, often expressed as a percentage of the cost. More properly, if we assume that firms operate in an environment of monopolistic competition, the markup rule is $p = (\frac{1}{1+\epsilon_k})\lambda$, where p is price, ϵ_k is the elasticity of substitution in the sector k of the firm, and λ is the

[11] This is the so-called value added approach to estimate GDP at current prices, as for example taken by Eurostat. Eventually, GDP estimates for some national accounts are based on a combination of detailed economic census data and other information (e.g. retail sales, housing starts, shipments of capital goods, etc.) that are not immediately available. For a reference to the U.S. case, see Landefeld et al. (2008).

marginal cost. Therefore, under monopolistic competition, markups measure the amount of profit that producers can make out of products that are differentiated within a sector. The general assumption is that products are different because of a perceived quality from consumers, and the elasticity of substitution in a sector catches the propensity of consumers to switch from one producer to another.

In this case, there are two main differences between the notions of firm-level markups and the value added content[12]. Markups do not consider the role of labor services, because labor (marginal) costs are yet another component of the overall marginal cost, besides the marginal cost of materials. Markups are obtained at the margin, i.e., considering the additional unit sold, whereas value added is derived by construction looking *ex post* at average prices of both sold units and used factors.

In other words, a measure of value added content at the firm level cannot be used to understand the pricing rule of the firm, nor it can be used to disentangle its market power from competitiveness[13]. Yet, it retains informative power on the generation and distribution of economic value at a finer-grained level than aggregate industries and countries retrieved from I-O tables.

A firm can be able to generate more or less value in a particular stage of the GVC for a given combination of production factors (e.g. labor skills, degree of innovation, productivity, etc.), on one hand, and in relationship with the characteristics of a specific production task, on the other hand (e.g., competition environment, knowledge intensity, demand and supply shocks, etc.). It can participate to GVCs and be able to retain an amount of surplus that is

[12] A proper microeconomic investigation of the notion of value added would be useful but beyond the scope of this methodological paper. We can just assume that the value added content can be written as $\frac{p(q)\cdot q - m(q)\cdot q}{p(q)\cdot q}$, where $p(q)$ is an inverse demand function, i.e., the price at which q can be sold given the existing demand, and $m(q)$ is the demand of intermediate inputs, i.e., the goods and services purchased on the market to process sold units. Computing it from simple accounting identities, we are not making any assumption on the underlying market environment.

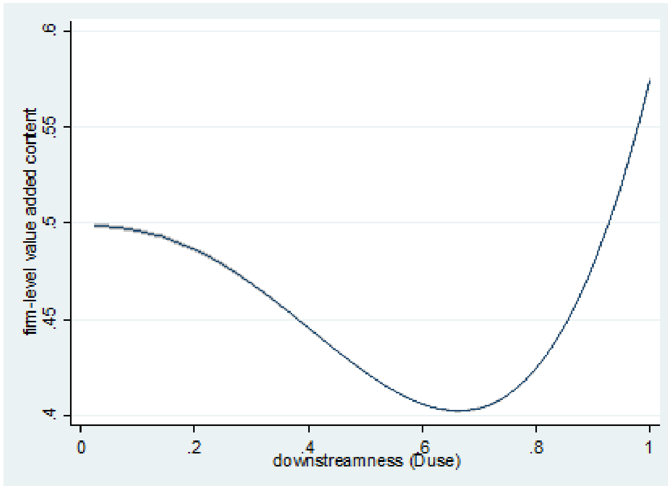
[13] Please note how similar considerations can be extended to aggregate measures of value added at the country and industry level, as the ones from (multi-country) I-O tables. Different industries and countries may entail different market environments that are usually neglected in GVC studies.

very different from similar firms across industries and countries. Therefore, the higher the amount of surplus retained from GVCs, the higher the possibility to distribute compensations to labor and capital.

In the following paragraphs, we will show how a *smile curve* analysis can track the generation and distribution of value added from firm-level databases. The concept of a smiling curve was first proposed by the founder of ACER, Stan Shih, who observed how both ends of his company's value chain were bringing higher profits than the middle part (Shih, 1996; Alcacer and Oxley, 2014). Hence, business scholars took inspiration and conceptualized the smile curve as a graph of how much economic value varies across the different production functions bringing the final products to consumers. Beyond business studies, the notion of a smiling curve has been since widely used by international organizations (OECD, 2013; UNCTAD, 2016), and a few scholars (Baldwin and Gonzalez, 2015; Meng et al., 2020) to discuss the possibly unequal gains from specialization across GVCs in developing and developed countries.

For the first time at the firm-level, Rungi and Del Prete (2018) performed an exercise on about 2.3 million firms active in the European Union in 2015 and showed that, indeed, a smile curve exists for the ensemble of manufacturing and services tasks. In Figure 6, we report the visualization of a fitted smile curve in a 99 percent confidence interval. On the x-axis, we report an ideal technological sequence measured by a so-called *Downstreamness* metrics originally proposed by Antràs and Chor (2013), whereas on the y-axis we report the fitted values of firm-level value added content in production, which we calculate as a ratio between the value added of a firm and its total sales. The smiling shape of Figure 6 is the result of a semiparametric polynomial function (Royston and Altman, 1994) of the value content on the *Downstreamness*, while controlling for firms' and market characteristics. The curvature indicates that tasks in the middle of the technological sequence generate on average relatively less value.

Figure 6: The Smile Curve in the European Union



Source: Rungi and Del Prete (2018). The exercise is performed on about 2.3 million of firms of any industry in the European Union. On the x-axis, the *Downstreamness* measure is sourced from Antràs and Chor (2013). On the y-axis, firm-level value added content is computed as $\frac{valueadded}{totalsales}$. The curve is the result of a fractional polinomial regression following Royston and Altman (1994).

The latter finding seems in line with the hypothesis that less knowledge-intensive tasks, like for example the production and assembly of parts and components, do not allow firms to reap the same gains from GVCs as if they were specialized in relatively more knowledge intensive tasks, like for example R&D, engineering, marketing and other so-called headquarters services[14].

2.2 A firm-level sample for the automotive global supply chain

In this Section, we introduce a firm-level sample for the automotive global supply chain as a case study of one of the most pervasive and relevant industries, with about 95 million vehicles produced around the world OICA (2019). Well before the pandemic crisis, the

[14]Baldwin and Evenett (2015) also speculate that there could have been 'tilts' in the smile curve over the last decades, because the production of intermediates and their assembly becomes less and less knowledge intensive, and generate on average relatively less value. The latter finding seems in line with the hypothesis that less knowledge-intensive tasks, like for example the production and assembly of parts and components, do not allow firms to reap the same gains from GVCs as if they were specialized in relatively more knowledge intensive tasks, like for example R&D, engineering, marketing and other so-called headquarter services.

