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Regionalisation and cross-region integration. Twin dynamics in the automotive international trade networks

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ABSTRACT

The paper analyses the changes that occurred over 25 years in the geography of trade in automotive parts and components. Using the Infomap multilayer clustering algorithm, we identify clusters of countries and their specific trades in the automotive international trade network, we measure the relative importance of each cluster and the interconnections between them, and we analyse the contribution of countries and of trade of components and parts in the clusters. The analysis highlights the formation of denser and more hierarchical networks generated by Germany's trade relations with EU countries and by the US preferential trade agreements with Canada and Mexico, as well as the surge of China. While the relative importance of the main clusters and of some individual countries change significantly, connections between clusters increase over time.

1. Introduction

In recent years, the automotive industry is undergoing a paradigm shift that will affect the entire supply chain and has the potential to redraw the boundaries of the sector, redefine key players and sourcing practices, and impact the relative advantage of countries and regions, reshaping existing industrial geographies. In 2018, after 25 years of the North America Trade Agreement (NAFTA), the United States requested new rules which, among other things, increased the regional content in the production of automotive components and parts traded between the three partner countries, United States, Canada and Mexico (USMCA). Signed by all three countries, the new trade agreement went into force on July 2020 but its impact on the automotive industry is yet highly uncertain. Another significant shift in this industry – the accelerated rise of electric vehicles to cope with the increasingly stringent targets of CO2 emissions – also became apparent in 2020 when, upon reopening after the COVID-19 related closures, the tide was running against internal combustion engine vehicles, with all major car manufacturers announcing major investments in electric vehicles. Finally, after the Ukraine invasion in February 2022, an increasingly unpredictable global geopolitical context advises the reorganisation of value chains. All these changes also interact with one another, outlining re-shoring strategies of some OEMs (Original Equipment Manufacturers) to keep their level of employment in the core countries, to reduce the risk of disruptions, or to counteract the regional content rule, as in the case of electric vehicles produced in Mexico with Chinese batteries (Pavlínek, 2022; Russo et al., 2022; Schwabe, 2020a, 2020b).

The analysis of the ongoing transformations requires the identification of a benchmark of the configuration of the automotive industry before all these changes began. With an original analytical framework of

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bilateral trade networks, this paper contributes to building this benchmark by defining the changing configurations of automotive components trade networks in the three decades preceding the recent turmoil.

In the economic literature on international trade, the automotive global value chains have been studied through network analyses focusing on the centrality of geographical regions and countries, but largely overlooking the contribution of countries' bilateral trade in components in structuring the subnetworks of countries and their specific role in the overall trade network. We overcome this limitation using the Infomap multilayer clustering algorithm (Rosvall and Bergstrom, 2008; De Domenico et al., 2015) on the UN Comtrade database (https://comtrade.un.org/data) of directed export and import flows, comprising 30 automotive components and parts among 42 countries (accounting for 98% of world trade flows of those items). This approach allows us to identify meso-scale entities, operationalized as clusters of countries, and their specific trades in the automotive international trade network. Further, this enables us to highlight – in their evolution over a period of 25 years - the relative importance of each cluster and the interconnections between them, as well as to analyse the contribution of countries and of components and parts in the clusters.

Thanks to the use of multilayer network models in detecting meso-scale entities, we address three issues. First, we identify the clusters of countries that define the trade networks without referring to conventional geographical areas but rather leveraging the pattern of recurring interactions in countries' bilateral trade flows in the various components. Second, we evaluate the contribution of countries and automotive components in determining the relative importance and structure of the various clusters over time. Third, we analyse the changes in the relative positions of countries within and across clusters and in their specialisations in multilateral exchanges. Specifically, the paper highlights the changes that occurred between 1993 and 2017 in the geography of trade relations, with particular regard to denser and more hierarchical networks generated by Germany's trade relations with the EU countries and the US preferential trade agreement with Canada and Mexico, as well as the upsurge of China. With a similar overall variety of traded components and parts within the main clusters (dominated respectively by Germany, US and China&Japan), the Infomap multilayer analysis singles out which components and parts determined the relative positions of countries in the various clusters and the changes over time in the relative positions of countries and their specialisations in multilateral trades. Countries' relative position in international trade depends on various dimensions, including a country's skills and competences, the position of its companies in the automotive supply chain, its industrial policies, the preferential trade agreements to which it is party. These dimensions determine the direction and size of trade flows, that are the focus of our analysis, and will be considered in interpreting the results.

The paper is structured as follows. To contextualize the method of analysis proposed in this paper, Section 2 surveys the literature on network analysis of international trade and highlights major results so far obtained and the gaps that we try to fill with our analysis. Section 3 presents the data sources. Section 4 describes the analytical model methodology of Infomap multilayer cluster detection adopted in our analysis (details on the mathematical model and parameters' setting used in the implementation of the algorithm are in Annex). Section 5 illustrates the results of the analytical model: the meso-scale entities detected by the algorithm and the pattern of twin dynamic of regionalization and cross-region integration. Section 6 builds on these results to focus on trade patterns - by cluster of countries, countries and products - and on the implications of environmental regulations on trade of internal combustion engine (ICE) components, which will be displaced by 2035 when EU, China and US will enforce more stringent norms for sustainable vehicles. Section 7 discusses the results and concludes with an outlook on further research directions this research opens up[1].

2. Issues in the network analysis of automotive trade of components and parts

The automotive industry is highly concentrated, with the top 20 automakers employing approximately 75% of all the sector's workforce and contributing about 88% of the global vehicle production volume in 2018 (Hoeft, 2020)[2]. While traditionally highly clustered in core areas, since the late 20th century this sector has embraced global sourcing, with peripheral areas taking on more prominence due to the profit-seeking strategies of producers seeking to exploit countries' differences in levels of development and factor costs (Harvey, 2014). The reorganisation of the automotive supplier industry, even in presence of governments' restrictions to trades, was made possible by technological and organisational changes that significantly reduced the number of suppliers and organised the remaining ones into tiers (Sturgeon et al., 2008; Womack et al., 1991). The requirements of just-in-time production, alongside constraints on regional value content in the US trade agreement with Canada and Mexico and the common request by OEMs to their main suppliers to be followed in their new locations (the so called "follow sourcing"), led to the increased clustering of especially Tier-1 suppliers around assembly plants (Pavlínek, 2018), with local, regional and national value chains nested within the global organisational structures and business relationships of the largest firms (Sturgeon et al., 2008: 304). The need to produce where you sell added to the production diaspora. The geographic structure of the automotive industry is now based on the presence of large assemblers and leading (global) suppliers in all major markets, organised in functionally integrated macro-regional production networks. The competitive process results in the dynamic nature of countries' positions within automotive production networks, with production (and trade) moving from countries that originally were at the centre of the automotive production (US, Germany, Japan) to a larger group of countries that were becoming integrated with the original ones in various configurations of dependency, structured by patterns of specialisation and integration in regional areas (Amighini and Gorgoni, 2014; Celi et al., 2018; Gorgoni et al., 2018; Klier and Rubenstein, 2008; Pavlínek, 2018, 2020, 2022; Sturgeon et al., 2008; Womack et al., 1991).

The fragmentation of production in global value chains and the emergence of regional specialisations have prompted the flourishing of a rich literature using network analysis, as trade data fit perfectly this methodology thanks to the availability of yearly official (e.g. from United Nations) datasets for all countries covering long time-spans with highly detailed commodity specification. A network approach is proposed to analyse and compare weighted trade networks over time, to focus on global value chains, to interpret the specific features characterising international trade (product complexity, centralized network). A selected group of contributions is examined in this Section describing their methods and results to highlight specific gaps that we overcome with the specific methodology proposed in our paper.

To characterise the dynamics of international trade, the seminal paper by Fagiolo et al. (2009) studies the topological properties of world trade by focusing on distribution dynamics and evolution. More specifically, they employ a weighted network approach to characterise, for

[1] Selected Figures and Tables marked with the symbol can be browsed online - by using the tool implemented with Tableau Public - with respect to data and community detection (part A), and to flows within and between clusters (part B). Changes over time in the relative positions of countries and their specialisations in multilateral trades can be explored in detail.

[2] Annex 1 presents figures on the share of production of vehicles by country (Fig. A1) and by car maker (Fig. A2) in the years 2003, 2013 and 2017 and export and imports of automotive components and parts and of motor cars (Table A1).

the period 1981–2000, the distribution of the most important network statistics: node connectivity, assortativity, clustering, and centrality, as well as link weights. The paper leads the way for various contributions using network analyses for assessing the distributional properties of these statistics (and their correlation structure), their predictive implications, and the impact of the adoption of alternative -economically meaningful -weighting schemes on the results.

In line with the exploration of topological properties of world trade, Barigozzi et al. (2011) conceptualise international trade in a multiplex framework[3], where each category of commodities is considered as a separate international trade network. Bilateral trade flows for 97 products (from UN Comtrade statistics, 2-digit Harmonized System 1996 classification) refer to a panel of 162 countries for which data is available over the period 1992–2003. The analytical perspective adopted by Barigozzi et al. (2011) allows for comparison across the different cluster configurations in which countries are embedded in specific trades, and shows the heterogeneity of commodity-specific community structures and that their statistical properties are quite different from those of the community structure of the aggregate network. The results of this paper are very important to address our empirical research issue, but the level of aggregation adopted in their analysis encompasses automotive components and parts in the single item "Vehicles (not railway, tramway, rolling stock); parts and accessories" and thus their results are not comparable with the ones obtained in our analysis.

With a focus on the similarity of global value chains (GVCs), Zhu et al. (2018) provide a new method to measure cross country similarities in the various GVCs, over time. They use the World Input–Output Database (WIOD) to construct both the upstream and the downstream global value networks. Their original method takes into account a crucial feature in comparing the various GVCs, i.e. the specialisation of countries in products that are absorbed in different proportions by domestic and export markets. Although central in the assessment of the relative position of countries in the GVCs, as in Barigozzi et al. (2011), the level of aggregation – in this case 35 sectors (from mining to services) in the WIOD - does not allow to focus on automotive components and parts, all-in-all in the "Transport equipment".

In order to describe changes in the overall structure of trade, another approach studies network components (subnetworks) and their density (see Fortunato and Hric, 2016, for a survey of theoretical contributions). In this strand of literature, Piccardi and Tajoli (2018) analyse network structures to interpret the specific features characterising international trade (product complexity, centralized network). Using data from the CEPII-BACI database, inter-country trade of 223 countries for 1242 products (HS 4-digit classification), they define a weighted, directed network for each product and compare their results with respect to the products' complexity, which they refer to three measures (overall strongly positively correlated): the Hausmann-Hidalgo Index (Hausmann et al., 2011), the Fitness Index (Tacchella et al., 2012) and the weighted average income per-capita of the exporting country (Hausmann et al., 2007). They conclude that the "trade networks that are more centralised are those that have more complex products". Although very focused on essential characteristics of the various subnetworks (i.e. the complexity of the traded products), this paper does not shed light on the empirical contributions of countries and specific products in shaping the subnetworks, which are one of the results of the present paper. Nonetheless, in a further development of our research project our results could be complemented with the same measures of product complexity they compute in their paper. This would allow to take into account - in the cross country specialisation in the automotive GVC - the background of competences that is embedded in the notion of product complexity.

[3] Arenas and De Domenico (2016) note that, historically, the term multiplex was coined to indicate the presence of more than one relationship between the same actors of a social network. The terms 'multiplex' and 'multilayer' are used almost indistinctly as they fundamentally refer to the same concept.

With a focus on the changing international structure of the automotive trade, Amighini and Gorgoni (2014) obtain results consistent with the literature stressing the regionalisation of production (Freyssenet et al., 2003; Klier and Rubenstein, 2008). They implement a network analysis to assess: (a) the impact of the rise of new supplying countries on the organisation of auto production and the geography of suppliers; (b) the contrasting tendencies towards globalisation and regionalisation of production. Both questions are close to the empirical issues addressed in our paper, but their method has some limitations with respect to concepts of regionalisation and globalisation. They use directed weighted shares of trade flows, in 1993 and 2003, of four groups of products that encompass 30 automotive components and parts. Aggregation in the four groups, instead of using individual components, is justified by Amighini and Gorgoni by the relative technological homogeneity within those groups, respectively: engines; rubber and metal parts; electrical and electric parts; and miscellaneous parts production. Their hypothesis is that fragmentation of production networks is largely driven by technological content and value-to-weight ratios (Hummels, 2007). Adopting a mutually exclusive geographical partition of countries in regional groups (Western Europe, Eastern Europe, North America, Latina America, Asia, and Oceania), Amighini and Gorgoni use an homophily measure called E-I index (McPherson et al., 2001) to assess the degree of regionalisation of each valued network. Implementing the classification of brokerage roles proposed by Gould and Fernandez (1989) on the four networks (computed for 1993 and 2003), the authors are able to assess the various brokerage roles of the various countries, within and between regional groups. The result of this analytical model is the emergence of an increasingly hierarchical specialisation, with regionalisation of production still dominating the auto industry and fewer countries accounting for most of the world trade, in particular in the case of electrical and electric parts and miscellaneous parts that show more hierarchical networks, interpreted as the increasing concentration in a few countries of trade flows of components with higher technological content. The countries composing the core change over time. Engine parts networks became more globalised, but still more regional than global.

Focusing on a similar issue and based on the same methodology, in a more recent paper, Gorgoni et al. (2018), implement the same brokerage measures on three years (1993, 2003 and 2013) referring in this paper on the same set of countries (and not on different set according the group of products under exam as in Amighini and Gorgoni, 2014), but refer only on three out of four the previous examined groups of automotive products, excluding the miscellaneous group. Their results confirm what previously observed, with a new result on the role played by China entering the core in 2013 and the Czech Republic and Poland becoming central in Europe.

The current network literature does not capture meso-scale entities (cluster of countries) as emerging properties of cross country trades across the many interrelated trades of component and parts. To overcome the limits of current trade network literature and to address the analysis of the complex networks generated by trade, in this paper we focus on detection of multilayer meso-level entities.

Even though the contributions of Piccardi and Tajoli (2018) is in line with the identification of subnetworks within a network, and is functional in discussing the regionalization characteristics of trade networks, this contribution fails to address the more complex features of such networks that derive from multiple types of interactions, measured by bilateral trade flows occurring over time among countries, with different overall volumes of trade and specific bilateral trade. Analysis of multilayer clustering yields evidence to create a better understanding of features characterising those subnetworks, but specific methods need to be adopted to identify the recurring patterns of countries' trade across the various items under analysis, rather than considering each group of items separately.

Amighini and Gorgoni (2014) and Gorgoni et al. (2018) have a different focus, i.e., countries' centrality measures. Although relevant for ranking countries, the centrality measures do not provide information about the multilayer meso-level entities determined by the relative positions of the countries in the various trade flows. Their contributions overlook the fact that meso-scale entities of complex networks cannot be solely disentangled by categorical partitions, such as grouping the countries according to their geographical position and grouping components and parts according to their relative technological homogeneity. As we observe in our analysis, results go in a different direction when the model relax their assumptions on predefined regional groups of countries and predefined grouping of products and relies on an algorithm of community detection.

With our analysis we aim to identify the changes in the topology of international trade in the automotive global value chains in the period 1993–2017, comparing the configuration of international trade networks (exports and imports) in the years 1993, 2003, 2013 and 2017. In particular, our aim is to identify the groups of countries and the components and parts around which the networks of relations are structured and how they change over time.