European Commission (2018) estimated that the automotive industry represented 6.1% of total EU employment, providing direct and indirect jobs to about 13.8 million of Europeans. Following OICA (2019), we know that the EU and the EFTA countries provide altogether about 19% of the vehicles sold around the world in 2018, down from about 27% registered in 2005. In absolute values, EU and EFTA producers were still delivering about 18.1 million motor vehicles both in 2005 and 2018, although Chinese producers emerged on a global stage in the same period, mainly as a consequence of an increase of demand from emerging countries.

Based on the definitions provided in Section 1, the automotive supply chain is made by all firms, wherever located, which exchange physical or intangible inputs for the completion of the final products. In this respect, a GVC of the automotive industry can include both manufacturing and services suppliers, whether they contribute directly or indirectly to the production process, and wherever they are located. To get an idea of how complex the production of a car is, Berlingieri et al. (2018) reports that about 500 components are needed as made of about 30,000 individual pieces at the moment they arrive to a factory to be assembled. In turn, each component requires the work of other direct or indirect suppliers.

As far as we know, there is no comprehensive firm-level database that can catch the actual extent of any GVC, let alone the one established by the automotive industry. Ideally, one needs to collect data on all the firms and their input/output transactions at a global level. The second best option is to look at firm-level financial accounts and rely on their industry affiliations to derive their GVC positions.

In Table 2, we identify a list of industries that participate to the production process of the motor vehicles, and then we look at the firm-level financial accounts of firms active in those industries. Following the European Automobile Manufacturers' Association (ACEA, 2012), we find a first perimeter of the automotive supply chain to which we add a set of industries that we believe were missing from the original list. In this way, we obtain a broader definition of the automotive supply chain, thus separating between manufacturing inputs, services inputs, production, sales and aftersales services.

For our purpose, we source firm-level financial accounts from Orbis, by Bureau van Dijk, in the period 2000 - 2017. In the third column of Table 2, we report the number of firms for which we can find the elementary accounts needed to estimate value added content. As it is evident, the final producers of motor vehicles (NACE rev. 2 code 291) are just a small share of the entire sample. Clearly, in absence of actual shipments of inputs, we are aware that our sample includes many firms that can participate to several supply chains. This is particularly evident in the case of services suppliers. We cannot exclude them from the analysis, given their crucial contribution to the GVC, but we are aware that their services can have a more general purpose and be delivered to suppliers not related to the automotive supply chain.

From an operative point of view, it implies that:

- we cannot attribute the entire value produced by these firms (and industries) solely to the automotive supply chain;
- we assume that, within each supplying industry, there is no difference between the average (tangible or intangible) input delivered to the automotive supply chain and the average (tangible and intangible) input that does not.

Table 2: Firms and industries on the automotive supply chain

NACE rev.2	Industry name	N. firms	%	In ACEA(2012)
	MANUFACTURING SUPPLIERS			
2060	Manufacture of man-made fibres	545	0.06%	No
2030	Manufacture of paints, varnishes, and similar coatings, printing ink and mastices	4,761	0.56%	No
2211	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres	841	0.10%	Yes
271	Manufacture of electric motors, generators, transformers and electricity distribution	9,509	1.13%	Yes
272	Manufacture of batteries and accumulators	685	0.08%	No
273	Manufacture of wiring and wiring devices	2,303	0.27%	No
274	Manufacture of electric lighting equipment	5,224	0.62%	No
2815	Manufacture of bearings, gears, gearing and driving elements	1,507	0.18%	Yes
2825	Manufacture of non-domestic cooling and ventilation equipment	3,756	0.45%	Yes
292	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	2,988	0.36%	Yes
293	Manufacture of parts and accessories for motor vehicles	16,380	1.95%	Yes
	SERVICES SUPPLIERS			
61	Telecommunications	16,729	1.99%	No
62	Computer programming, consultancy and related activities	99,655	11.85%	No
63	Information service activities	28,406	3.38%	No
69	Legal and accounting services	112,406	13.36%	No
70	Activities of head office; management consultancy activities	117,444	13.96%	No
7112	Engineering activities and related technical consultancy	76,618	9.11%	No
7120	Technical testing and analysis	15,442	1.84%	No
73	Advertising and market research	60,207	7.16%	No
74	Other professional, scientific and technical activities	74,211	8.82%	No
	PRODUCTION			
291	Manufacture of motor vehicles	46,214	5.49%	Yes
	SALE			
451	Sale of motor vehicles	46,214	5.49%	Yes
453	Sale of motor vehicles parts and accessories	48,438	5.76%	Yes
4540	Sale, maintenance and repair of motorcycles and related parts and accessories	8,508	1.01%	No
	AFTERSALE			
452	Maintenance and repair of motor vehicles	74,088	8.81%	Yes
771	Renting and leasing of motor vehicles	11,925	1.42%	No
	Total	841,138	100.00%	

Note: Firm-level data are sourced from Orbis, by Bureau Van Dijk (a Moody's Analytics Company). The table considers only firms for which value added or original data on sales and materials can be retrieved. The perimeter of the automotive supply chain is derived from ACEA (2012), to which we manually add a selection of other relevant industries.

Table 3: Geographic coverage

Host economy	N. firms	%
European Union (28)	494,817	59.77%
Other Europe	79,740	9.63%
Russia and CIS	121,263	14.65%
North America	888	0.11%
South and Central America	20,005	2.42%
Africa and Middle East	1,418	0.17%
South-East Asia	109,217	13.19%
Oceania	466	0.06%
Total	827,814	100.00%

Note: Host economy is derived by looking at the country where the company is legally registered. Please note that we exclude firms that report missing information on the country of registration.

Finally, in Table 3 we report the geographic coverage by main hosting region. Firms from our sample come from about 127 countries. The most represented area in terms of number of firms is the European Union, followed by the aggregate including Russia and the Commonwealth of Independent States, and then by South-East Asian countries. Please note how a main concern regards the coverage of North America (US, Canada and Mexico), where only 888 firms from any industry are retrieved. As far as we know, there is no external source that we can compare for a sample validation. The main reason for missing values in the United States is because financial accounts do not include details for value added or material costs. Yet, we do know that the North American producers, especially from US, are among the most active on global markets, and we expect a sample selection bias that we must address in following analyses.