Our analytical model of trade multilayer networks allows to conceptualise the notions of "regionalisation" and "globalisation" as emergent properties of the clusters of countries and trades identified in the world trade network, and not as *a priori* attributions of countries in their geographical position, highlighting the relative importance of the clusters of countries and of individual countries over time.

Countries' position in international trade depends on various dimensions, including skills and competences within the country (Hausmann et al., 2011), the position of its companies in the automotive supply chain, and the preferential trade agreements to which the country is a member. The country's set of skills, wages, regulations, innovation ecosystems and absorptive capacity shape the structure of supply of automotive components and parts, which also depends on other production specialisations in the country, as well as the location of domestic and foreign car makers' plants in the country, and on the role assigned by carmakers to supply from that country with respect to their global supply chains. Supply of components and parts, in fact, is embedded in the relationships between carmakers, with their different ramifications for assembly plants in the various final markets and their networks of supplier companies in the various countries. Regional trade agreements affect the centrality of countries by stimulating demand in specific trade and promoting changes in technologies and the organisation of industries. These dimensions, that determine the direction and size of trade flows, do not enter into the analysis of data at country level but are considered in interpreting the results.

3. Data

3.1. Automotive components and parts: selection criteria and data source

Within the context of the Standard International Trade Classification Revision 3 (SITC Rev. 3), no 2- or 3-digit aggregate would fit an analysis focusing on the set of components and parts specifically traded in the automotive global value chains (see Annex 2 for details). Thus, we chose to adopt the same list of trade items used in the previous literature. In particular, we adopt the same list of 30 SITC Rev.3 items proposed by Amighini and Gorgoni (2014), leveraging their careful selection which largely avoids the inclusion of components and parts not belonging to the automotive industry[4]. These items, listed in Table 1, were grouped into four main categories: Electrical and Electric Parts, Rubber and Metal Parts, Engines and Parts, Miscellaneous Parts.

The data source is the UN Comtrade International Trade Statistics Database. Under analysis is the set of (gross) bilateral export and import flows in 1993, 2003, 2013 and 2017. These years allow a comparison of the impact of NAFTA (signed in 1992) after 10 and 20 years, and the latest year available for data analysis; and will constitute a benchmark for a pre-post assessment of the geography of production due to the net zero emission target of the EU and USA regulations. For those years, three-year average data are considered (the year under analysis, the year before and the following year). For each year and for each flow (import and export[5]) shares of trade flows of the various components and parts are computed. We focus on the trade relations of the top 42 reporting countries[6] with all the countries in the UN Comtrade database. The remaining countries represent tiny fractions of the global trade both individually and as a group. Indeed, the 42 countries represent, respectively, in 1993 and 2017, 98.1% and 97.1% of the total exports of those 30 SITC items (details in Annex 3).

3.2. Data description

In terms of export shares (Table 1), the biggest and most heterogeneous group is Miscellaneous Parts, comprising a slightly increasing share of almost two thirds of trade. In 1993, the main items - respectively, almost 35% and 11% of total trade - refer to "other parts and accessories" (classified, respectively, in SITC 78439[7] and 78432); the group Engines and Parts accounted for almost 19% of trade, the main item being "Internal Combustion Engines"; Rubber and Metal Parts, with 9.3% of trade, which decreases in 2003. Electrical and electronic parts have a similar share over the 25 years, with the share of Electric Accumulators (storage batteries) increasing to almost 6% of total trade, while Sealed-beam Lamp Units fell to one third.

An analysis of export shares by year and country (Fig. 1, top panel) shows a substantial change in the relative importance of the various countries. In 1993, the first five exporters of automotive components and parts - Japan, US, Germany, France and Canada – accounted for 67.3% of total exports, down to 44.8% in 2017 (only Germany managed to maintain its share). Conversely, China, Mexico, South Korea, and the Central and Eastern European (CEE) countries increased their overall share from 7% in 1993 to 33,5% by 2017. The big shift occurred between 1993 and 2003; thereafter, China and Mexico consolidated their increasing importance, while the US continued its decline.

Turning to imports, Fig. 1 (bottom panel) highlights the marked imbalances in Japan's trade, while a comparison with Germany suggests a different response by the companies of the two countries to the challenges of globalisation (Celi et al., 2018; Hufbauer and Jung, 2021; Simonazzi et al., 2022; Sturgeon et al., 2008; Womack et al., 1991). The US maintained considerable (though slightly declining) importance as an importing country, while Canada's poor performance (declining shares of both exports and imports) suggests a progressive

[4] According to Amighini and Gorgoni (2014, Annex Table A1 Auto Parts Classification pp. 944–45), such "classification is partly similar to the parts product listings adopted by the US Office of Aerospace and Automotive Industries (OAAI) ... [and] attempts to closely approximate the core automotive industry by excluding certain items for example, parts explicitly listed for motorcycles, golf carts, snowmobiles, agricultural equipment, etc." (ibid., footnote 5).

[5] With regard to export flows, as in Gorgoni et al. (2018), "data are tabulated using importer records, more reliable than the corresponding exporter records".

[6] The 42 countries are: Argentina, Australia, Austria, Belarus, Belgium, Benelux Union (Belgium, the Netherlands, and Luxembourg), Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Hong Kong, Hungary, India, Indonesia, Ireland, Italy, Japan, Malaysia, Mexico, Netherlands, Philippines, Poland, Portugal, Romania, Russia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, Turkey, UAE, UK, Ukraine, US. The 1993 data (1992–1994) data refer to Belgium-Luxembourg, while for the following years there are only the data for Belgium. Thus, there are 42 countries in total (Luxemburg never appears in the list). Details of the list of countries in Annex 3.

[7] See Annex 2, Table A3 for the list of products included in the item 784.39 (SITC Rev.3) "other parts and accessories of the motor vehicles of groups 722, 781, 782", which are, respectively: 722: Tractors (excluding those of 71414 & 74415); 781: Motor vehicles for the transport of person; 782: Motor vehicles for transport of goods, special purposes.

Table 1
List of automotive components and parts, by group, and their share of export, in the years 1993, 2003, 2013, 2017.

group description	SITC & description	year 1993	2003	2013	2017
Rubber and Metal Parts	6251_Tyres, pneumatic, new, of a kind used on motor cars (including station wagons and racing cars)	6.47	5.31	6.95	5.86
	62551_Tyres, pneumatic, new, other, having a herring-bone or similar tread	0.56	0.43	0.66	0.44
	62559_Tyres, pneumatic, new, other	0.62	0.46	1.11	0.73
	62591_Inner tubes	0.30	0.12	0.13	0.10
	62592_Retreaded tyres	0.16	0.08	0.09	0.09
	62593_Used pneumatic tyres	0.19	0.08	0.08	0.05
	62594_Solid or cushion tyres, interchangeable tyre treads and tyre flaps	0.16	0.12	0.18	0.13
	69915_Other mountings, fittings and similar articles suitable for motor vehicle	0.77	1.12	1.00	1.11
	69961_Anchors, grapnels and parts thereof, of iron or steel	0.04	0.03	0.04	0.03
Electrical and Electric Parts	76211_Receivers, radio-broadcast, not capable of operating without an external source of power...incorporating sound-recording or reproducing apparatus	3.69	3.15	1.69	1.20
	76212_Receivers, radio-broadcast, not capable of operating without an external source of power...not incorporating sound-recording or reproducing apparatus	0.45	0.24	0.16	0.21
	77812_Electric accumulators (storage batteries)	3.04	3.89	4.81	5.76
	77823_Sealed-beam lamp units	0.19	0.13	0.10	0.06
Engines and Parts	71321_Reciprocating internal combustion piston engines for propelling vehicles, of a cylinder capacity not exceeding 1000 cc	0.78	0.42	0.37	0.38
	71322_Reciprocating internal combustion piston engines for propelling vehicles, of a cylinder capacity exceeding 1000 cc	8.86	8.56	6.13	5.72
	71323_Compression-ignition internal combustion piston engines (diesel or semi-diesel)	3.88	4.94	5.84	5.35
	77831_Electrical ignition or starting equipment of a kind used for spark- ignition or compression-ignition internal combustion engines	2.84	2.41	2.76	2.72
	77833_Parts of the equipment of heading 778.31	0.77	0.68	0.56	0.57
	77834_Electrical lighting or signalling equipment (excluding articles of subgroup 778.2)	1.70	1.77	2.78	3.50
Miscellaneous Parts	7841_Chassis fitted with engines, for the motor vehicles of groups 722, 781, 782 and 783	1.57	0.91	0.49	0.43
	78421_Bodies (including cabs), for the motor vehicles of group 781	0.28	0.63	1.11	0.88
	78425_Bodies (including cabs), for the motor vehicles of groups 722, 782 and 783	0.86	1.02	0.77	0.79
	78431_Bumpers and parts thereof, of the motor vehicles of groups 722, 781, 782 and 783	1.11	0.90	1.01	1.13
	78432_Other parts and accessories of bodies (including cabs), of the motor vehicles of groups 722, 781, 782 and 783	10.66	13.70	12.23	12.50
	78433_Brakes and servo-brakes and parts thereof, of the motor vehicles of groups 722, 781, 782 and 783	4.91	5.24	5.01	4.90
	78434_Gearboxes of the motor vehicles of groups 722, 781, 782 and 783	6.96	7.29	10.58	10.55
	78435_Drive-axles with differential, whether or not provided with other transmission components	1.73	1.62	3.82	3.58
	78436_Non-driving axles and parts thereof, of the motor vehicles of groups 722, 781, 782 and 783	1.07	1.17	0.00	0.00
	78439_Other parts and accessories, of the motor vehicles of groups 722, 781, 782 and 783	34.87	33.06	29.10	30.83
	82112_Seats of a kind used for motor vehicles	0.51	0.49	0.44	0.41

marginalization of the country, to the advantage of Mexico. As largely discussed in the literature (Sturgeon et al., 2008; Womack et al., 1991), since the 1980s, Japanese OEMs practiced an original model of integration with their suppliers largely located very close to their assembly plants, to enhance the just-in- time feature of their lean production model. This explains the very modest quantity of imports of components and explains why their exports decline progressively with the expansion of their investment in assembly plants abroad, together with their network of suppliers that became located nearby (refer to Sturgeon et al. 2008, pp. 308–309, 311–15), an issue that we discuss in the next paragraph. A different production model, and a peculiar geopolitical context, is the one of China (Schwabe, 2020b).

3.3. Network of countries' bilateral trade flows

The changes in the relative position of countries in their network configurations are illustrated in Fig. 2. The size of the nodes is proportional to the country's share of exports with slices proportional to shares of export and import of vehicles (respectively, dark green and light green) and export and import of components and parts (respectively, red and orange) out of the total country's trade exchange. The thickness of the link between countries is proportional to their trade flow, compared to the maximum share over the four years. It should be noted that for each year, export and import flows between two countries have the same thickness, but opposite direction.

The graphs highlight a clear structure of subnetworks of trade flows with an evident geographical base: one subnetwork centred in Europe, on the left in each graph, another in the Pacific area (embracing countries in East Asia, the US and Canada), on the right in each graph. The change in the positions of Japan and Germany relative to the United States on the one hand, and the inversion in the relative positions of Mexico and Canada in their trade with the US on the other, are explained by the different strategies of car manufacturers targeting the US market. In the 1970s–80s, US companies had to respond to the increasing foreign (mainly Japanese) competition in their own, hitherto protected, market. The Japanese threat threw the US auto industry into panic and triggered the US government's response. The protection of the domestic market from import penetration attracted foreign direct investment. Japanese TNCs brought Tier 1 suppliers with them, but they also instructed US parts suppliers on better manufacturing and quality control methods, and component manufacturing was upgraded. Exports were partially replaced by local production. Faced with the risk of losing control of their home market to foreign manufacturers, US carmakers resorted, among other strategies, to offshoring of labour-intensive operations, relocation to the Southern non-unionised states in the US and delocalisation of assembly plants to Mexico, even before the NAFTA was signed. The creation of a North American free trade area attracted FDI to Mexico (the cheapest location) to export to the US. Thus, over the two decades, OEMs moved their assembly plants to the United States and, subsequently to Mexico, becoming a source of demand for components and parts for their supply chains, thus inverting the relative positions of Mexico and Canada in their trade with the US.

In the case of Europe, since the 1990s - following the fall of the iron curtain first, and then the Eastern enlargement of the European Union - massive relocation of production eastward has allowed the main European OEMs, and especially the German ones, to take advantage of the creation of the Common Market and meet the challenges represented by Japanese and, later on, Korean TNCs (Brincks et al., 2018). Unlike in the US, however, these processes contributed to reinforcing the competitive position of the lead country and its 'national champions'. In fact,

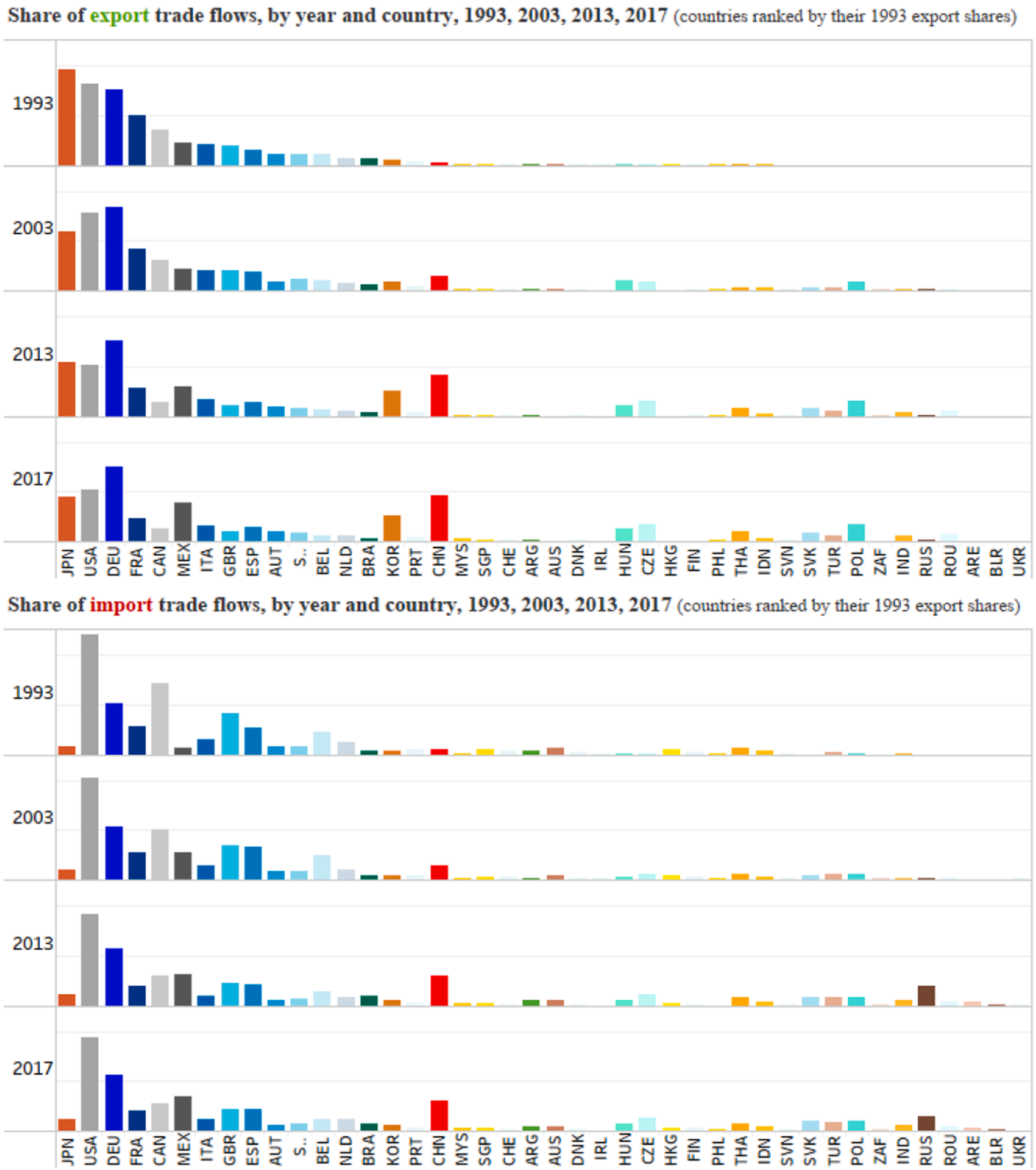

Fig. 1. Export and import shares by country in 1993, 2013, 2003 and 2017.

compared to the US, German companies offshored a higher share of components and small cars, while retaining at home a higher share of production and assembly of premium cars (Simonazzi et al., 2020). Therefore, although production plants in Europe and North America have increasingly been located in peripheral regions - Mexico in North America and former communist countries in Europe - the consequences on the composition of trade (as well as on production and employment) have been substantially different (Simonazzi et al., 2022).

Finally, China's impressive rise in relative importance is justified by its entry into the WTO in 2001, its thriving domestic market, as well as its policy of attracting FDI to create a domestic auto industry. Although comprehensive, this analysis leaves the role and relationship among the different groups of countries undefined: to identify such multilayer meso-level entities, emerging in the trade flows, we use the Infomap multilayer methodology which we will describe in detail in Section 4.

4. Methods: multilayer network analysis

4.1. A multilayer method for module detection

As noted in the previous section, the international trade of automotive components can be conceptualized as a network where countries constitute nodes and trade relations are ties between these nodes. For example, in the trade network that we analyse, we may focus on a pair of bilateral trade flows, such as the one between two countries like US and Mexico, where both countries have import and export of the same product, e.g. *SITC code 78433 - Brakes and servo-brakes and parts thereof, of the motor vehicles of group*: we may expect that this specific bilateral trade corresponds to products of different quality or characteristics in the same category of classification. Taking into account cross country bilateral trade exchanges over all the 30 automotive components and parts contributes in profiling the specific relative position of countries in

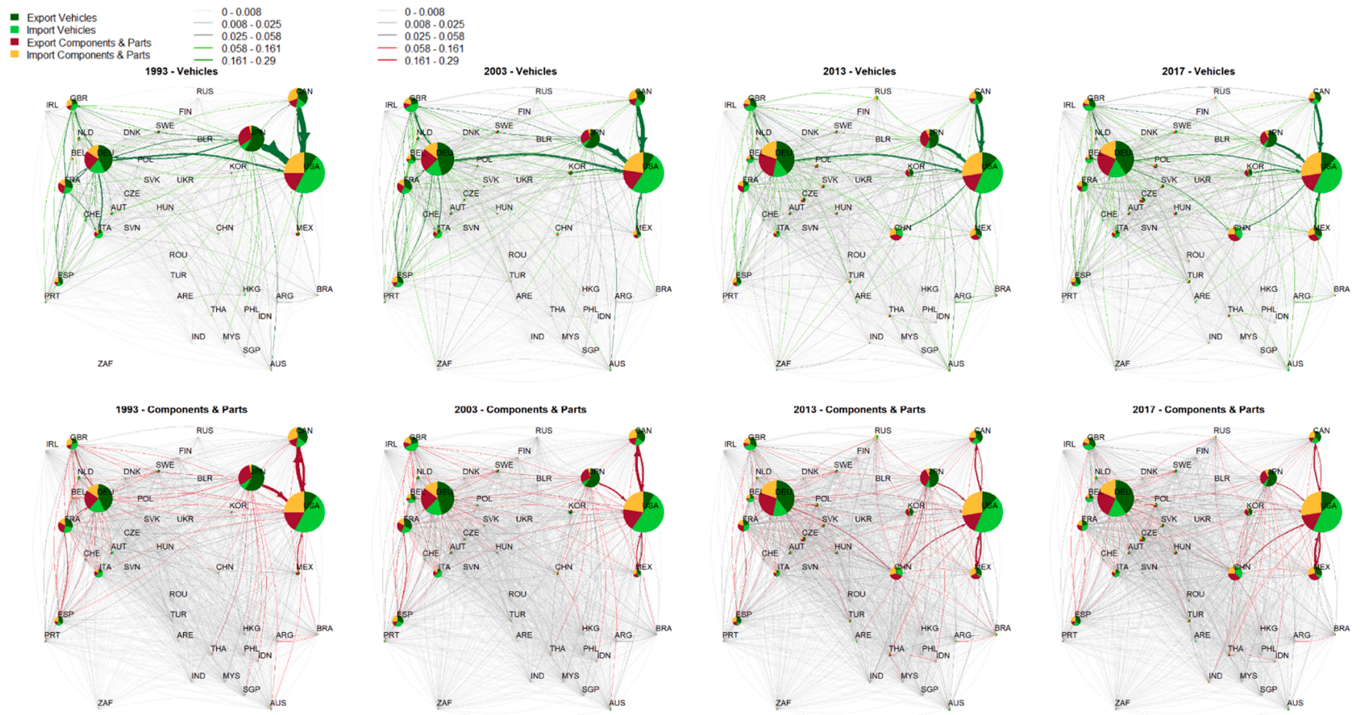

Fig. 2. Bilateral export and import trade of vehicles (SITC Rev.3: 781) and automotive components and parts (30 items, SITC Rev.3), in 1993, 2003, 2013 and 2017, 42 countries
NODES [countries] approximation of relative geographical position in the graph; *size* proportional to the total share of trade exchange (export + import) in the year; *slices*: shares of export and import of vehicles (respectively, dark green and light green) and export and import of components and parts (respectively, red and orange) out of the total country's trade exchange; *EDGES* [bilateral trade flows, top panel: vehicles, bottom panel: components and parts]: *thickness* proportional to trade share, compared to the maximum share over the four years; *colour of edges*: 5 classes based on the distribution of shares for all years. Arrows indicate the direction of export flows.

the overall network. While dyadic patterns are important in identifying the relative role of countries, identifying groups of countries can provide a much richer picture of the power, importance and evolution of countries in their networks.

Over time, many algorithms have been proposed to identify cohesive subgroups of nodes as clusters (or modules) within networks (prominently, Blondel et al., 2008; Fortunato and Hric, 2016; Girvan and Newman, 2002). Classical network models, however, do not take account of the complexity exhibited by systems in which multiple levels of descriptions are required to preserve microscopic information on interactions of different types - in our trade network: all the cross country bilateral trade exchanges over the 30 products – that evolve over time.

Instead of examining separately and then comparing the trade networks of each product (as in Barigozzi et al., 2011; Piccardi and Tajoli, 2018) or groups of products (as in Amighini and Gorgoni, 2014, or Gorgoni et al., 2018), to this end, it is expedient to use more sophisticated models such as multilayer networks, which are able to take into account the additional levels of complexity (Boccaletti et al., 2014; De Domenico et al., 2013; Kivela et al., 2014). In this class of models, a pair of nodes can be related by one or more types of interactions or relationships. Each interaction type (in our case: directed weighted trade flow, i.e., value of import or export, for each product) is mapped into a 'layer' of description. A layer collects all the pairwise interactions of the same type. Within each layer, nodes (i.e. countries) are usually referred to as 'state-nodes' (for example: when we consider - for any given year - export of the US to the other 41 countries, in the layer "brakes" we are considering the state-node "US-exporting brakes, in that year"). Connections between state-nodes define intra-layer connectivity (for example, all the bilateral trade flows of brakes, in a given year). The set of all state-nodes corresponding to the same node defines their physical node (i.e., the total export, or import, of a country in a given year). Connections between state-nodes of the same physical nodes, or between state-nodes of distinct physical nodes, define inter-layer connectivity, which plays an important role in shaping the collective phenomena emerging from the dynamics in the system (De Domenico et al., 2016)[8].

Data presented in Section 3 are mapped in the multilayer model. Each country in our dataset constitutes a physical node and every layer studies trade relationships (separately for import and export) of a category of components. To obtain the most effective estimations, the trade data will be considered at the most disaggregated level available in trade statistics. In particular, we consider 60 layers (30 components and parts, by import and export) for each of the four years, and for each of the 42 nodes (the countries)[9].

We use the Infomap multilayer algorithm of module detection (Rosvall and Bergstrom, 2008; De Domenico et al., 2015) to identify meso-structures (hereafter clusters) that are intermediate between the network as a whole and the individual countries (nodes) that have trade relationships with other countries. We refer the reader to Annex 4 for a more technical description of the algorithm.

It should be noted that the level of economic complexity (Hidalgo, 2021) discussed in this manuscript refers to the multi-layer analysis of the automotive world trade. More complex economies tend to be more

[8] Figure in Annex 11 schematises the example of countries in the multi-layer framework and highlights nodes and state-nodes.

[9] For some countries, trade flows do not cover all the SITC codes in all the years. The weights adopted in the analysis, the structure of the .net file, and optimal relax rate for the multilayer algorithm are presented in Annex 4.

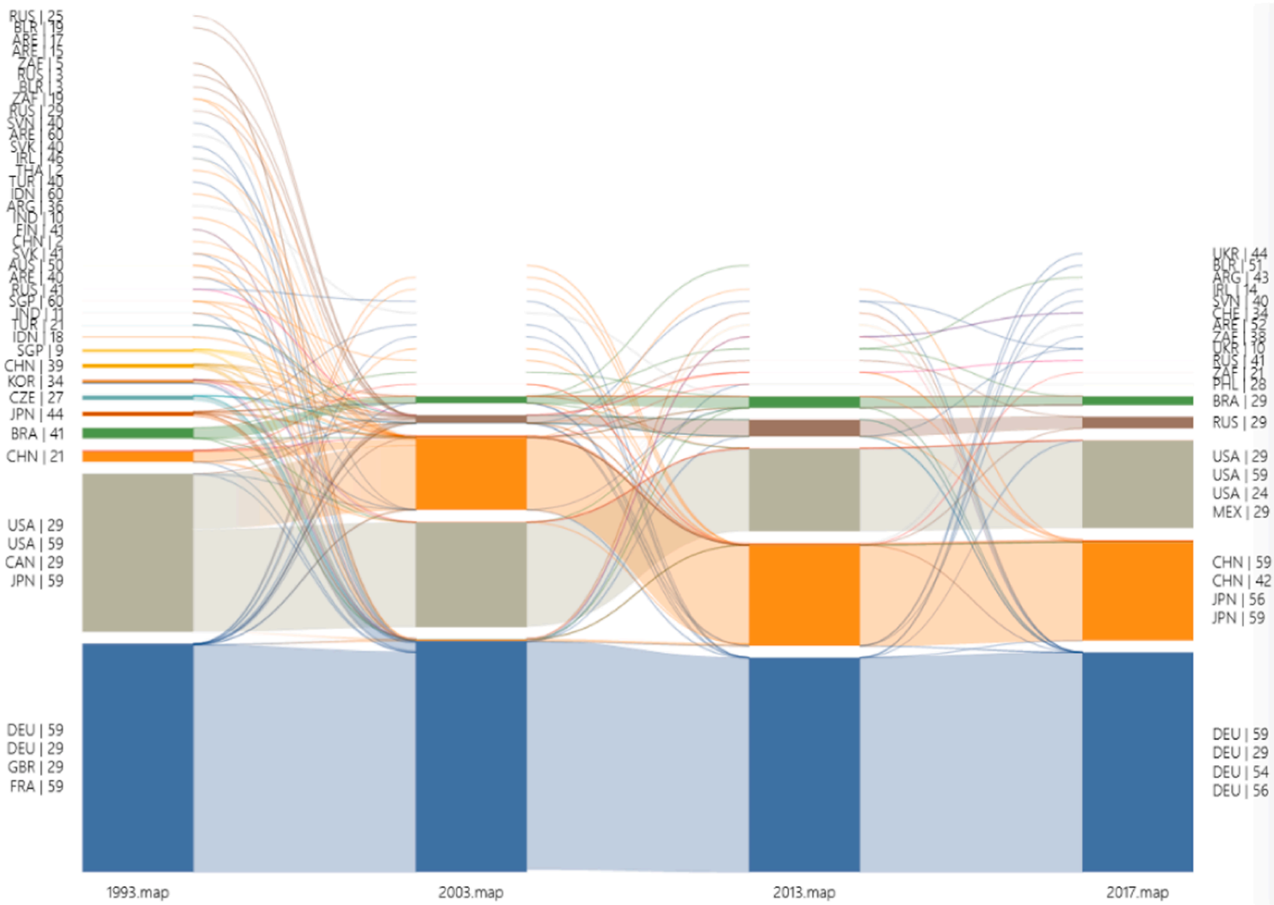

Fig. 3. Clusters of countries trade exchanges: alluvial, 1993–2017.
Clusters are lined up in columns, by each year. Size of cluster proportional to the Infomap flow. Labels on the left side (1993) and on the right side (2017) refer to the top combinations country and layer (at most four are shown i). Colours refer to the ID of the cluster and are associated with the top country-and-layer. Colours of clusters with a very low Infomap flow may not be visible and are just in white. Clusters are ranked by their value of Infomap flow.

embedded in the international trade of various classes of components while less complex ones will have more specialized roles in the trade multi-layer network (e.g. by being active in few layers or by being pure importers/exporters of fewer categories of goods). In this sense, the level of embeddedness of a country in the overall network reflects the degree of economic complexity of the automotive sector in a country.

4.2. *The multilayer model of international trade over time*

The algorithm is designed to identify multilayer meso-level entities, in our case clusters of countries and their specific trades, for each year. However, the flow used to compute the modules provides also a metric to assess the relative importance of the clusters detected and the contribution of the individual countries and their links (weighted bilateral trade) in determining those clusters. Indeed, the algorithm normalises trade flows, occurring within layers and between layers, in an index (Infomap flow) ranging from 0 to 1. Thus, aggregating flows within and across layers (i.e. classes of components and parts for the automotive industry) and modules (i.e., groups of combinations of countries and components/part) makes it possible to identify the key clusters, how (and how strongly) they relate to each other, and where their key components come from (i.e. from which layers).

5. Results: clusters of automotive trade and their determinant over time

The Infomap multilayer algorithm identifies clusters of countries in the world trade of automotive components and parts and permits decomposing the flow, in terms of the underlying layers (components and parts) and nodes (countries), within and between the detected clusters of countries, thus identifying the building blocks to answer our research questions[10]. In this Section, we interpret the results on clusters of automotive trade detected by the Infomap algorithm, and we assess the connections between clusters of countries in terms of the countries' specific trade across clusters.