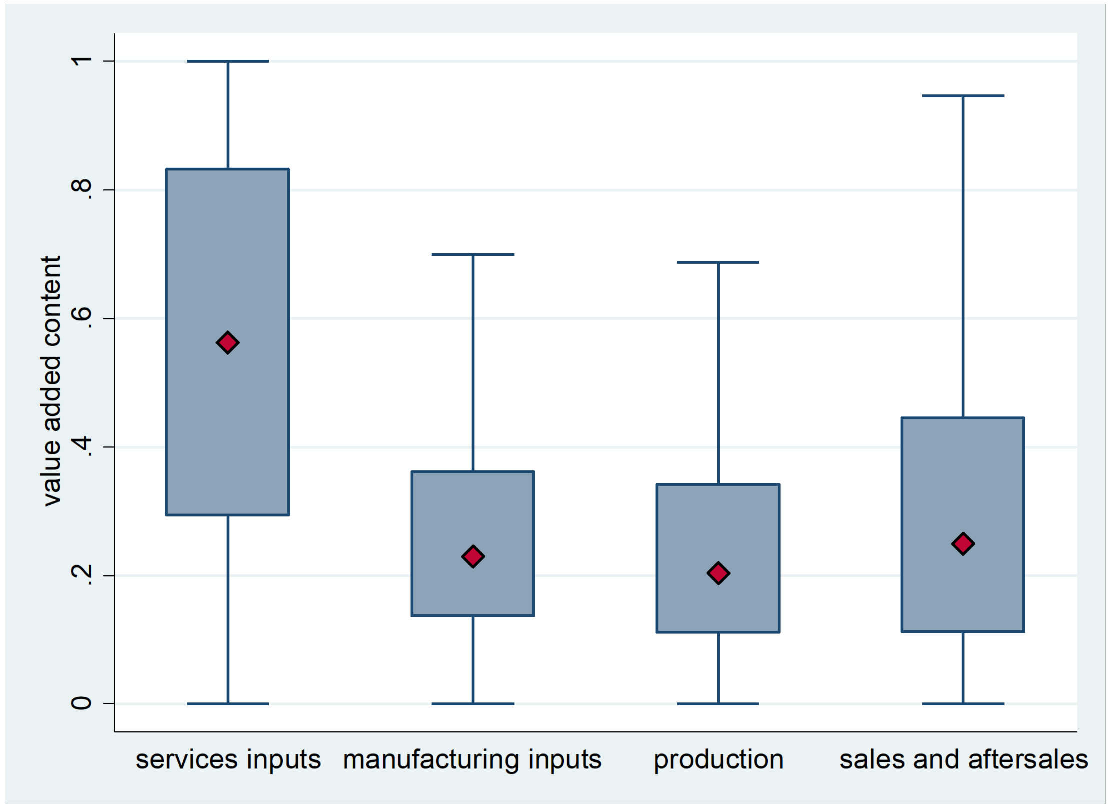
2.3 The Smile Curve of the automotive supply chain

In Figure 4, Figure 5 and Figure 6, we plot preliminary evidence elaborated from the sample of firms described in the previous section. We reclassify industries by business functions, as they are approximately ordered starting from services inputs (including, among others, engineering, technical testing, advertising, headquarter services, etc.) through manufacturing suppliers, then reaching final production, sale and aftersales services.

In boxplots of Figure 7, we observe the existence of an asymmetric *smiley* curve in the median values by looking at the red squared dots. Indeed, services inputs generate on average a greater share of value added content in production, even if interquartile ranges catch a great degree of heterogeneity at the firm level, in an interval from 24 to 82 percent. Such heterogeneity at the firm level can be explained by both characteristics of the firms and by peculiarities of the market environment. A more specific econometric strategy in Section 2.4 controls for confounding factors. On the other hand, both manufacturing suppliers and final producers generate on average a much smaller share of value content, and the interquartile ranges are narrower, in an interval between 14 and 38 percent. Sales and aftersales show a slighter higher variation from about 15 to 43 percent.

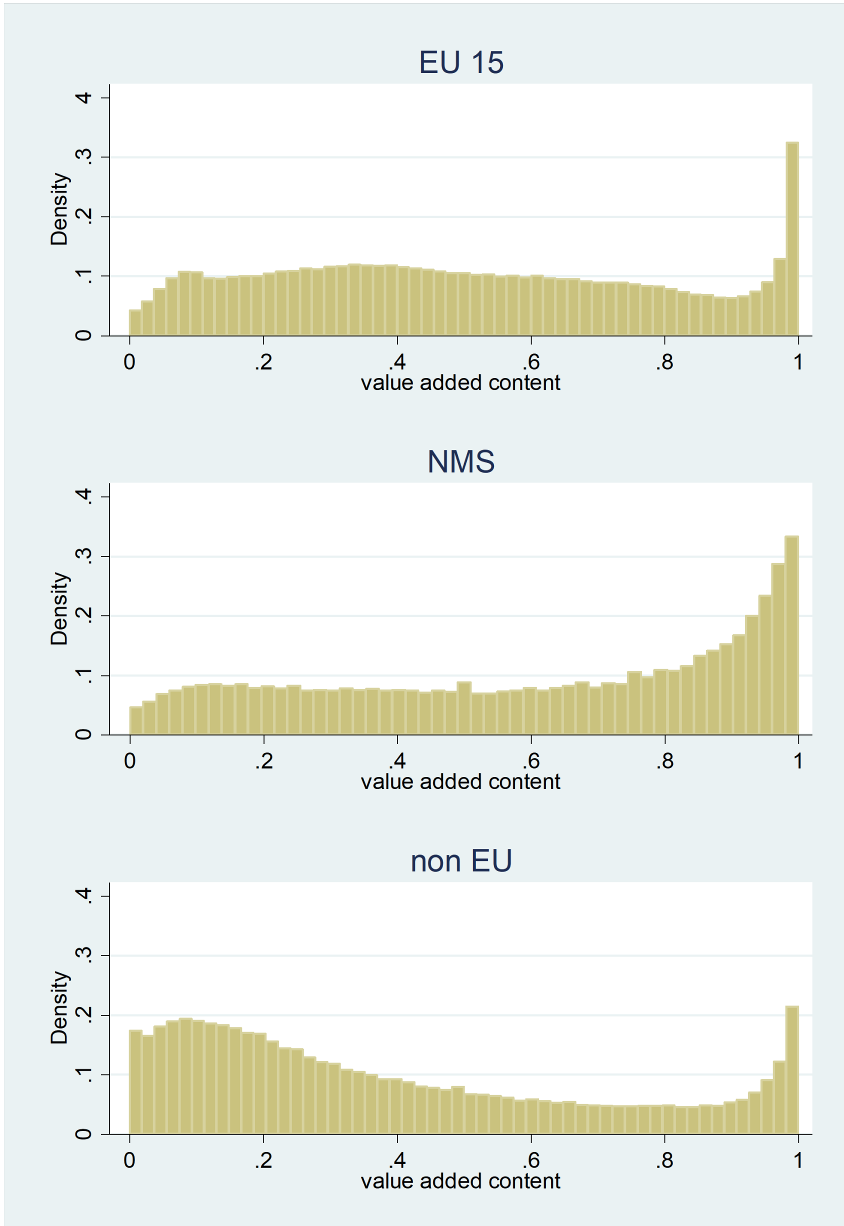
In a nutshell, the stages that contribute the most value to the automotive supply chain are to be found among services inputs, whereas the simple production of cars and the provision of parts and components have both a relatively lower value added content.