5.1. *Meso-scale entities, by year*

In contrast with geographical clustering, where each country has a unique position in the trade network, the clusters identified using the

[10] Infomap flow is decomposable by node (the countries), by layer (the SITC codes for the export and import trades) and by flow from state-node to state-node (which represent the random walk paths along the countries' bilateral trade of a specific component), thus providing information on each of the determinants of the detected clusters. See Annex 5 with the details on the Infomap output files analysed in this section. To visualize a random walker path see https://www.mapequation.org/apps/multilayer-network/index.html

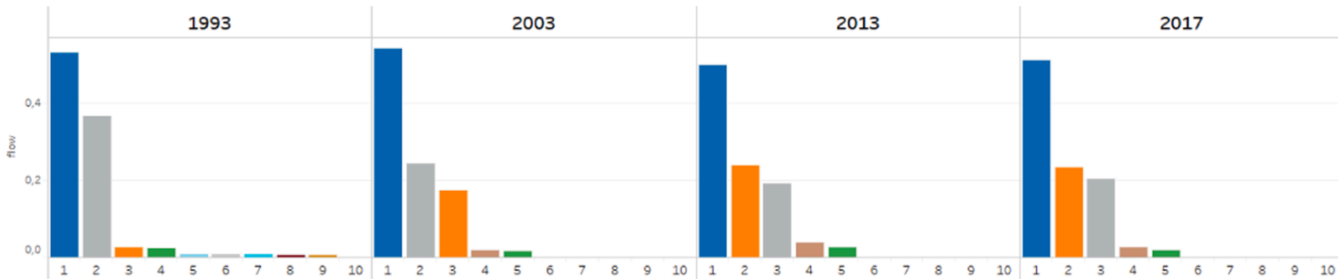

Fig. 4. – Infomap flow by cluster.
Only the first ten clusters in terms of Infomap flow, accounting for 97% of the total flow, are displayed.

Infomap multilayer algorithm must be interpreted keeping in mind two general aspects deriving from the algorithm itself. First, a country might belong to more than one cluster, according to the specific bilateral trade in which it is involved. Second, when we compare clusters over time, we consider the countries and specific trade characterising them, and we assign a label and colour to facilitate such a comparison, but we should not forget that the internal composition of each cluster in terms of countries and trade could change over time. This is desirable as the multilayer clustering allows focusing on structural determinants, thus providing a new perspective on the analysis of trade networks and on countries' positions in the changing clusters over time.

The identification of the clusters is the first result of our analysis. A summary of the number of clusters and changes occurring over time is presented in Fig. 3 with alluvial diagrams[11], in Fig. 4 with respect to the relative importance of each cluster (as measured by their Infomap flows) and in Fig. 5 with a view to the connections among clusters.

While the overall composition of exports by SITC components and parts shows little change in the observation window (Table 1), results from the Infomap multilayer analysis show that the structure of the international trade flow underwent a very considerable change, and this is the second result of our analysis: the number of multilayer clusters decreases over the four years (from 39 in 1993 to 16 as from 2003), the main three clusters become more prevalent, and – as from 2003 - the third top cluster has only a few countries. More in detail, several of the clusters that characterize the network in 1993, subsequently merge into major clusters. This is the case of cluster 6, which in 2003 was incorporated into the cluster led by Germany, and of clusters 5, 7 and 8, which were incorporated into the cluster led by Japan[12].

The multilayer algorithm clearly yields a spatial distribution of clusters that is largely associated with the geographical position of countries, but singles out also specific sub clusters in those geographic areas, such as the ones led by the Czech Republic, Thailand, Indonesia, and Turkey, and their characterising trade: this is the third result of our analysis that would not have emerged by focusing only on networks of countries' bilateral trade by geographic area.

A fourth result refers to the consolidation, over the years, of the overall importance of the three main clusters, which remains very high (see Fig. 4 and detailed figures in Annex 6, Table A11): the Infomap flow ranges from 93%, in 1993, to 95% in 2017, although there was an increase to 96% in 2003 and a successive reduction to 93% in 2013. Clusters' relative importance and internal composition changed over time. We identify four main dynamics:

– the blue cluster, the biggest across the four years, is always led by Germany; its very high level of flow declines in 2013 but rises again in 2017;
– the grey cluster, initially the second top group, declines in importance, becoming in 2013 the third cluster. In 1993 it was led by the US and Japan, but since 2003, it has been led by the US alone and mainly embeds the NAFTA countries;
– the orange cluster, led by Japan and later on by China, becomes increasingly important, emerging, in 2013, as the second top cluster;
– two smaller clusters, one centered on Brazil and Argentina (green), and one led by the Russian Federation (brown), had a growing importance from 2003 to 2013 but declined in 2017.

Given the overarching importance of the first three clusters with respect to all the others, we will focus our analysis on these clusters and their evolution over time. Minor clusters will be discussed solely in relation to their evolving connections with the main clusters.

5.2. Internal vs external flows and overlapping nodes across clusters

The four graphs in Fig. 5 summarise the relative importance of trade of automotive components and parts within and between clusters[13]. The clusters are drawn as circles with the same colours they have in the alluvial diagram (for the nine main clusters, light green for all the others) and area proportional to the Infomap flow generated within the cluster. The thickness of links between clusters is proportional to the flow between clusters. This figure supports our fifth relevant result: cross-cluster connections increase for most clusters[14] and the overall Infomap flow generated by those connections increases from 18.5%, in 1993, to about 30%, in 2017[15] (Table 2).

For each year, we can assess the overall contribution of each country in determining meso-scale entities and their connections. Comparing 1993 with 2017, the top ten countries accounted respectively for 74% and 62% of the total Infomap flow[16], with a significant growth of several other minor countries. Connections across clusters highlight bridges across specific trades in components and parts that keep the whole

[11] An alluvial diagram represents changes in network structure over time.

[12] In 1993, these clusters were led, respectively by: JPN (cl-5) with a main trade on Reciprocating internal combustion piston engines for propelling vehicles; CZE (cl-6) with a main trade on Drive-axles with differential, whether or not provided with other transmissions; KOR (cl-7 with a main trade on Inner tubes; CHN (cl-8) with a main trade on Anchors, grapnels and parts thereof, of iron or steel.

[13] Clusters and their relations are represented in the graphs realized with the visualisation tool of Infomap Network Navigator and with Adobe Illustrator to change colours of nodes.

[14] Details in Annex 6.

[15] In order to explore Infomap flow generated within and between clusters, it is necessary to consider all states-nodes, regardless of the module they belong to and then aggregate data by module. See Annex 5 for details on the Infomap output file used to implement this analysis.

[16] Detailed figures on Infomap flow - generated within and between clusters - by country are available in Fig. A7.

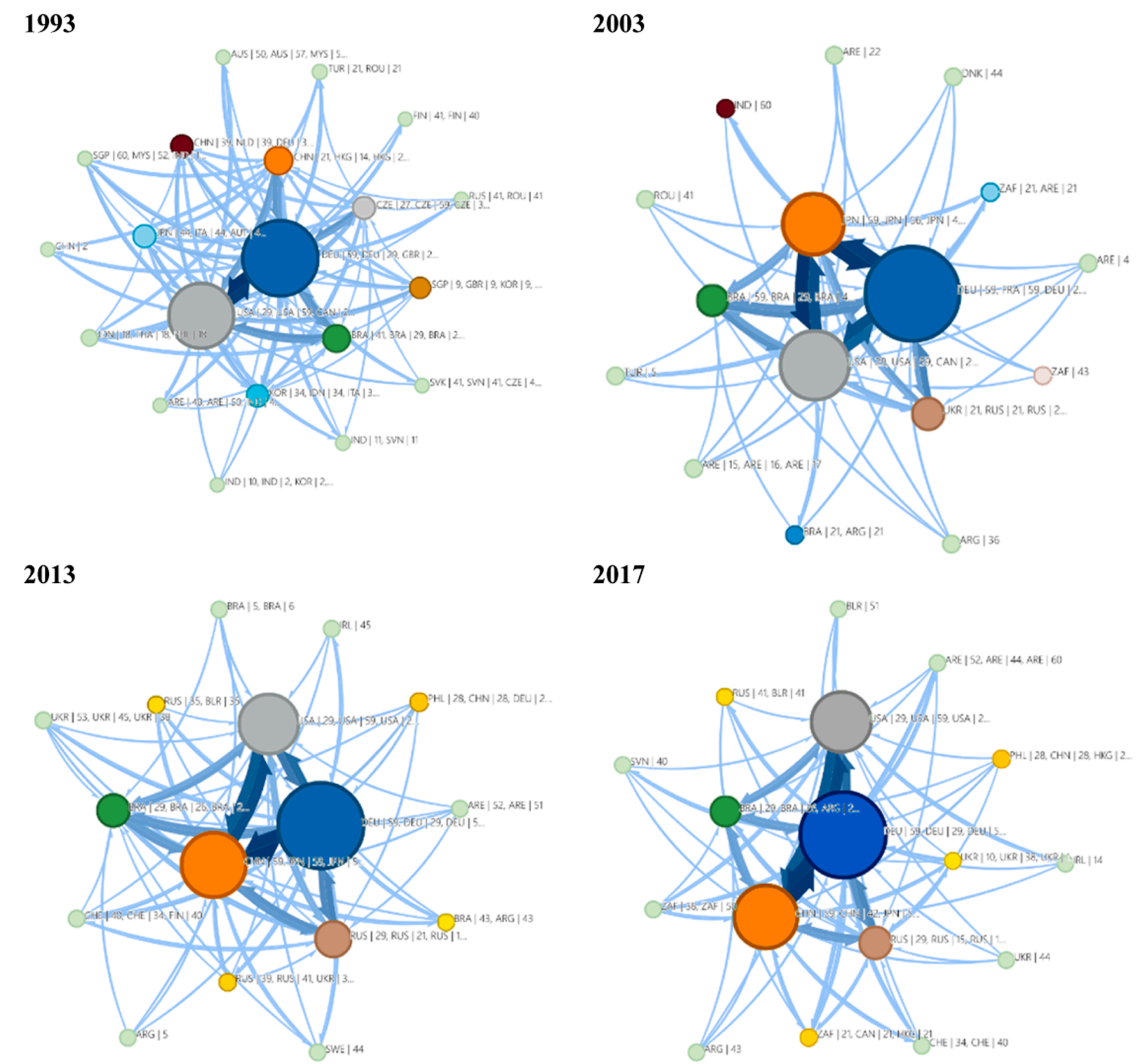

Fig. 5. Infomap flows within and between clusters.
Clusters are drawn as circles with the same colours they have in the alluvial (for the nine main clusters, light green for all the others); circles are proportional to the Infomap flow generated within the cluster; thickness of links between clusters is proportional to the Infomap flow between clusters.

Table 2
Percentage of Infomap flow generated within and between clusters, by year.

year	within the cluster	between clusters
1993	81.5%	18.5%
2003	75.5%	24.5%
2013	70.5%	29.5%
2017	70.1%	29.9%

network together. Significantly, those bridges can propagate shocks within and across clusters (depending on the nature of the shocks, e.g., a new trade agreement, a change in final demand due to new requirements for vehicles, supply chain disruptions).

Some countries are present in multiple clusters, owing to their possible role as bridges in the world automotive components trade. It is thus interesting to explore their specific characteristics: Do they show preferred countries in the direction of their trade? Are they balanced in trade with the different clusters to which they belong, or are they actually receiving most of their flow from a single cluster and from specific trade? To address these questions, in Section 6, we turn analysis from the Infomap flow to the trade shares. Having identified clusters and their determinants we can process the results of the Infomap flows within and between clusters (i.e., list of pairs state-nodes-from and -to) to produce results in terms of export and import shares, which we can

Table 3
Export shares in the top three clusters, generated within the clusters and with other clusters, by year
The first cluster is always Germany-led; the second cluster is US&Japan-led in 1993, US-led in 2003; and China&Japan-led in 2013 and 2017: the third cluster is China-led in 1993, China&Japan-led in 2003, US-led in 2003 and 2013. In the table, different colours highlight this information.

Cluster	1993			2003			2013			2017		
	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total
1	40.6	7.0	47.6	45.3	7.8	53.1	38.1	12.0	50.1	39.0	10.8	49.9
2	41.1	7.7	48.8	23.1	3.1	26.2	11.2	17.8	29.0	10.3	17.7	28.0
3	1.0	0.4	1.5	6.5	12.6	19.1	16.3	2.8	19.1	17.3	3.5	20.8
1+2+3	82.7	15.1	97.9	74.9	23.5	98.4	65.6	32.6	98.2	66.6	32.0	98.7

Table 4
Export shares from the top three clusters, generated within the clusters and with other clusters, by year and by group of components and parts.
Colours of figures, by cluster and year, as in Table 3.

		Rubber and Metal Parts				Electrical and Electric Parts				Engines and Parts				Miscellaneous Parts			
		1993	2003	2013	2017	1993	2003	2013	2017	1993	2003	2013	2017	1993	2003	2013	2017
Within the cluster	1	4.8	3.7	3.8	3.3	1.9	1.7	1.4	1.5	7.3	8.5	7.3	7.1	26.5	31.4	25.6	27.2
	2	2.5	1.2	1.0	0.7	3.7	1.2	1.9	1.8	7.6	4.7	1.5	1.4	27.3	15.9	6.8	6.3
	3	0.0	0.5	0.9	0.8	0.0	1.7	0.7	0.8	0.3	0.8	3.6	3.9	0.7	3.6	11.1	11.8
	Total	*7.4*	*5.3*	*5.7*	*4.8*	*5.6*	*4.6*	*4.0*	*4.1*	*15.3*	*14.0*	*12.4*	*12.4*	*54.5*	*50.9*	*43.6*	*45.3*
with other clusters	1	0.7	0.5	0.9	0.8	0.2	0.2	0.3	0.4	1.3	1.6	2.7	2.4	4.8	5.5	8.1	7.3
	2	0.9	0.2	3.0	2.5	1.4	0.2	2.2	2.4	1.5	0.8	2.5	2.6	3.9	1.9	10.1	10.2
	3	0.0	1.5	0.3	0.2	0.0	2.3	0.2	0.3	0.4	2.1	0.5	0.6	0.0	6.7	1.8	2.4
	Total	*1.6*	*2.3*	*4.2*	*3.4*	*1.7*	*2.7*	*2.7*	*3.1*	*3.2*	*4.4*	*5.7*	*5.5*	*8.7*	*14.1*	*20.0*	*19.9*
1+2+3		*9.0*	*7.6*	*9.9*	*8.3*	*7.2*	*7.3*	*6.7*	*7.2*	*18.4*	*18.4*	*18.1*	*18.0*	*63.2*	*65.1*	*63.5*	*65.2*

associate with the various clusters[17].

6. From Infomap flow to trade shares: patterns of trade by cluster

In this section, we explore the patterns of export and import shares of the three main clusters, paying special attention to the embedding of satellite clusters of countries and their changing importance (Section 6.1). We then focus (Section 6.2) on trade in components and parts of internal combustion engines (ICEs), around which many changes will occur in the ongoing shift toward electric vehicles: the relative importance of countries in the various clusters can provide an indication of the impact of the reduction of trade on ICEs and their components and parts, even though other elements should be taken into account to discuss the timing and pattern of change across countries (see Pavlínek, 2022, and Schwabe, 2020a, for a broad account on this issue).

To make figures comparable across clusters, countries, components and parts, the shares of trade refer to the total of each year.

6.1. Patterns of trade shares of the three main clusters: within cluster and with other clusters

For the top three clusters, Table 3 shows the trade shares by cluster, within and between clusters, by year[18]. The overall importance of the three top clusters increases, thus confirming a result of increasing concentration of trade flows discussed in the literature. But we observe that also the cross-cluster connections generated by these clusters increases as well (from 15.1% in 1993 to 32.0% in 2017, at aggregate level), with different patterns of change by cluster.

Cluster 1 - the Germany-led cluster - increased its importance from 47.6% to 49.9% of world exports between 1993 and 2017. Over this period, it slightly increased its cross-cluster connections (from 7.0% to 10.8% of world exports) and changed its internal structure, absorbing in 2003 a minor cluster in trade of specific components, led by the Czech Republic (as observed in Section 5.1), which, in 1993, was structured around trade with countries also outside the Germany-led cluster.

In 2003, the Pacific area – which in 1993 was embedded in cluster 2 – appears to be split into two distinct trade areas, the Asian and the American, which initially reduced their overall importance on world trade (from 50.3% in 1993 to 45.3% in 2003) and then increased to 48.8% in 2017. Focusing on the US-led cluster (cl-2 in 2003), we observe that it contributes little to cross-cluster connections and, also in 2013 and 2017 (when it becomes the third cluster), its contribution is very low, being respectively 2.8% and 3.5%. In contrast, the China&Japan-led cluster (which becomes the second cluster from 2013) contributes progressively, with a larger increasing shares to cross-cluster connections: from 12.6% in 2003, to 17.8% in 2013 and 17.7% in 2017.

Cross-cluster connections can be seen also with respect to the group of components (Table 4). As can be guessed by the previous comment, the largest contribution comes from the China&Japan-led cluster that fosters cross cluster connection for all the groups of products, and significantly for the Miscellaneous Parts (which accounts for almost 20% of the cross cluster connections in 2017, half due to the China&Japan-led cluster), but also for Rubber and Metal parts, and Electrical and Electric Parts. The Germany-led cluster is second in importance in fostering cross cluster connections, with a significant contribution for the Engine and parts.

These results on cross-cluster connections represent an original contribution to the debate on trade networks in the automotive sector, allowing the assessment of which countries and which specific components and parts determine the pattern of increasing cross-cluster connections, which is discussed below.

[17] It should be noted that the Infomap multilayer algorithm does not simply measure the inflow and outflow of countries' trade, and does not reflect the weight of aggregated bilateral flows between countries. At a country level, a measure summarising those flows can be obtained by computing a centrality measure that takes into account recursive interactions among nodes.

[18] Figures for the top six clusters can be browsed in Annex 7 and can be explored online (see url in footnote 2 above).

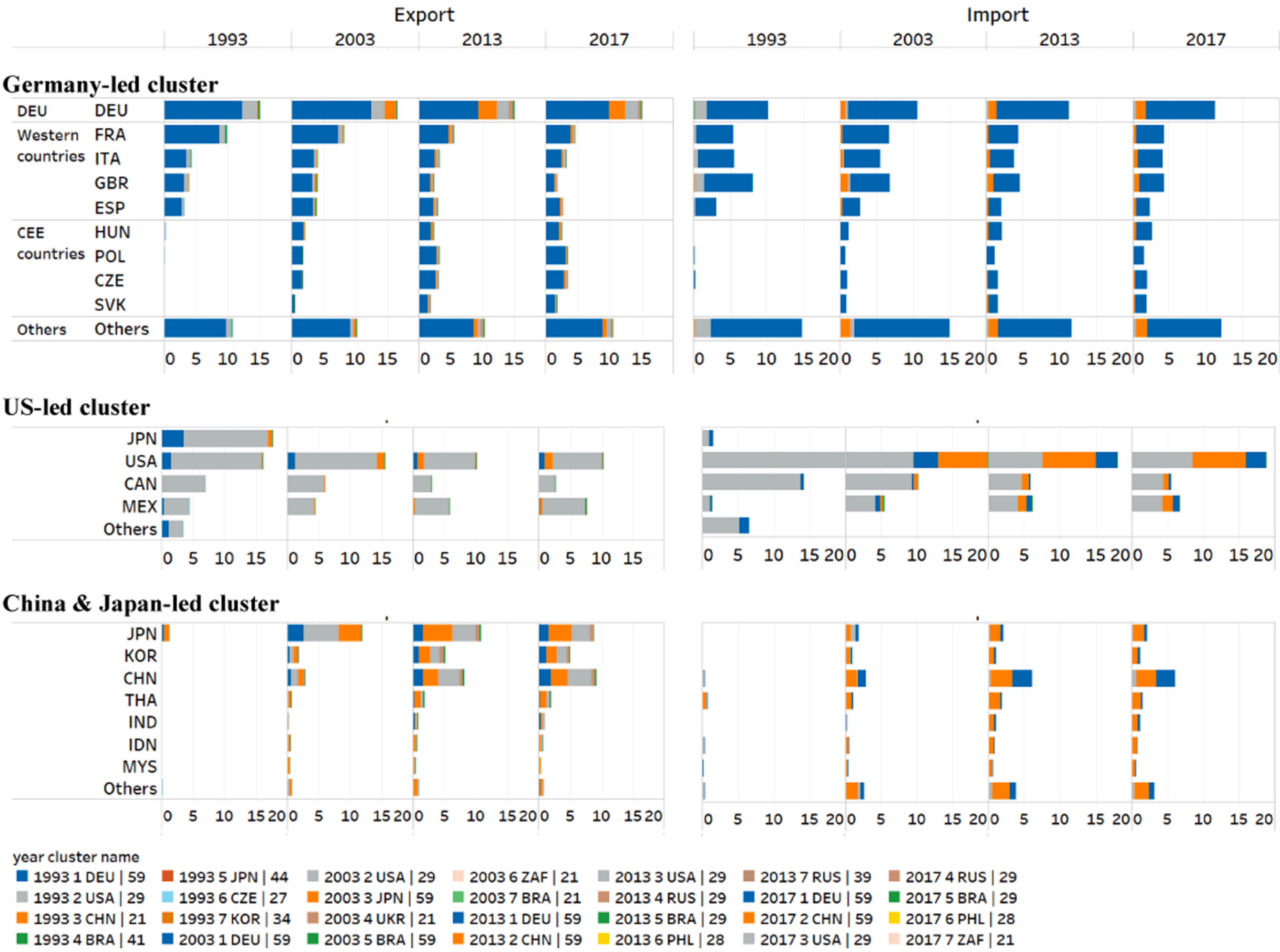

Fig. 6. Top three clusters: countries' export and import shares, by year, and cluster.

6.1.1. Roles of countries in cross-cluster connections

We have observed (Fig. 2) the intensification of bilateral trade flows that, over time, embedded more and more countries. Having clustered subnetworks of trade flows, we can now identify which countries contribute more and across which clusters they are active. From Fig. 6 we can easily compare the cross-cluster contribution of the main countries in each cluster over the years under analysis (countries are listed in decreasing order of their export shares within each cluster). The overall composition of the top three clusters is very different due to the heterogeneity in the number of countries involved in each cluster, in their relative importance, and in their cross-cluster contribution. Due to these differences it is expedient to comment separately the three main clusters.

6.1.1.1. The Germany-led cluster. The composition of countries of the Germany-led cluster shows the practically stable share of Germany's exports, the declining importance of the four countries structuring this cluster in 1993 (France, Italy, Spain, and the United Kingdom), that were supplanted by the CEE countries (Czech Republic, Hungary, Slovakia and Poland). The former reduced their overall share from 21.3% in 1993 to 12.7% in 2017, while, over the same period, the latter passed from 0.5% of world exports in 1993 to 11.4% in 2017 (see Table A16). The 21 other countries in this cluster account for a fairly stable overall share of world exports (about 10.4%), while they started with a larger (14.1% in 1993) and initially increasing share of imports that then fell to 12.7% in 2017. Most of these countries are other European countries embedded in the cluster, with a smaller proportion of countries also present in the US-led and the China&Japan-led clusters.

With respect to cross-cluster connections, the greater contribution to exports is given by Germany, while the four main Western countries of the cluster give a lower and decreasing contribution (from 3.1% in 1993 to 2.4% in 2017, with slight differences among the four countries), which is not completely compensated by the CEE countries (rising from 0.5% in 2003 to 1.6% in 2017). The cross-cluster connections made possible by imports of components and parts from countries outside the clusters (7.5% in 2017) are smaller than the ones for exports, returning in 2017 to the same level as 1993, after a 1.2% reduction in 2003 and a slight increase in 2013.

Examining export and import shares, it emerges that Germany increased its export share towards both the US-led and the China &Japan-led clusters, and to a lesser degree towards the other minor clusters (led, respectively, by Brazil, Ukraine and Russia). Germany's imports from other clusters were less relevant, and were concentrated specifically from the China&Japan-led cluster since 2003. In this respect, similar dynamics can be observed also for the other countries in this cluster.

6.1.1.2. The US-led cluster. In 1993, Japan was part of the US-led cluster, with shares of world exports of 17.7% for Japan and 16.2% for the US, and the other two main countries - Canada and Mexico -

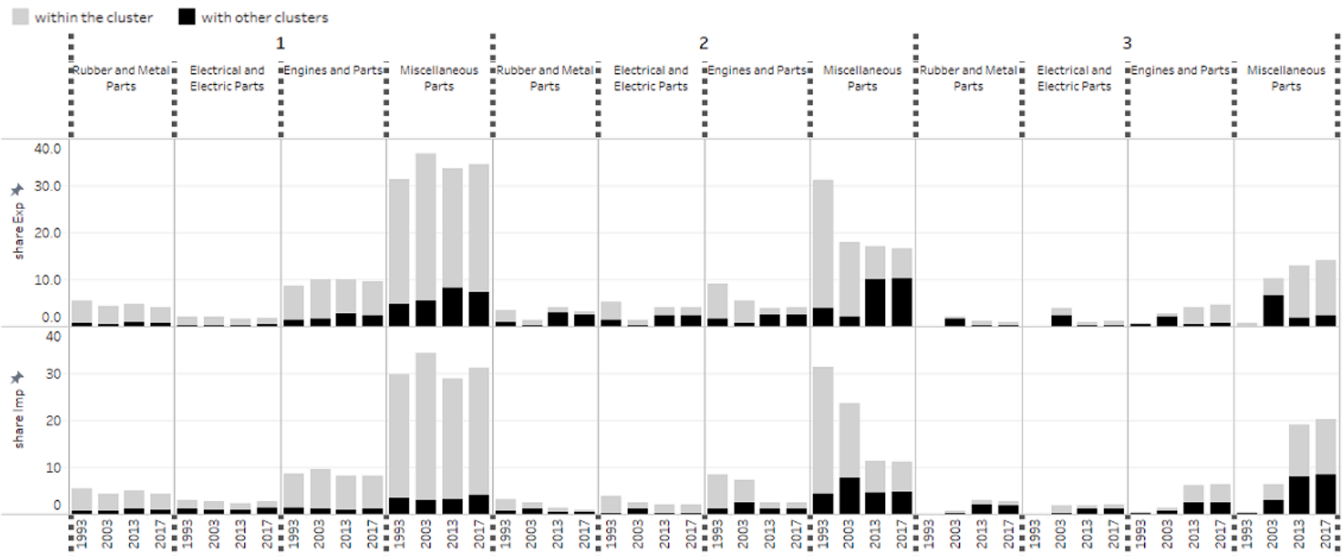

Fig. 7. Share of export and imports of group of components and parts, by cluster and year, within the cluster and with other cluster.

Table 5
Contribution of the top 10 components and parts to cross-cluster connections: export shares by cluster and year. Components and parts are ranked according to their total export shares, in 1993.

SITC codes	SITC code description	Group of SITC codes	with other clusters											
			1				2				3			
			1993	2003	2013	2017	1993	2003	2013	2017	1993	2003	2013	2017
78439	Other parts and accessories of the motor vehicles of groups 722, 781, 782 and 783	Miscellaneous Parts	2.7	2.5	3.0	2.9	2.0	0.9	4.6	5.1		3.1	0.8	0.9
78434	Gearboxes of the motor vehicles of groups 722, 781, 782 and 783	Miscellaneous Parts	0.7	0.9	1.8	1.5	0.9	0.3	2.0	1.8	0.0	1.6	0.4	0.6
78432	Other parts and accessories of bodies (including cabs), of the motor vehicles	Miscellaneous Parts	0.5	1.1	1.5	1.4	0.4	0.5	1.4	1.4		0.9	0.2	0.3
6251	Tyres, pneumatic, new, of a kind used on motor cars (including station wagons and racing cars)	Rubber and Metal Parts	0.5	0.3	0.6	0.5	0.7	0.1	2.0	1.6		1.0	0.1	0.1
77812	Electric accumulators (storage batteries)	Electrical and Electric Parts	0.2	0.2	0.2	0.3	0.6	0.1	1.4	1.9		1.2	0.2	0.3
78433	Brakes and servo-brakes and parts thereof, of the motor vehicles of groups 722, 781, 782 and 783	Miscellaneous Parts	0.4	0.5	0.5	0.5	0.2	0.1	1.0	1.0		0.6	0.1	0.1
77831	Electrical ignition or starting equipment of a kind used for spark-ignition or compression-ignition ICE	Engines and Parts	0.2	0.2	0.2	0.2	0.3	0.1	0.8	0.8		0.6	0.2	0.2
71323	Compression-ignition internal combustion piston engines (diesel or semi-diesel)	Engines and Parts	0.2	0.3	0.8	0.8	0.1	0.1	0.3	0.3	0.4	0.2	0.1	0.1
78435	Drive-axles with differential, whether or not provided with other transmission components	Miscellaneous Parts	0.1	0.1	0.4	0.4	0.1	0.0	0.7	0.6	0.0	0.3	0.1	0.1
77834	Electrical lighting or signalling equipment (excluding articles of subgroup 778.2)	Engines and Parts	0.1	0.1	0.4	0.4	0.1	0.1	0.5	0.6		0.2	0.1	0.1

accounting, respectively, for about 7.0% and 4.4%. The remaining 16 countries in the cluster accounted an overall 3.5% of exports.

After 1992, the NAFTA attracted significant foreign direct investments from Japan to the US, Mexico and Canada (Carreto Sanginés et al., 2021). Since 2003, the cluster is led by the US and embeds the three countries belonging to NAFTA, with Canada and Mexico trading mainly within the cluster, for both exports (respectively 2.6% and 6.9%) and imports (4.4% and 4.3%). While US exports declined continuously, (from 15.6% in 2003 to 10.2% in 2013 and 10.4% in 2017), Mexico's importance increased over time (to 7.7% in 2017) at the expense of Canada (whose share falls to 2.7% in 2017) (see Figs. 2 and 6; and for more details Tables A18 and A19). As for imports, in 2003 US trade across clusters accounts for 10.5% of the world's total, while 8.6% were imports within the cluster. Similar shares were observed in 2013.