Figure 7: The Smile Curve of the automotive supply chain



Note: Value added content is computed as $\frac{valueadded}{sales}$. On the x-axis, business functions follow the classification introduced in Table 2. Red squared dots show median values, and boxplots indicate interquartile ranges.

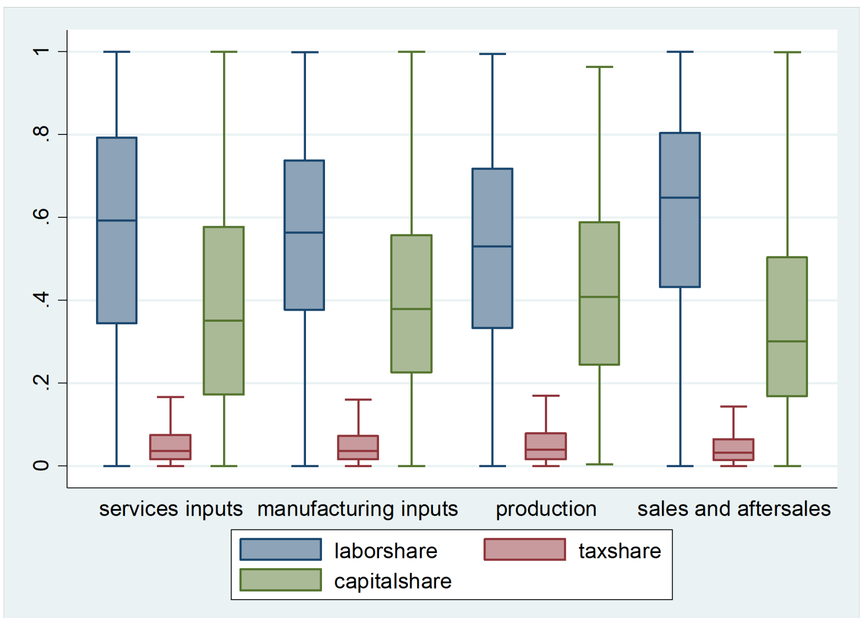
Figure 8: Heterogeneity within hosting economies



Note: Value added content is computed as $\frac{valueadded}{sales}$. Densities include firms from any industry reported in Table 2. From the upper panel, we report: i) EU 15 old members (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom); ii) New Member State (Malta, Cyprus, Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Slovenia, Hungary, Romania, Bulgaria, Croatia); iii) non-EU countries.

In Figure 8, we explore the heterogeneity of firm-level value added in the European Union and elsewhere. Interestingly, a common feature of all panels in this Figure is a sort of bimodality in the distributions. A bunch of firms piles on the right tails, mainly from services inputs, as they are able to generate a higher share of value, while a variable share of firms locate at a distance on the left tails, mainly providing manufacturing inputs. Notably, firms outside the European Union, both in manufacturing and in services, generate much less value than firms operating in the European Union: 38 and 53 percent, respectively.

Figure 9: Distribution of value among production factors



Note: Labor, capital, and tax shares are derived from firm level financial accounts, computed as ratio where denominators are costs of employees, profits, and taxation, respectively. Business functions are derived from classification of industries as in Table 2. Boxplots represent interquartile ranges and centered lines are median values.

Eventually, in Figure 9 we track how value is distributed to compensate production factors. From firm-level financial accounts, we have costs for employees (including social charges and retirements costs) and profits. We can further retrieve information on tax payments. They are all taken as ratios over value added. Therefore, the boxplots give us an idea of how much compensations can vary within and across business functions. The labor and capital shares are calculated as simple ratios on the value added. Remarkably, interquartile ranges are always wide for both capital and labor compensations. We do find a great degree of heterogeneity also in how value is distributed among production factors. Yet, *prima facie*, there is no differential pattern across business functions.

2.4 Patterns of domestic value retention

In this Section, we test the hypothesis that activities performed by domestic companies generate on average a higher value added content than activities performed by foreign firms. For this scope, we introduce the following basic strategy:

$$y_{ickt} = \gamma_o + \gamma_1 dom_i + \gamma_2 X_{it} + \vartheta_k + \rho_{ct} + \varepsilon_{ickt} \tag{3}$$

where the dependent variable $ickt$ is the (log of) value added content of a firm i located in a country c operating in an industry k at time t. Therefore, our main coefficient of interest is γ_1, which indicate whether a domestic-owned firm has a value added premium over foreign-owned firms, because dom_i is a binary variable equal to one if the ultimate owner of company i is a country resident, and zero otherwise[15]. The matrix $\mathbf{X}_{it}$ gathers firm controls including firm size, capital intensity and, labor productivity. Industry fixed effects ϑ_k control for time-invariant task characteristics, for example an implicit higher or lower substitutability among producers. Country-*per*-time fixed effects ρ_{ct} control for time-varying peculiarities of the hosting economy, including for example different business environments or corporate tax rates. Errors are clustered three-way for industry, country-time, and origin country, following the procedure by Cameron et al. (2011). Results are reported in Tables

[15] For our scope, we collect information on companies ownership and classify them following international standards for the identification of corporate control structures (OECD, 2005; UNCTAD, 2009, 2016), according to which a company is foreign-owned if a parent company controls an outright majority of voting rights (50% plus one stake). Similar data on multinational enterprises have been used in Alviarez et al. (2017), Cravino and Levchenko (2016), and Del Prete and Rungi (2017)

4, 5, 6, 7, thus considering all countries, the entire European Union, and then separately the older EU 15 Members and the New Member States.

Table 4: Domestic value added retention - All countries

Dependent variable: *value added content*$_{it}$	All	Services inputs	Manuf inputs	Production	Sales & after
$Domestic_i$	.0098**	.0121**	.0238***	.0607***	-.0021
	(.0049)	(.0013)	(.0052)	(.0188)	(.0022)
N. obs.	547,073	360,077	89,421	3,451	90,321
Firm controls	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Hosting country × Year fixed effects	Yes	Yes	Yes	Yes	Yes
Origin country fixed effects	Yes	Yes	Yes	Yes	Yes
Three-way clustered errors	Yes	Yes	Yes	Yes	Yes
R-squared	.462	.315	.320	.376	.523

Note: Errors are clustered by industry, hosting country-*per*-year, and origin country following Cameron et al. (2011). **, *** stand for p-value< .05 and p-value< .01, respectively.