6.1.1.3. The China&Japan-led cluster. The China&Japan-led cluster has emerged since 2003, with a growing importance - over the years - of China and South Korea, and – to a lesser extent - Thailand, India,

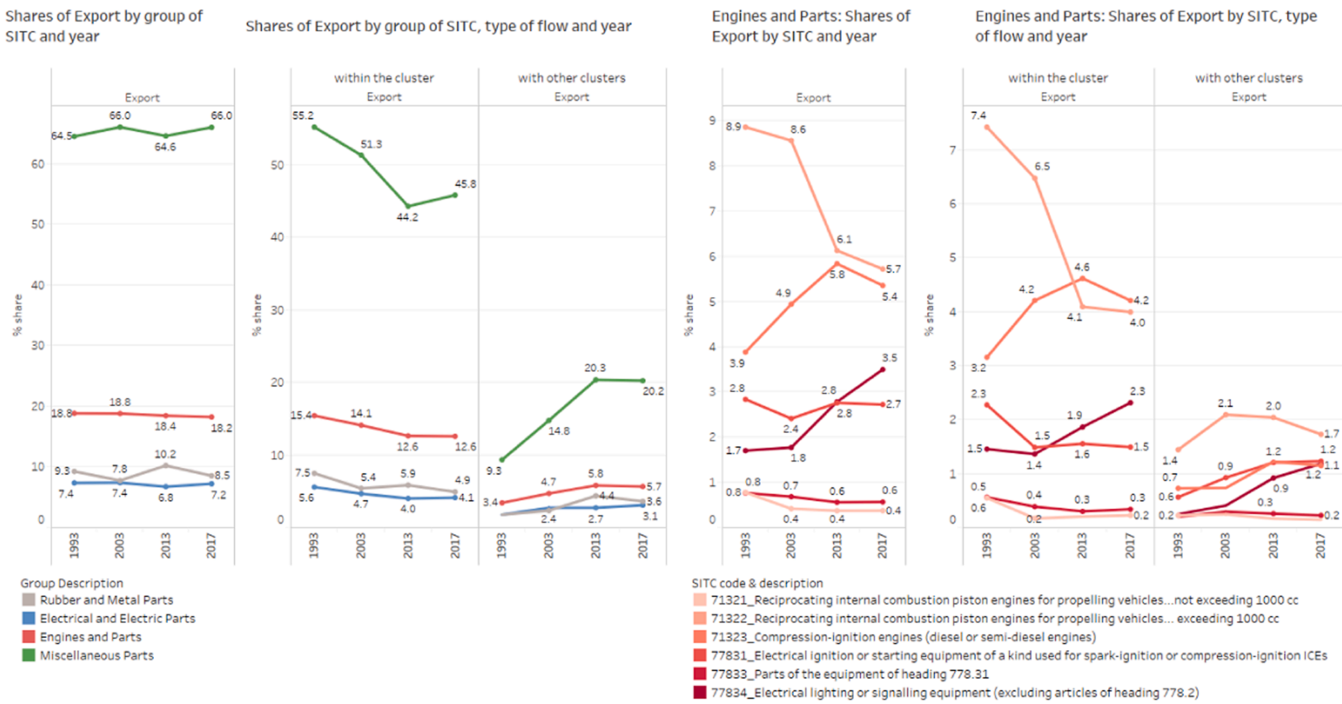

Fig. 8. Export trade shares (total, within and between clusters), by group of automotive components and parts, and by SITC code of Engine and Parts, 1993, 2003, 2013, 2017.

Table 6
ICEs: Trade shares of export from the top six countries, by country, within the top three clusters and with other clusters, 2017.
SITC codes: 713.21, 713.22, 713.23, 778.31, 778.33 and 778.34. Countries are ranked by total share in the year.

	Total	within the cluster				with other clusters			
Country.From		*Total*	1	2	3	*Total*	1	2	3
USA	2.41	*1.99*			1.99	*0.42*			0.42
DEU	2.18	*1.35*	1.35			*0.83*	0.83		
JPN	1.69	*0.64*		0.64		*1.05*		1.05	
MEX	1.65	*1.49*			1.49	*0.16*			0.16
HUN	1.14	*0.96*	0.96			*0.18*	0.18		
CHN	1.14	*0.31*		0.31		*0.83*		0.83	
6 countries	10.21	*6.72*	2.30	0.95	3.47	*3.49*	1.02	1.89	0.58
All countries	18.23	*12.57*	7.08	1.44	3.94	*5.66*	2.36	2.58	0.60

Indonesia and Malesia. Six other countries are embedded in this cluster for some trade, mainly for imports. The overall pattern of trade with other clusters is specular with the above observations on the Germany-led and the US-led clusters. The largest impact to the upsurge of this cluster is given by China, exploiting the advantage of having become a member of WTO in 2001 and having cumulated strong production relations with OEMs and global tiers-1, through the Chinese joint venture policy that attracted them and created strong production links both in the European markets and North-American market.

With respect to exports, the US is very important for China; Brazil and Argentina are important partners for Korea, Thailand and Indonesia, while Russia is a very important partner for several countries in the cluster. The other countries embedded in this cluster - Thailand, Hong Kong, India, Indonesia and Malaysia - have different patterns of trade shares and, since 2003 they moved towards more balanced trade shares with the US-led and the Germany-led clusters.

6.1.2. Roles of components and parts in cross-cluster connections

Over the 25 years considered in this study, the three main clusters show different dynamics with respect to the group of components and parts (Fig. 7). Indeed, while cluster 1 has a relatively stable composition of exports and imports in terms of shares (both within and with other clusters), clusters 2 and 3 have opposite trends in Miscellaneous Parts.

Table 5 shows, for the three main clusters, the top 10 items that contribute to cross-cluster connections with a share of over 0.1% of world trade. "*Other parts and accessories of the motor vehicles…*" - itself a miscellaneous group – in 2017 contributed with 8.9% to all exports across clusters (it was 4.9% in 1992), with the China&Japan-led cluster accounting for 5.1%. The China&Japan-led and the Germany-led clusters contribute to cross-cluster connections through exports of "*Gearboxes of the motor vehicles…*" with a similar export share (respectively, 1.8% and 1.5%) and "*Other parts and accessories of bodies (including cabs), of the motor vehicles*" (with a share of 1.4%). The fourth item is "*Tyres, pneumatic, new, of a kind used on motor cars (including station wagon)*" for which the China&Japan-led cluster is three times more important than the German-led one (respectively, 1.6% and 0.5% of exports). The next five items[19] show a larger importance of the China&Japan-led cluster. Finally, in the case of "*Compression-ignition internal combustion piston engines (diesel or semi-diesel)*" the Germany-led cluster - and most notably Germany itself - was activating the higher cross-cluster connection in 2013.

Beyond the above comments on biggest single items, the web of interconnections involves many countries and components and parts. Detailed patterns of groups of products can be explored in the Supplementary Material (Annex 8) and navigated with the online tool.

6.2. From vehicles with internal combustion engines (ICE) to electric vehicles

It is estimated that, with the transition from the internal combustion engine (ICE) to the electric engine, the average number of powertrain components could drop from 1500 to just 230 (Schulte, 2020). In this section, we use the results of the analysis reported so far to gauge the potential effects of the electrical transition on trade, that is, which countries and which bilateral trade flows could be more negatively affected, though we cannot say yet which new trade flows, competences and countries will emerge. To this end, we focus our attention on the components required to convert the engine's power into actual movement namely, the engine, transmission, driveshaft, differentials, axles. In other terms, we focus on the components that connect the engine to the wheels, which are represented by the six SITC codes in the group Engines and Parts[20]. Their share in the total exports of the four groups of automotive components and parts is relatively stable over the years. However, though still accounting for the largest part of total trade, their share of within-cluster trade declines (from 15.4%, in 1993, to 12.6% in 2017) (Fig. 8). Moreover, the dynamics of the sub-groups within Engines and Parts varies considerably, reflecting the changes in location and product that the automotive sector underwent over the period.

The overall impact on trade of the transition from ICE to electric will affect the leading countries: in 2017, 56% of the total export of Engines and Parts is generated by six countries: United States, Germany, Japan, Mexico, Hungary, China (see Table 6 and details in Annex 10). Though the largest part occurs within clusters, almost one third of those exports go to countries in other clusters (a feature in line with what we observed above about cross-cluster connections)[21]. This means that the transition risks disrupting a large part of transactions within each cluster, especially the ones headed by the US and Germany.

On the import side, in 2017 the US was the largest importer of Engines and Parts from countries in other clusters (1.7%), and it imported a similar share from within its cluster. Conversely, Germany imported more from countries within the cluster than from countries in other clusters. Finally, in line with the strategy of its car makers, Japan imported small shares from other countries, mainly from the Germany-led cluster.

These preliminary results suggest that the transition could entail a significant restructuring of trade flows, especially within clusters, which could affect more heavily the integrated peripheries, while also impacting the leading countries in their trade between clusters[22].

[19] Namely: *"Electric accumulators (storage batteries)", "Brakes and servo-brakes and parts thereof, of the motor vehicles of group", "Electrical ignition or starting equipment of a kind used for spark-ignition", "Drive-axles with differential, whether or not provided with other transmission*" and "*Electrical lighting or signalling equipment".*

[20] The list of items classified in the SITC codes 713.21, 713.22 and 713.23 is available in Annex 8.

[21] Explore on line data on internal combustion engines: shares of export and import by country, SITC code and year [flows within and between clusters (part B)].

[22] For a mapping in the emerging electro mobility, see Russo et al. (2022) and Acerbi et al. (2022) on battery production.

7. Discussion and conclusion

The automotive industry is undergoing a radical transformation. The transition to electric and digital vehicles, as well as environmental and geopolitical challenges, are bound to change the global structure of automotive production. The pandemic first, and then Russia's war with Ukraine and the ensuing Western sanctions have disrupted nearly every aspect of the global supply chains, as the lack of even a single component may be enough to halt production. Actual or anticipated shortages have led to reconsidering the need to shorten value chains, diversify supplies and/or identify those components that need to be re-shored to prevent dependence on overseas sources for critical parts. Moreover, with the new world of mobility and electrification accelerated by climate change, a whole segment of the value chain producing parts and components for the internal combustion engine will have to restructure or downsize. Batteries and chips, and their inputs, are at the forefront in the OEMs' worries.

Although the geography of countries bilateral trades is only one of the many dimensions impacting on the configuration of the automotive industry, in the complex set of interacting changes, occurring at company level, country policy level and in the geopolitical environment, the definition of the geography of trade can provide a benchmark for the analysis of the possible repercussions of the ongoing transformations in the various specialisations of many regions and countries involved in the automotive GVC.

The analytical model implemented to define the geography of trade before all the now occurring changes is not meant as a deterministic framework or as a prediction tool. Too many technical developments, product innovations (such as *mobility as a service* that is expected to impact the number of cars to be produced), geopolitical processes, renewable energy production and energy cost impact on the future configuration of the automotive GVC, making it essentially unpredictable through trade network analysis. With regard to such a complex scenario, future analyses of the outcome of those many interacting elements will benefit from a pre-post comparison of networks configurations outlined using the presented analytical framework.

Our analytical model allows to conceptualise the notions of "regionalisation" and "globalisation" as emergent properties of the clusters of countries and trades identified in the world trade network, and not as *a priori* attributions of countries in their geographical position. We show that, while the relative importance of the main clusters and of some individual countries changes significantly, connections between clusters increase over time, providing in this way an original contribution to the debate on regionalisation vs. globalisation on GVCs. This twin dynamic characterizes the automotive international trade networks over the 25 years under analysis.

With automotive global value chains in the described state of turmoil, the definition of the pre-turmoil situation presented in the paper can prove an indispensable starting point for analysis of the possible repercussions of the current technological and geo-political transition on geographical clusters and the sectorial specialisations of the main regions and countries. In the economic literature on international trade, study of the automotive global value chains has been addressed using network analysis, focusing on the geographical regions and on the different types of bridging role of countries, while largely overlooking the contribution of countries' bilateral trade in components and parts to the structuring of the subnetwork of countries and their specific position in the overall trade network.

Many dimensions impact on international trade network (recalled at the end of Section 2): skills, wages, regulations, innovation ecosystems and absorptive capacity shape the structure of supply of automotive components and parts, which also depends on other production specialisations in the country, the location of domestic and foreign car makers' plants in the country, the role assigned by carmakers to supply from that country with respect to their global supply chains. Countries' centrality in international trade depends on those dimensions. In addition to these dimensions one must consider that trade network is only one of the various interrelated networks that should be considered for a full understanding of the trade pattern: networks of technologies, competences and organisations, regional trade agreements and preferential trade arrangements are intertwined with the trade flows operated by TNCs (car manufacturers and Tier 1 suppliers), which in turn affect countries' trading. Analysis of those networks will call for ad hoc investigation into the dynamics of change which occurred in the automotive value chains, with a specific focus on who produces what and where.

With a focus on bilateral trade networks, the paper provides original contributions on both analytical and descriptive perspective.

The analytical value that is added by the multilayer clustering method presented in the paper lies in the identification of clusters and in the adoption of a metrics that allows to compare over time the changes in trade flows which led to the changing configuration of clusters. The analysis has evidenced answers to the three empirical issues, presented in the Introduction: an increasing concentration of trade; the emerging spatial distribution of clusters, confirming the relevance of proximity in trade exchanges and the presence of sub clusters in those geographic areas, that would not have emerged by focusing only on networks of countries' bilateral trade by geographic area; and the increase of cross-cluster connections, thus highlighting increasing cross-region integration.

We chose to focus on the three main clusters – the Germany-led cluster, the US-led cluster and the China&Japan-led cluster - to highlight important examples of persisting differences in within-cluster relations. As for the changes in the geography of trade relations, we find denser and more hierarchical clusters generated, respectively, by Germany's trade relations with EU countries, the US preferential trade agreements with Canada and Mexico, and the surge of China. The results reflect the impact of the signing and undoing of trade treaties in changing geopolitical scenarios. The major shift in international trade driven by NAFTA (in particular the triangulation of trades occurring via Mexico) can be compared with the effects expected under the new USMCA trade agreement, and the repositioning of the main OEMs following the new protectionist policies inaugurated by the Trump administration and continued by the current one.

Conversely, the structural changes within the Germany-led cluster highlight the strategy of the German OEMs aimed at integrating the CEE countries in ever closer connections, each of them still maintaining trade relations outside the Germany-led cluster, thus strengthening their connections with (but also their dependence on) world trade.

Focusing on the composition of trade, the largest clusters show a similar structure, although the quality and characteristics of the various components and parts are likely to differ significantly. The Infomap multilayer analysis allows to single out which components and parts determined the relative positions of countries in the various clusters; it also identifies smaller clusters that turn out to be highly specialised with a different trade orientation. Finally, the detailed analysis focusing on individual components and parts casts light on the trade patterns related to the production of internal combustion engines (ICEs). The results show the different dynamics of parts and components for ICEs over time, and the potential impact of the transition to electric vehicles on the main countries exporting ICEs. Although new components will be needed for electric vehicles, their production will not necessarily be located in the same places where ICEs and their components are now being produced (Pavlínek, 2022). Analysis of the potential impact of these changes will call for more detailed classification of trade statistics and information on the production structure of the countries at present involved in the export of ICE components and parts, and of those countries that will be specialising in components and parts for electric mobility.

To conclude, over the years, the regionalisation of trade thickened (many small clusters of countries disappear), but the links between clusters almost doubled at the aggregate level, with a significant contribution of the countries in the China&Japan-led cluster.

The application of the multilayer method to the automotive international trade networks evidenced an emerging model characterised by regionalization – with denser and more hierarchical large clusters complemented by smaller specialized ones - and cross-region integration: this is the most original analytical result of the paper. This twin dynamic of regionalization and cross-region integration is likely to be very different in the coming years, with the reorganization of global value chains following the pandemic, the war and the transition to electric and autonomous driven vehicles in Europe, US and China.

The issue of redesigning the supply chain has entered the agenda of carmakers and debates on national/local sovereignty, together with the need to reconsider redundancy as a more efficient solution - compared to just-in-time or free-pass production methods - and logistics and transport as possible causes of bottlenecks in supply chains. In the short term, the impact of these events has been shifted on to price increases along the supply chain or has affected cars' performance (as in the case of cars delivered in reasonable time and with a reasonable price, but with fewer microchip devices). In the medium term, reorganisation of the automotive industry will be marked by the carmakers' commitment to comply with the requirements of CO_2 emissions, durability of batteries, smarter mobility – issues subject to heated debate and on which there is no agreement between the countries (as emerged in COP26 and COP27). Our analysis, presenting a picture of the trade conditions *before* these changes, offers a benchmark for analysis of the changes *post*-transition.