Table 5: Domestic value added retention - European Union 28

Dependent variable: *value added content*$_{it}$	All	Services inputs	Manuf inputs	Production	Sales & after
$Domestic_i$	.0151***	.0162***	.0328***	.0728***	-.0003
	(.0047)	(.0053)	(.0065)	(.0194)	(.0031)
N. obs.	412,517	294,081	40,888	1,593	73,730
Firm controls	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Hosting country × Year fixed effects	Yes	Yes	Yes	Yes	Yes
Origin country fixed effects	Yes	Yes	Yes	Yes	Yes
Three-way clustered errors	Yes	Yes	Yes	Yes	Yes
R-squared	.429	.278	.174	.347	.539

Note: Errors are clustered by industry, hosting country-*per*-year, and origin country following Cameron et al. (2011). **, *** stand for p-value< .05 and p-value< .01, respectively.

Table 6: Domestic value added retention - European Union 15

Dependent variable: *value added content*$_{it}$	All	Services inputs	Manuf inputs	Production	Sales & after
$Domestic_i$	.0190***	.0192***	.0385***	.0761***	-.0041
	(.0057)	(.0059)	(.0072)	(.0203)	(.0046)
N. obs.	355,188	237,494	31,044	1,369	63,433
Firm controls	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Hosting country × Year fixed effects	Yes	Yes	Yes	Yes	Yes
Origin country fixed effects	Yes	Yes	Yes	Yes	Yes
Three-way clustered errors	Yes	Yes	Yes	Yes	Yes
R-squared	.407	.232	.191	.309	.505

Note: Companies are located in Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom. Errors are clustered by industry, hosting country-*per*-year, and origin country following Cameron et al. (2011). **, *** stand for p-value< .05 and p-value< .01, respectively.

Table 7: Domestic value added retention - European Union NMS

Dependent variable: *value added content*$_{it}$	All	Services inputs	Manuf inputs	Production	Sales & after
$Domestic_i$	.0203	.0171	.0438	.0310	.0291**
	(.0144)	(.0133)	(.0320)	(.0434)	(.0118)
N. obs.	77,326	56,584	9,844	224	10,296
Firm controls	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Hosting country × Year fixed effects	Yes	Yes	Yes	Yes	Yes
Origin country fixed effects	Yes	Yes	Yes	Yes	Yes
Three-way clustered errors	Yes	Yes	Yes	Yes	Yes
R-squared	.446	.320	.213	.348	.578

Note: Companies are located in Malta, Cyprus, Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Slovenia, Hungary, Romania, Bulgaria, Croatia. Errors are clustered by industry, hosting country-*per*-year, and origin country following Cameron et al. (2011). **, *** stand for p-value< .05 and p-value< .01, respectively.

When we look at the entire sample in Table 4, we detect a pattern of value added retention in the domestic country. This is particularly true in the case of the European Union, which represents the bulk of our sample, in Table 5. Overall, we register a higher value added content if the company is domestic-owned, specifically in the cases of services inputs, manufacturing inputs, and final production. On the contrary, aftersales activities are not significantly different when we consider ownership.

Interestingly, premia are always higher for firms engaged in final production, on the fourth columns across tables. In the EU subsample, domestic firms generate up to 7.3% more value added than foreign-owned firms. The lowest albeit significant difference is detected in the case of services inputs, in which case domestic-owned firms retain up to 1.6% more value added in the EU.

Within EU, value added content is higher for domestic firms in old EU 15 members, as shown in Table 6, while there is no significant difference in value added content in New EU Member States overall, when we look at Table 7, with the exception of aftersales activities[16].

Please note that previous results can be interpreted only in terms of correlations. We do control for many time-invariant characteristics of countries and industries, given our specification in eq. (3), but there may still be several reasons why domestic ownership correlates with a higher value added content.

On one hand, there could be a deliberate choice of producers to retain in the resident country the activities that generate a higher value because they are the ones where competitive advantage is. As from our findings, however, higher value added can be generated (and retained) across all business functions, except for aftersales services.

On the other hand, we cannot exclude that some countries more than other can favor value added retention within domestic firms, given for example the institutional environment,

[16] In Appendix, we include a table with value added retention by single EU countries. A main difference between EU15 and NMS is still there, but with some exceptions, e.g., Belgium has a negative coefficient and Bulgaria has a positive coefficient.

the regulation of labor markets, the competitive environment. It seems to be the case when we compare results in Tables 6 and 7.

Finally, we cannot exclude that some governance solutions allow some firms to generate and retain more economic value from across the GVC, due for example to some form of monopolistic or monopsonistic power. We briefly introduce this topic in Section 3.1

Indeed, we remember from Section 2.1 that a firm-level value added content includes both a markup and a labor component. Both components can be the outcome of different equilibria in the capital and labor markets. In other words, there can be unobserved characteristics of the demand and the supply in both capital and labor markets that can drive our preliminary findings, and which require further investigation.

3 The geographic dimension of Global Value Chains

3.1 An organizational problem

Following the general definition we introduced at the beginning, any firm that buys or sells intermediate inputs is plugged into a value chain, be it domestic or global, where many other producers interact on a more or less sophisticated web of supply relationships. Therefore, an organizational problem arises for which different solutions are possible. How do firms coordinate their activities?

One possibility is that companies just operate through market relationships, they sign supply contracts among independent parties, and they exchange arms' length the intermediate goods and services that are needed. That is a world where the market does coordination. Yet, more than often, a lead firm emerges that has some market or technological advantage. Depending on the effort spent by the lead firm in the coordination of the supply chain, the governance can become more relational or hierarchical. Relational governance has a lower level of chain governance because the lead firm acknowledges other buyers/suppliers their unique competences and, thus, a high degree of independence. Chain governance starts getting more hierarchical when the lead firm provides a high level of support and retains a higher governance power. The higher the integration with a lead firm, the more likely it is that exclusive contracts are signed, and therefore some monopsonistic or monopolistic power is exerted, for which the lead firm internalizes a share of the economic surplus.

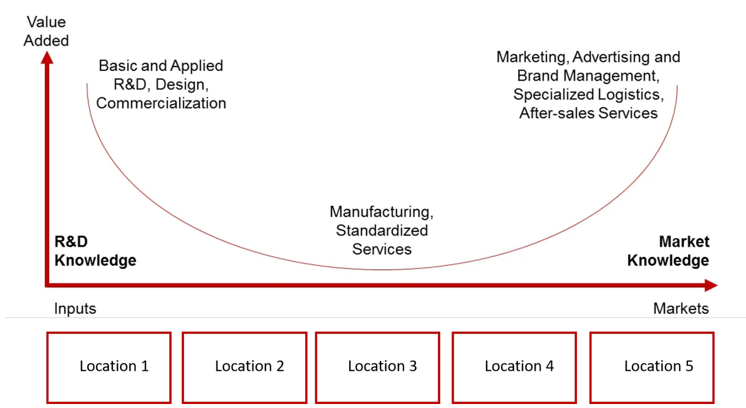
In fact, most studies often consider firms as if they were operating in a single supply chain, i.e., with a single customer downstream and a single buyer downstream, assuming they have exclusive contracts. While this is often the rule in quasi-hierarchical chains, firms in modular or market relationships more likely engage with multiple value chains, possibly subject to various forms of governance, hence serving a variety of national and international markets.