CRediT authorship contribution statement

Margherita Russo: Conceptualization, Data curation, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Fabrizio Alboni:** Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jorge Carreto Sanginés:** Funding acquisition, Writing – review & editing. **Manlio De Domenico:** Formal analysis, Investigation, Methodology. **Giuseppe Mangioni:** Formal analysis, Investigation, Methodology, Software, Writing – review & editing. **Simone Righi:** Formal analysis, Investigation, Methodology, Software, Writing – original draft. **Annamaria Simonazzi:** Conceptualization, Funding acquisition, Investigation, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Supplementary materials

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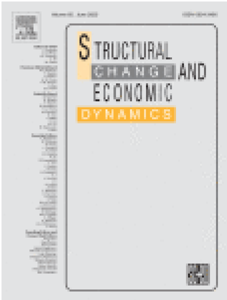
Appendix. Supplementary materials



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Regionalisation and cross-region integration. Twin dynamics in the automotive international trade networks,

***Structural Change and Economic Dynamics*,** 2023, ISSN 0954-349X, https://doi.org/10.1016/j.strueco.2023.07.006

Abstract: The paper analyses the changes that occurred over 25 years in the geography of trade in automotive parts and components. Using the Infomap multilayer clustering algorithm, we identify clusters of countries and their specific trades in the automotive international trade network, we measure the relative importance of each cluster and the interconnections between them, and we analyse the contribution of countries and of trade of components and parts in the clusters. The analysis highlights the formation of denser and more hierarchical networks generated by Germany's trade relations with EU countries and by the US preferential trade agreements with Canada and Mexico, as well as the surge of China. While the relative importance of the main clusters and of some individual countries change significantly, connections between clusters increase over time.
Keywords: international trade; regional specialisation; automotive components and parts; dynamics of change; Infomap multilayer analysis

Selected Figures and Tables marked with the symbol can be browsed online - by using the tool implemented with Tableau Public - with respect to data and community detection (part A), and to flows within and between clusters (part B). Changes over time in the relative positions of countries and their specialisations in multilateral trades can be explored in detail.

Annex 1 - Figures on automotive sector

Source: Authors elaboration on data of the International Organization of Motor Vehicle Manufacturers, available at https://www.oica.net/production-statistics/

Figure A1 – Share of production of vehicles by country, 2003, 2013, 2017

Countries listed according to their share in 2003

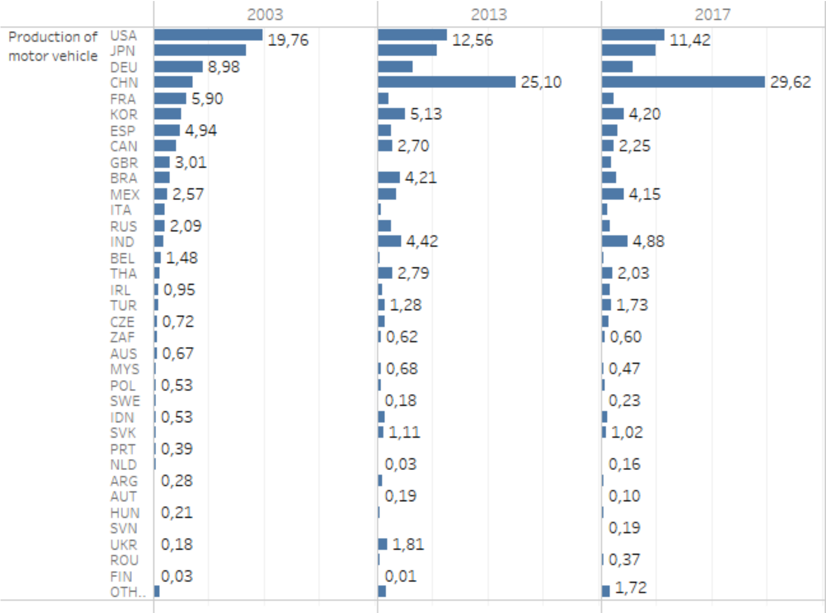


Figure A2 Share of production of vehicles, by car maker, in 2017

Source: Russo et al. Who produces what and where. Companies and countries in vehicle production, 1999-2017 INET_project, "Geopolitical and technological challenges for the automotive global value chains.

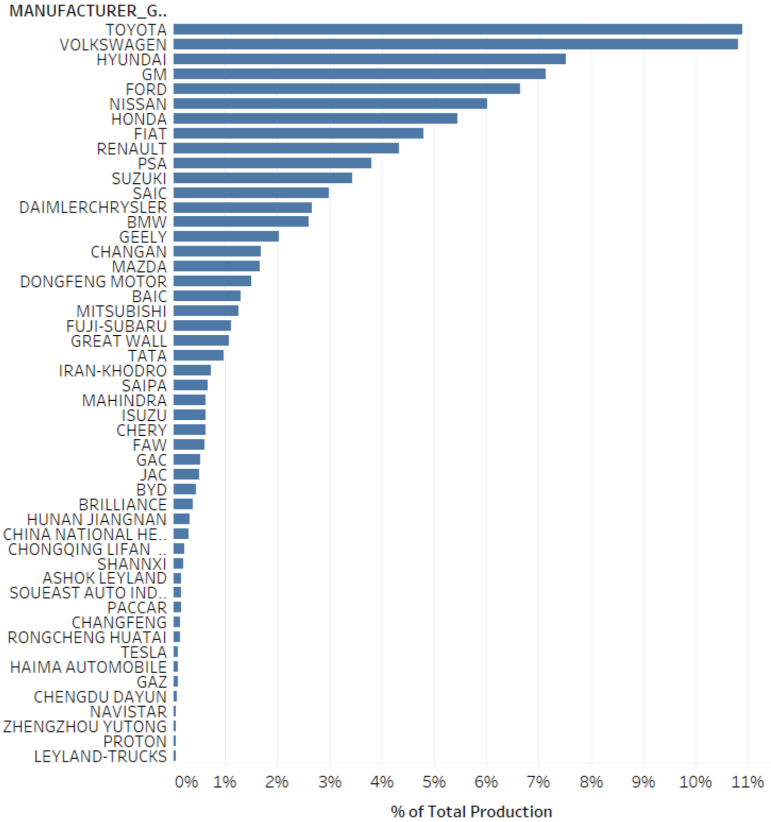


Table A1 – Export and import of automotive components and parts and of motor cars and other motor vehicles, 1993, 2003, 2013, 2017 (billion USD at current price)

Export

		Components & Parts	Vehicles	Total Export	Components & Parts	Components & Part	Vehicle
		billion USD at current price			*% on Total Export*	*% on World Total*	*% on World Total*
1993	42 countries	139.8	193.9	333.8	41.9	97.8	99.4
	others	3.2	1.1	4.3	73.9	2.2	0.6
	World total	143.0	195.1	338.1	42.3	100.0	100.0
2003	42 countries*	276.6	395.4	672.0	41.2	97.4	98.8
	others	7.5	4.8	12.3	60.9	2.6	1.2
	World total	284.1	400.2	684.3	41.5	100.0	100.0
2013	42 countries*	575.8	666.8	1242.6	46.3	97.0	97.8
	Others	17.9	14.7	32.6	55.0	3.0	2.2
	World total	593.7	681.4	1275.2	46.6	100.0	100.0
2017	42 countries*	616.7	730.7	1347.5	45.8	97.0	97.7
	Others	19.2	17.0	36.2	53.1	3.0	2.3
	World total	636.0	747.7	1383.7	46.0	100.0	100.0

Import

		Components & Parts	Vehicles	Total Import	Components & Parts	Components & Part	Vehicle
		billion USD at current price			*% on Total Import*	*% on World Total*	*% on World Total*
1993	42 countries*	125.1	174.8	299.8	41.7	93.3	91.2
	Others	9.1	16.8	25.8	35.1	6.7	8.8
	World total	134.1	191.5	325.7	41.2	100.0	100.0
2003	42 countries*	270.6	370.5	641.1	42.2	94.0	91.6
	Others	17.4	34.1	51.5	33.8	6.0	8.4
	World total	288.0	404.6	692.6	41.6	100.0	100.0
2013	42 countries*	547.1	581.3	1128.4	48.5	92.6	85.2
	Others	43.4	101.3	144.7	30.0	7.4	14.8
	World total	590.5	682.6	1273.1	46.4	100.0	100.0
2017	42 countries*	593.0	660.1	1253.0	47.3	93.0	88.0
	others	44.6	89.8	134.4	33.2	7.0	12.0
	World total	637.6	749.9	1387.5	46.0	100.0	100.0

Values, for each year, are the three-year average of trade in the year in analysis, the year before and the following year.
Components & Parts:
SITC rev.3 codes:
6251, 62551, 62559, 62591, 62592, 62593, 62594, 69915, 69961, 76211, 76212, 77812, 77823, 71321, 71322, 71323, 77831, 77833,
77834, 7841, 78421, 78425, 78431, 78432, 78433, 78434, 78435, 78436, 78439, 82112
Vehicle:
SITC rev.3 code 781: Motor cars and other motor vehicles principally designed for the transport of persons (other than public-transport type vehicles), including station wagons and racing cars
42 countries:
ARG, AUS, AUT, BLR, BEL, BRA, CAN, CHN, HKG, CZE, DNK, FIN, FRA, DEU, HUN, IND, IDN, IRL, ITA, JPN, MYS, MEX, NLD, PHL, POL, PRT, KOR, ROU, RUS, SGP, SVK, SVN, ZAF, ESP, SWE, CHE, THA, TUR, UKR, ARE, GBR, US
Data source: UN Comtrade

Annex 2 - Details on SITC Rev.3 codes

The details below make clear why it is not significant to consider data at 2-digit level, being aggregation of items not relevant for the automotive sector. For each code, the number of 3-digit codes for the 4-digit and 5-digit codes we select from SITC Rev.3 are listed.

Table A2 – Two-digit aggregation of the selected codes

62 Rubber manufactures, n.e.s.
has **3** sets of 3-digit codes:
we select only 625 Rubber tyres, tyre treads or flaps & inner tubes
69 Manufactures of metal, n.e.s. :
has **8** sets of 3-digit codes:
we select only 699 Manufactures of base metal, n.e.s.
76 Telecommunication and sound recording apparatus
has **4** sets of 3-digit codes:
we select only 762 Radio-broadcast receivers, whether or not combined
77 Electrical machinery, apparatus and appliances, n.e.s.
has **8** sets of 3-digit codes:
we select only 778 Electrical machinery & apparatus, n.e.s.
71 Power generating machinery and equipment
has **6** sets of 3-digit codes:
we select only 713 Internal combustion piston engines, parts, n.e.s.
77 Electrical machinery, apparatus and appliances, n.e.s.
has **8** sets of 3-digit codes:
we select only 778 Electrical machinery & apparatus, n.e.s.
78 Road vehicles
has **6** sets of 3-digit codes:
we select only 784 Parts & accessories of vehicles of 722, 781, 782, 783
82 Furniture and parts thereof
has **1** set of 3-digit codes:
we select only 821 Furniture & parts
Table A3 below lists the products included in item 784.39 (SITC Rev.3)

Table A**3 - List of products included in item 784.39 (SITC Rev.3)**

"other parts and accessories of the motor vehicles of groups 722, 781, 782" (see table above)

– Casings, clutch, for road motor vehicles (excl. motor cycles) or tractors1
– Casings, steering-gear, for road motor vehicles (excl. motor cycles) or tractors1
– Clutches, non-magnetic (excl. integral parts of engines), for road motor vehicles (excl. motor cycles) or tractors1
– Connecting-rods for brakes or clutches of road motor vehicles (excl. motor cycles) or tractors1
– Discs, wheel, for road motor vehicles (excl. motor cycles) or tractors1
– Exhaust-pipes for tractors1
– Hub-caps for road motor vehicles or tractors1
– Levers, clutch, for road motor vehicles (excl. motor cycles) or tractors1
– Levers, gear-change, for road motor vehicles (excl. motor cycles) or tractors1
– Levers, handbrake, for road motor vehicles (excl. motor cycles)1
– Levers, steering, for road motor vehicles (excl. motor cycles) or tractors1
– Linings, clutch, mounted, for road motor vehicles (excl. motor cycles) or tractors1
– Mufflers for road motor vehicles (excl. motor cycles) or tractors1
– Pedals, accelerator, brake and clutch, for road motor vehicles or tractors1
– Plates, clutch, for road motor vehicles (excl. motor cycles) or tractors1
– Racks and pinions, steering, for road motor vehicles1
– Radiators for road motor vehicles or tractors1
– Rims, wheel, for road motor vehicles (excl. motor cycles) and tractors1
– Axles, steering-wheel, for road motor vehicles or tractors1
– Servo-steering mechanisms for road motor vehicles1
– Shock absorbers, for road motor vehicles (excl. motor cycles) or tractors (excl. tractors of heading 744.11)1
– Silencers for road motor vehicles (excl. motor cycles) or tractors1
– Spokes, wheel, for road motor vehicles (excl. motor cycles) or tractors1
– Steering gear (and parts thereof), for road motor vehicles (excl. motor cycles) or tractors1
– Steering-column tubes, for road motor vehicles (excl. motor cycles) or tractors1
– Steering-columns for road motor vehicles (excl. motor cycles) or tractors1
– Steering-wheels for road motor vehicles or tractors1
– Suspension parts (excl. springs) for road motor vehicles (excl. motor cycles)1
– Tailpipes for road motor vehicles (excl. motor cycles)1
– Tanks, fuel, for road motor vehicles (excl. motor cycles) or tractors1
– Tie-rods, steering knuckle, for road motor vehicles or tractors1
– Torsion bars for road motor vehicles or tractors1
– Tracks and sets of wheels for tracked road motor vehicles1
– Tracks for track-type tractors1
– Wheel covers for road motor vehicles or tractors1
– Wheels, road, whether or not fitted with tyres, for road motor vehicles (excl. motor cycles) or tractors1

The SITC 72,78, 79 codes encompass machineries and vehicles for which components and parts cannot be disentangled by the final product in which they are used

Table A4 - List of SITC codes in items 722, 781, 782

Motor vehicles of groups

code	description
72	Specialised machinery
721	Agricultural machinery (excluding tractors) & parts
722	Tractors (excluding those of 71414 & 74415)
78	Road vehicles
781	Motor vehicles for the transport of persons
782	Motor vehicles for transport of goods, special purposes
783	Road motor vehicles, n.e.s.
784	Parts & accessories of vehicles of 722, 781, 782, 783
785	Motorcycles & cycles
786	Trailers & semi-trailers
79	Other transport equipment
791	Railway vehicles & associated equipment
792	Aircraft & associated equipment; spacecraft, etc.
793	Ships, boats & floating structures

Annex 3 - List of countries and commodities under analysis

Table A5 - List of the selected 42 countries: continental region, area, country name, Iso-alpha3 code colour

continental_ regions	Area	Country	ISO-alpha3 code	
Africa	Africa	South Africa	ZAF	
Americas	Central America	Mexico	MEX	
	Northern America	Canada	CAN	
		USA	USA	
	South America	Argentina	ARG	
		Brazil	BRA	
Asia	Eastern Asia	China	CHN	
		China, Hong Kong SAR	HKG	
		Japan	JPN	
		Rep. of Korea	KOR	
	South-eastern Asia	Indonesia	IDN	
		Malaysia	MYS	
		Philippines	PHL	
		Singapore	SGP	
		Thailand	THA	
	Southern Asia	India	IND	
	Western Asia	Turkey	TUR	
		United Arab Emirates	ARE	
Europe	Eastern Europe	Belarus	BLR	
		Czechia	CZE	
		Hungary	HUN	
		Poland	POL	
		Romania	ROU	
		Russian Federation	RUS	
		Slovakia	SVK	
		Ukraine	UKR	
	Northern Europe	Denmark	DNK	
		Finland	FIN	
		Ireland	IRL	
		Sweden	SWE	
		United Kingdom	GBR	
	Southern Europe	Italy	ITA	
		Portugal	PRT	
		Slovenia	SVN	
		Spain	ESP	
	Western Europe	Austria	AUT	
		Belgium	BEL	
		France	FRA	
		Germany	DEU	
		Netherlands	NLD	
		Switzerland	CHE	
Oceania	Australia and New Zealand	Australia	AUS	