The latter is an important element to consider when one wants to consider the costs and benefits of participating in GVCs, as it has been often discussed regarding developing countries (Amendolagine et al., 2019; Navas-Alemán, 2011). Eventually, a fully hierarchical supply chain is made by parent companies that coordinate subsidiaries from headquarters. When the coordination span across different countries, we have a fully-grown multinational enterprise (MNE).

It follows from previous considerations that there is an important link between the organization problem faced by firms participating in GVCs, and their ability to generate and retain economic value, therefore upgrading or updating their production processes when it is necessary to stay competitive. There is no automatic guarantee that new technologies can spread and skills can be built by participating in GVCs, because there is always a possibility that some governance solutions keep some producers stacked in lower value added activities, while keeping for lead firms headquarters services (R&D, engineering, design, etc.) that provide competitive advantages.

In this context, the most coveted production stages are R&D services. Not by chance, their role and location along GVCs are the most studies (see, among others, Belderbos et al. (2016)). In fact, R&D labs are traditionally the least internationalised business functions, although a growing number of MNEs are starting to offshore them more than in the past. Concerns are increasingly raised that they tend to relocate next to where factories have been already offshored, because the lab and the plant interact better in physical proximity. Castellani and Lavoratori (2020) find that the propensity to co-locate is higher among firms that have less international experience, whose supply chain is less geographically dispersed, and whose share of intangible assets is lower. In this respect, co-location appears as a substitute for the firms' ability to coordinate complex organizational structures at a distance. Therefore, bigger MNEs are better positioned to exploit the benefits of production unbundling across countries, while smaller firms should be aware of the difficulties coming from geographic dispersion.

Figure 10: Location choices along GVCs



Note: Author's drawing based on Mudambi (2008)

Let's grasp the intuition of the organizational problems by looking at Figure 10. This is a partial modification of an original drawing from Mudambi (2008). Firms from more advanced and developing economies can participate to the smiley curve, however the locations that are able to attract investments on the segments of the *smiley* curve that generate more value are also the ones that could benefit from a higher growth potential. Eventually, these are also the most strategic stages of production, where intangible assets are generated. Patents, brands, best managerial practices feed value into the rest of the supply chain.

In this context, we can assume that there is a simultaneous and triple trade-off problem to solve when choosing a GVC governance. A producer has to decide:

1. whether to locate a production stage in physical proximity to other producers, and to which producers, depending on the logistics and coordination costs that such a choice entails;
2. whether to invest or not in an upgrade to move towards higher-value segments, depending on the costs of building skills and invest in intangible assets;
3. whether to vertically integrate into a hierarchical chain, e.g. an MNE, depending on the coordination costs of a bigger corporate structures, as a parent or as a subsidiary.

Clearly, each of the previous choice is linked to the others, and they are all heavily influenced by the local business environment and institutional context.

3.2 Are there co-location patterns along GVCs?

Quantitative analysis on the geography of firms' location revolves around two notions of agglomeration economies and market selection, and how to separate them (Combes and Gobillon, 2015; Combes et al., 2012). The idea is that firms are more productive, on average, when they tend to locate in proximity because they can benefit from local interactions across different dimensions, including the possibility to find local suppliers of tangible and intangible inputs. On the other hand, larger agglomerations of firms toughen competition, allowing only the most productive to survive. Thus, the presence of areas more densely populated by firms can generate relevant geographical disparities in the allocation of productive resources within countries or regions (Fontagné and Santoni, 2018).

In many related works, the presence of local supply chains is assumed implicitly as a location advantage, but never explicitly studied *per se*. Even the notion of industrial districts, which dates back to Marshall (1920), tends to identify areas in which there is a prevalence of small-medium and specialized companies, where different externalities and complementarities can boost spillovers. Among externalities and complementarities, local suppliers may have a role (Porter et al., 2009; Porter, 1990). Yet, recent investigations claim that agglomeration economies and industrial districts become less relevant in times of a global production unbundling, because many traditional strengths turns into weaknesses, including the relatively smaller size (Cainelli et al., 2018; Giunta et al., 2012).

The bad news is that, as far as we know, nobody has really evaluated the evolution of firms' local agglomerations in times of GVCs. In the previous Section 3.1, we discussed recent results regarding the co-location of R&D labs in proximity of productive plants (Castellani and Lavoratori, 2020; Belderbos et al., 2016), but we do not know of any systematic analysis that checks explicitly for different production stages along GVCs.

On the other hand, the good news is that finer-grained geographic information from firm-level data is increasingly available. In preparation of a study on this topic, we started processing firm-level addresses from Orbis, by Bureau Van Dijk, to obtain geographic coordinates and identify firms' local agglomeration. Here we present first efforts from the subset of automotive manufacturing firms located in Italy and active in the period 2010-2017. We consider the whole 2-digit NACE rev. 2 code for the automotive industry, including a total of 2,657 firms that deliver either final or intermediate manufactured goods.

From our point of view, Italy is a showcase of a country where there is a long tradition of industrial districts Becattini (1990), and where the presence of the automotive industry is non-negligible. Our first effort was to bring firm-level addresses from Orbis to geographic coordinates using a combination of Googlemaps and Openstreetmap.[17] After further data

[17]Please note that for some companies in Orbis we did find already information on latitudes and longitudes for a smaller subset of firms, but after a series of random checks we did not find correspondence between

processing, we reconstruct the entry and exit on a year-by-year basis, and import data on ArcGis, the well-known mapping software. In Table A1, we report the time coverage showing differences that take into account both exits and new entries, based on the legal status information available from financial accounts.

Table 8: Time coverage of automotive manufacturing (NACE code 29) in Italy

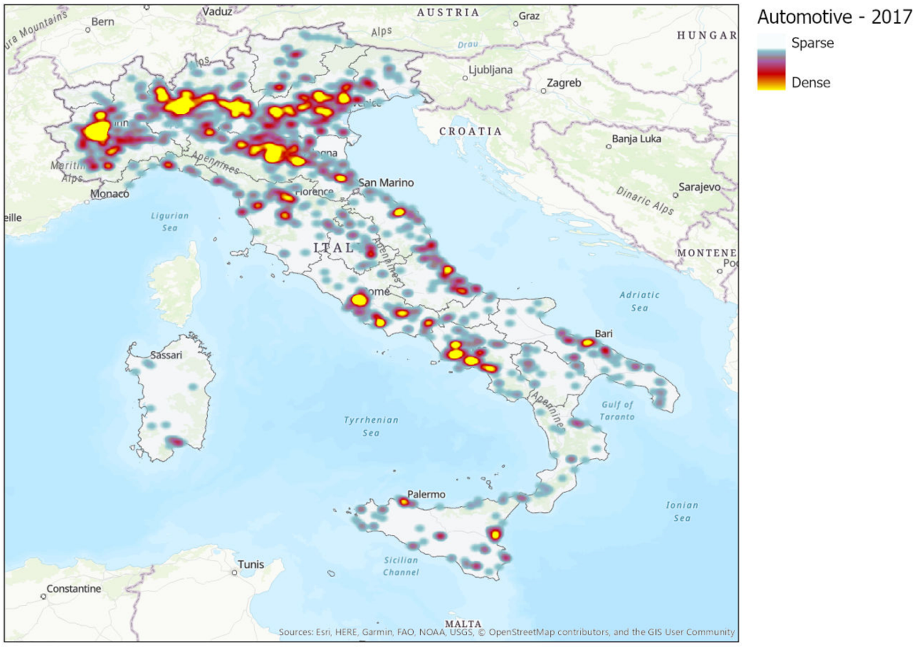
Year	2010	2011	2012	2013	2014	2015	2016	2017
N. firms	2,657	2,601	2,538	2,498	2,490	2,489	2,490	2,497

Note: Number of firms changes by considering the exit of inactive companies and the entry of newly-born companies, based on information from the legal status and the incorporation dates available from Orbis, by Bureau Van Dijk. Only firms with complete addresses are included.

First maps are reported in following Figures 11 and 12, 13, and 14. In the first map, we check for areas that are more densely populated by automotive companies, and we find that there are several areas of agglomeration around the peninsula, more concentrated in the North than in the South of the country. Yet, at this stage, we can say that the sector is widespread in different areas, i.e., we cannot really think of an exclusive district for the automotive chain. Clearly, the automotive producers do not really fit in the traditional notion of an industrial district, because they cannot afford small size. Production of final cars and parts and components requires some minimum efficient scale of production, usually higher than other lighter industries.

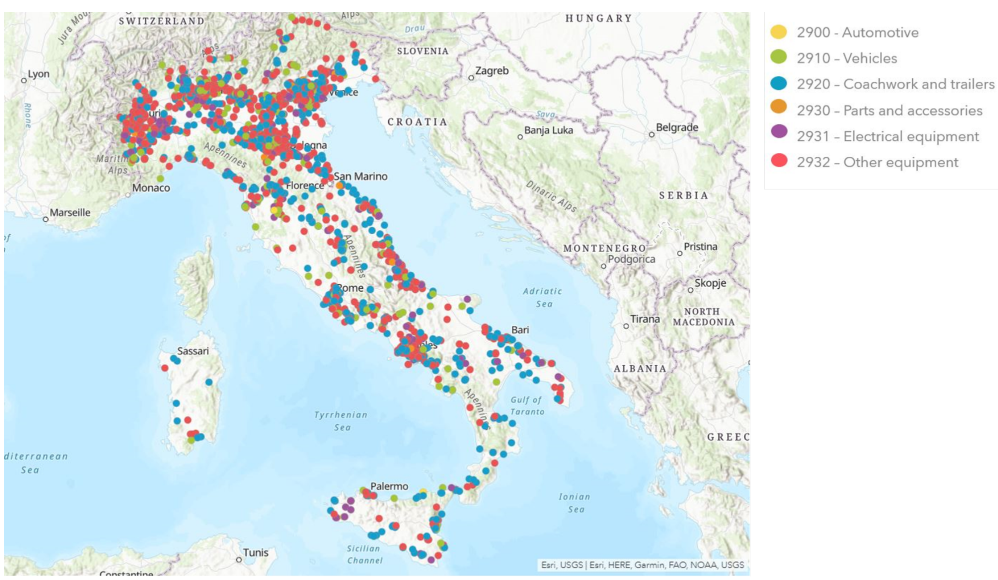
those and the correct ones, mainly because the municipality was not correctly specified, and there were similar names for streets and squares in other municipalities.

Figure 11: Clustering firms of the automotive manufacturing in Italy - year 2017



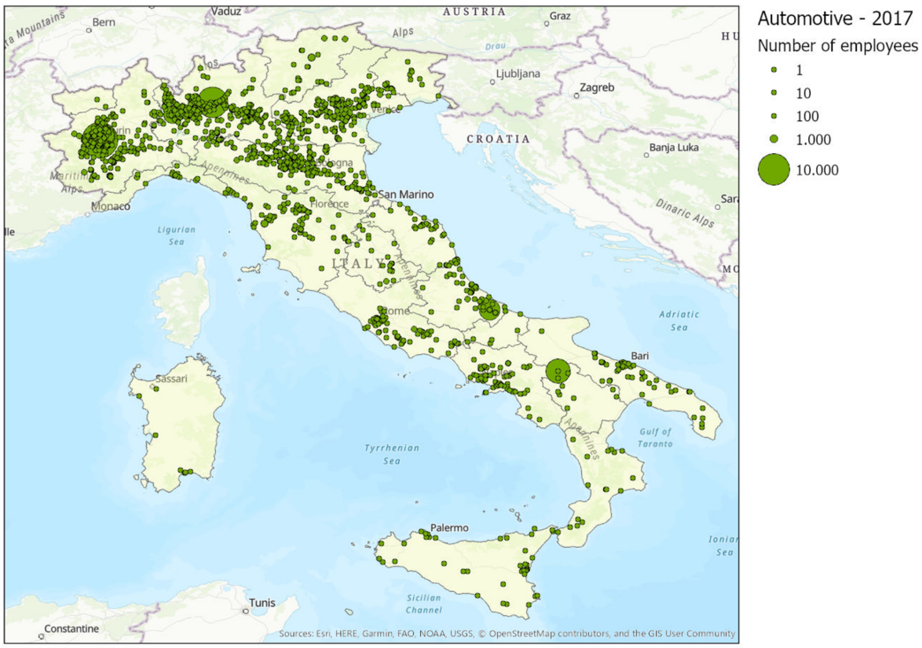
Note: Firms are clustered by number if operating in the NACE rev. 2 29 industry.

Figure 12: Mapping automotive subsectors in Italy - year 2017



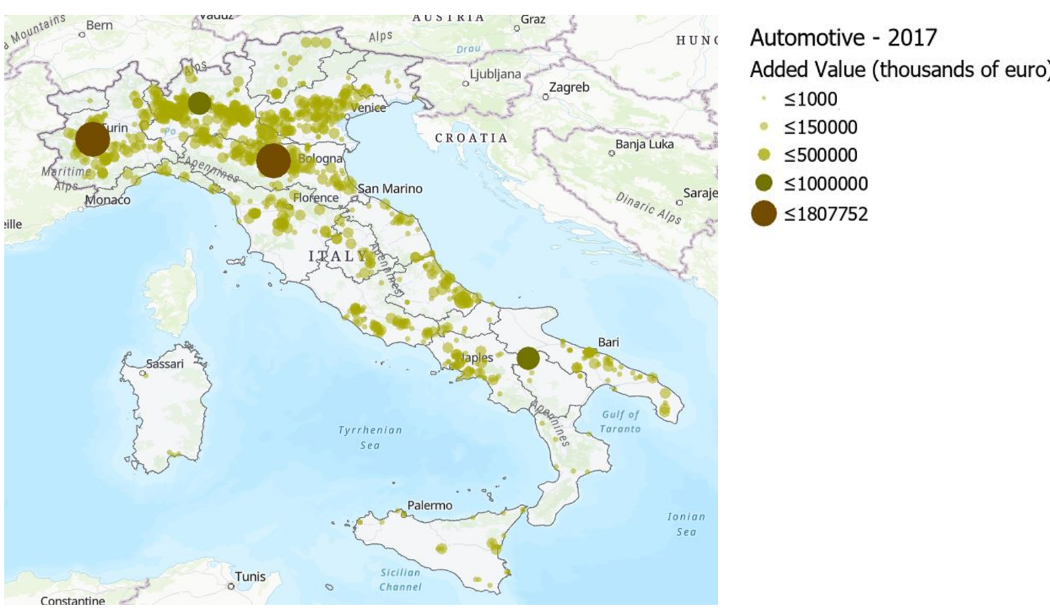
Note: Firms are clustered by number by each subsector in the NACE rev. 2 29 industry.

Figure 13: Mapping employment in the Italian automotive - year 2017



Note: Values are aggregated from local firms in the NACE rev. 2 29 industry.

Figure 14: Mapping value added in the Italian automotive - year 2017



Note: Note: Values are aggregated from local firms in the NACE rev. 2 29 industry.

When we look at Figure 12, it is evident that there is no specific pattern of co-location between producers of final goods and parts and components, at least at this scale. There are plants for equipment, coachwork and trailers scattered all around the entire territory, albeit relatively less present in the South and on the Islands. Eventually, the lack of specialization seems evident also after we weigh the geographical presence by considering local aggregates of employees and value added, in Figures 13 and 14. Clearly, the most relevant areas are Piedmont and Lombardy, where bigger agglomeration go well beyond the administrative borders of the regions. Bigger plants, like the one in Melfi, in the South of the country, do show their higher size both in terms of occupation and value added, but they do not always come with an agglomeration of satellite businesses in the parts and components.

Clearly, what we miss here is the ensemble of services inputs, which in most cases we cannot attribute exclusively to one single industry. We discussed this point in Section 1.4. In fact, most business services tend to locate in urban areas, where they can sell their services to many clients, including the ones from the automotive industry. In this case, as well, we could not claim that they tend to co-locate next to the automotive supply chain.

3.3 Conclusion

In this contribution, we discuss how firm-level data and Input-Output tables can combine to analyze the competitive position of firms in Global Value Chains. For this purpose, we make use of some stylized facts that we derive from the automotive supply chain, as the latter is one of the most relevant and pervasive in the European economy.

First of all, we show that the complex configuration of most production processes requires switching to a network approach while considering the case of a 'chain' as a corner solution of simpler buyer-supplier relationships. Therefore, we show how I-O tables can be used to visualize the central position of industries and countries in an entire economy, and we show how recent theoretical advances in production networks allow constructing consistent metrics for ranking inputs. Eventually, we discuss how a production network analysis is particularly suitable to understand the impact of different shocks in a modern economy, including the ones from a pandemic crisis. For example, in the case of the automotive producers, we find that they are particularly sensitive to what happens on upstream services industries.

In the second part of this contribution, we propose a measure of firm-level value added content to catch the generation and distribution of economic surplus from participation in GVCs. Although a bulk of the empirical analyses on GVCs extracts information from multi-country I-O tables, we argue that a simple indicator extracted from financial accounts allows better catching the heterogeneous response of firms to a global unbundling in production. For example, in the case of the automotive supply chain, we showed how service inputs are the ones that generate the highest value, while a final assembly of cars is a more standard production stage that generates lower value. Interestingly, we find that domestic producers usually retain a higher share of value added across all business functions, excluding aftersales, up to a 7.3% in the case of EU final producers.

Finally, in the third part, we show how firm-level data can be used to detect geographic agglomerations of economic activities at a finer-grained level, and thus study changing location patterns over time. After we derive latitudes and longitudes from firms' postal addresses, we show the case of automotive producers in Italy, and we visualize how production of intermediate inputs scatters all across the territory, thus forming several denser areas but not unique districts of co-location in the proximity of final producers.

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Appendix

Table A1: Value added retention in EU countries

Country	Domestic retention	st. err.	N. obs.	R squared (adj)
Austria	.0167*	(.0098)	1,957	.3427
Belgium	-.0209**	(.0036)	13,616	.4560
Bulgaria	.0372***	(.0050)	17,431	.4109
Cyprus	-.0744	(.0519)	91	.7947
Czech Republic	-.0190***	(.0040)	17,614	.4559
Germany	.0126***	(.0029)	18,580	.3019
Denmark	.0018	(.0107)	1,944	.3567
Estonia	-.0370***	(.0082)	3,165	.5792
Spain	.0239***	(.0019)	57,401	.4579
Finland	.0381***	(.0049)	9,532	.3849
France	.0034	(.0022)	38,193	.4824
United Kingdom	.0144***	(.0020)	51,522	.2832
Greece	.0137	(.0085)	2,262	.2971
Croatia	.0249***	(.0066)	5,076	.4739
Hungary	.0464***	(.0173)	2,491	.4918
Ireland	.0145	(.0141)	2,994	.2041
Italy	.0081***	(.0021)	52,297	.4108
Lithuania	.0237*	(.0140)	1,055	.4018
Luxembourg	.0742***	(.0200)	513	.5058
Latvia	.0004	(.0076)	3,159	.4885
Malta	-.0318	(.0295)	296	.3628
Netherlands	.0269***	(.0084)	3,673	.2525
Poland	-.0265***	(.0066)	7,194	.4442
Portugal	-.0094***	(.0031)	17,015	.5370
Romania	-.0117	(.0082)	11,341	.3913
Sweden	.0404***	(.0022)	62,712	.4478
Slovenia	-.0431***	(.0086)	3,385	.5123
Slovak Republic	-.0327***	(.0065)	8,421	.5108

Note: Errors are clustered by 4-digit industries. **, *** stand for p-value< .05 and p-value< .01, respectively.

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