Table A6 - Export by country and year 1993, 2003, 2013, 2017 (current values and share, by year)

Countries are ranked according to their total share in 1993 of export towards the 42 countries [values at current price]

Country	Export 1993	Export % 1993	Export 2003	Export % 2003	Export 2013	Export % 2013	Export 2017	Export % 2017	Diversity 1993	Diversity 2003	Diversity 2013	Diversity 2017	Cluster
Grand Tot..	120,241,533,772	100.00	260,184,027,700	100.00	533,274,046,502	100.00	574,419,930,612	100.00					
JPN	22,879,746,113	19.03	31,065,911,841	11.94	57,916,698,480	10.86	50,659,423,325	8.82	14	9	10	10	4
USA	19,475,568,851	16.20	40,512,264,391	15.57	54,579,645,089	10.23	59,878,943,927	10.42	10	8	12	12	4
DEU	18,187,657,802	15.13	43,198,589,478	16.60	81,128,649,298	15.21	87,008,429,533	15.15	9	10	11	12	4
FRA	11,907,011,593	9.90	21,540,919,253	8.28	30,107,163,738	5.65	26,930,311,718	4.69	9	8	8	10	2
CAN	8,423,411,680	7.01	15,971,095,728	6.14	15,360,556,735	2.88	15,609,929,977	2.72	10	9	6	6	1
MEX	5,336,810,682	4.44	11,562,546,347	4.44	31,889,156,504	5.98	44,085,402,162	7.67	9	8	10	9	2
ITA	5,188,779,581	4.32	10,647,461,726	4.09	17,902,879,131	3.36	18,780,285,841	3.27	15	15	11	10	5
GBR	4,694,096,401	3.90	10,375,582,754	3.99	12,076,644,972	2.26	11,255,522,663	1.96	14	9	11	10	4
ESP	3,817,676,075	3.18	10,064,001,475	3.87	15,755,281,665	2.95	16,005,789,369	2.79	9	12	11	14	7
AUT	2,884,049,974	2.40	4,402,295,403	1.69	10,474,861,537	1.96	11,601,723,678	2.02	8	8	8	6	1
SWE	2,841,403,041	2.36	5,983,842,261	2.30	9,855,775,169	1.85	10,325,980,131	1.80	9	6	6	4	6
BEL	2,595,614,798	2.16	4,975,147,010	1.91	7,227,927,488	1.36	7,453,538,904	1.30	15	14	14	13	3
NLD	1,762,729,835	1.47	3,402,356,575	1.31	6,608,370,716	1.24	6,884,072,988	1.20	13	13	13	13	3
BRA	1,633,831,502	1.36	2,749,632,965	1.06	5,139,499,449	0.96	3,640,643,811	0.63	13	14	10	11	5
KOR	1,341,633,078	1.12	4,608,218,036	1.77	28,002,108,116	5.25	29,852,175,934	5.20	13	11	9	10	5
PRT	950,651,315	0.79	2,375,748,163	0.91	4,051,614,590	0.76	4,554,528,014	0.79	6	5	7	8	2
CHN	798,033,205	0.66	7,148,699,426	2.75	44,163,488,016	8.28	52,809,119,858	9.19	11	14	15	18	3
MYS	491,340,234	0.41	1,104,401,750	0.42	1,963,008,509	0.37	2,492,442,066	0.43	10	8	15	11	4
SGP	464,361,686	0.39	415,276,454	0.16	855,149,506	0.16	1,245,420,902	0.22	8	14	12	9	7
CHE	439,575,142	0.37	912,356,891	0.35	1,575,083,537	0.30	1,581,593,155	0.28	11	7	4	5	6
ARG	418,248,415	0.35	627,828,181	0.24	1,626,556,833	0.31	1,011,866,151	0.18	5	7	9	6	2
AUS	412,175,226	0.34	606,979,872	0.23	709,560,562	0.13	570,528,342	0.10	5	6	11	11	2
DNK	324,331,462	0.27	624,048,508	0.24	1,071,286,792	0.20	1,016,148,755	0.18	12	12	7	10	5
IRL	297,835,857	0.25	232,059,296	0.09	268,798,452	0.05	294,911,982	0.05	5	11	13	15	7
HUN	296,368,084	0.25	5,206,769,973	2.00	12,223,078,672	2.29	14,724,712,725	2.56	11	4	6	6	6
CZE	281,823,619	0.23	4,528,597,981	1.74	16,676,855,915	3.13	20,131,778,870	3.50	14	9	11	12	4
HKG	237,813,558	0.20	273,043,288	0.10	324,622,795	0.06	456,748,547	0.08	13	13	11	11	5
FIN	209,394,831	0.17	449,116,636	0.17	771,692,914	0.14	789,704,964	0.14	13	9	11	12	4
PHL	192,124,806	0.16	719,647,410	0.28	1,663,845,497	0.31	1,560,768,427	0.27	8	10	7	6	1
THA	189,876,353	0.16	1,736,830,593	0.67	9,872,770,094	1.85	11,439,387,424	1.99	14	12	10	11	5
IDN	189,789,220	0.16	1,393,512,606	0.54	3,527,524,215	0.66	3,697,868,760	0.64	9	8	9	10	2
SVN	171,415,359	0.14	645,719,395	0.25	1,947,225,237	0.37	2,282,840,612	0.40	8	8	6	7	1
SVK	166,681,281	0.14	1,411,762,675	0.54	9,379,292,954	1.76	10,471,760,271	1.82	13	4	7	7	6
TUR	165,036,907	0.14	1,414,998,939	0.54	5,746,348,399	1.08	6,251,188,693	1.09	9	7	9	9	2
POL	153,524,700	0.13	4,790,376,857	1.84	16,855,679,933	3.16	20,100,668,210	3.50	12	7	13	12	4
ZAF	143,733,558	0.12	741,955,735	0.29	957,365,910	0.18	771,025,396	0.13	8	11	5	9	1
IND	109,314,843	0.09	576,585,387	0.22	4,639,812,152	0.87	5,851,308,750	1.02	18	14	11	13	3
RUS	80,702,777	0.07	425,260,199	0.16	1,158,334,463	0.22	1,222,862,006	0.21	18	11	6	7	8
ROU	33,474,016	0.03	504,211,878	0.19	5,892,258,390	1.10	7,960,927,034	1.39	9	7	6	8	1
ARE	32,697,602	0.03	64,086,387	0.02	265,541,254	0.05	357,998,290	0.06	9	12	8	5	1
BLR	12,219,410	0.01	52,148,168	0.02	721,076,344	0.14	631,372,112	0.11	11	9	9	11	4
UKR	8,969,305	0.01	142,139,813	0.05	340,956,483	0.06	168,276,339	0.03	11	10	11	10	4

Table A7 - List of selected SICT3 commodities and shares of the 42 countries exports, out of the world trade, 2017

group_descr	commodity_co	Layer	commodity	1993	2017
Rubber and Metal Parts	6251	1	Tyres, pneumatic, new, of a kind used on motor cars (including station wagons and racing cars)	97.45%	94.18%
	62551	2	Tyres, pneumatic, new, other, having a 'herring-bone' or similar tread	98.53%	88.87%
	62559	3	Tyres, pneumatic, new, other	83.50%	94.37%
	62591	4	Inner tubes	86.02%	88.65%
	62592	5	Retreaded tyres	98.64%	96.67%
	62593	6	Used pneumatic tyres	99.11%	98.09%
	62594	7	Solid or cushion tyres, interchangeable tyre treads and tyre flaps	85.36%	77.26%
	69915	8	Other mountings, fittings and similar articles suitable for motor vehicles	98.40%	98.16%
	69961	9	Anchors, grapnels and parts thereof, of iron or steel	87.86%	89.68%
Electrical and Electric Parts	76211	10	Radio-broadcast receivers not capable of operating without an external source of power, ...combined with sound recording or reproducing apparatus	98.94%	98.86%
	76212	11	Radio-broadcast receivers not capable of operating without an external source of power, ...not combined with sound recording or reproducing apparatus	99.66%	99.32%
	77812	12	Electric accumulators (storage batteries)	96.17%	94.45%
	77823	13	Sealed beam lamp units	99.57%	96.55%
Engines and Parts	71321	14	Reciprocating piston engines of a cylinder capacity not exceeding 1000 cc	98.13%	98.28%
	71322	15	Reciprocating piston engines of a cylinder capacity exceeding 1000 cc	99.99%	99.90%
	71323	16	Compression-ignition engines (diesel or semi-diesel engines)	99.32%	99.78%
	77831	17	Electrical ignition or starting equipment of a kind used for spark-ignition or compression-ignition internal combustion engines	99.48%	98.42%
	77833	18	Parts of the equipment of heading 778.31	97.92%	96.11%
	77834	19	Electrical lighting or signalling equipment (excluding articles of heading 778.2), windscreen wipers, defrosters and demisters of a kind used for cycles or motor vehicles	98.09%	93.41%
Miscellaneous Parts	7841	20	Chassis fitted with engines, for the motor vehicles of groups 722, 781, 782 and 783	99.25%	99.21%
	78421	21	Bodies (including cabs), for the vehicles of group 781	99.65%	97.28%
	78425	22	Bodies (including cabs), for the vehicles of groups 722, 782 and 783	99.65%	97.95%
	78431	23	Bumpers and parts thereof	95.46%	93.07%
	78432	24	Other parts and accessories of bodies (including cabs)	98.95%	97.56%
	78433	25	Brakes and servo-brakes and parts thereof	99.22%	99.03%
	78434	26	Gear boxes	99.45%	98.54%
	78435	27	Drive-axles with differential, whether or not provided with other transmission components	98.68%	99.57%
	78436	28	Non-driving axles and parts thereof	99.10%	0.00%
	78439	29	Other parts and accessories	97.22%	97.11%
	82112	30	Seats of a kind used for motor vehicles	99.18%	96.30%
			Total	98.11%	97.08%

Table A8 - Share of trade by group of automotive components and parts and SITC, in the years 1993, 2003, 2013, 2017

Groups of automotive components and parts are listed in decreasing order of their share of export in 1993. Commodities are listed according to their SITC code

Group Descr	Sitc3	Commodity	Export 1993	Export % 1993	Export 2003	Export % 2003	Export 2013	Export % 2013	Export 2017	Export % 2017	Ubiquity 1993	Ubiquity 2003	Ubiquity 2013	Ubiquity 2017	Cluster
Grand Total			120,241,533,772	100.00	260,184,027,700	100.00	533,274,046,502	100.00	574,419,930,612	100.00					
Miscellaneous Parts	7841	Chassis fitted..	1,892,081,323	1.57	2,377,781,187	0.91	2,635,596,399	0.49	2,450,255,971	0.43	14	11	16	14	5
	78421	Bodies (inclu..	337,316,618	0.28	1,645,956,440	0.63	5,919,414,806	1.11	5,039,970,623	0.88	11	13	5	6	7
	78425	Bodies (inclu..	1,033,455,493	0.86	2,655,246,198	1.02	4,098,011,173	0.77	4,537,203,167	0.79	16	11	11	12	6
	78431	Bumpers and..	1,337,596,361	1.11	2,345,133,416	0.90	5,362,040,162	1.01	6,466,598,006	1.13	7	9	19	16	8
	78432	Other parts a..	12,815,391,966	10.66	35,657,918,244	13.70	65,224,793,253	12.23	71,808,285,219	12.50	6	10	17	17	8
	78433	Brakes and s..	5,900,301,246	4.91	13,634,266,183	5.24	26,718,045,282	5.01	28,161,558,079	4.90	18	14	12	12	6
	78434	Gearboxes of..	8,367,903,054	6.96	18,956,288,726	7.29	56,445,343,049	10.58	60,599,882,619	10.55	6	9	9	12	4
	78435	Drive-axles w..	2,076,283,839	1.73	4,208,296,188	1.62	20,379,515,842	3.82	20,577,761,907	3.58	15	8	12	12	6
	78436	Non-driving a..	1,281,807,588	1.07	3,056,573,375	1.17	121,512	0.00	30,917	0.00	14	10	3	4	7
	78439	Other parts a..	41,928,691,580	34.87	86,009,536,819	33.06	155,204,295,063	29.10	177,092,617,146	30.83	13	15	15	17	2
	82112	Seats of a kin..	609,040,606	0.51	1,274,145,216	0.49	2,360,459,543	0.44	2,335,991,359	0.41	10	14	10	12	5
Engines and Parts	71321	Reciprocatin..	934,076,273	0.78	1,090,134,450	0.42	1,997,301,608	0.37	2,160,429,732	0.38	5	8	9	11	4
	71322	Reciprocatin..	10,655,892,777	8.86	22,278,321,161	8.56	32,679,656,477	6.13	32,844,569,834	5.72	11	9	12	9	5
	71323	Compression..	4,664,784,801	3.88	12,854,593,069	4.94	31,123,972,096	5.84	30,746,642,450	5.35	11	11	14	15	5
	77831	Electrical igni..	3,415,906,245	2.84	6,271,818,539	2.41	14,705,440,549	2.76	15,630,395,784	2.72	17	15	16	18	2
	77833	Parts of the e..	920,928,878	0.77	1,782,033,958	0.68	2,993,819,558	0.56	3,261,567,008	0.57	17	17	13	15	2
	77834	Electrical ligh..	2,047,133,739	1.70	4,609,434,332	1.77	14,831,184,353	2.78	20,076,794,122	3.50	16	17	16	15	2
Rubber and Metal Parts	6251	Tyres, pneu..	7,783,426,228	6.47	13,823,796,019	5.31	37,046,217,093	6.95	33,674,990,713	5.86	25	24	24	26	1
	62551	Tyres, pneu..	672,455,978	0.56	1,126,318,507	0.43	3,543,092,458	0.66	2,531,086,816	0.44	19	21	18	19	2
	62559	Tyres, pneu..	742,570,557	0.62	1,205,581,109	0.46	5,917,656,957	1.11	4,203,563,273	0.73	24	17	15	12	3
	62591	Inner tubes	365,753,027	0.30	308,551,033	0.12	699,880,078	0.13	559,813,821	0.10	22	19	12	10	3
	62592	Retreaded ty..	196,925,330	0.16	199,104,261	0.08	455,252,731	0.09	541,705,681	0.09	25	17	18	12	3
	62593	Used pneum..	226,097,470	0.19	213,449,422	0.08	428,022,182	0.08	296,568,211	0.05	18	14	14	21	2
	62594	Solid or cushi..	190,161,779	0.16	318,664,285	0.12	935,027,397	0.18	752,908,557	0.13	22	19	14	14	3
	69915	Other mounti..	931,401,353	0.77	2,915,193,660	1.12	5,318,427,928	1.00	6,347,388,801	1.11	8	7	11	14	4
	69961	Anchors, gra..	52,878,453	0.04	85,039,068	0.03	214,172,056	0.04	186,844,683	0.03	24	14	11	15	3
Electrical and Electric Parts	76211	Radio-broadc..	4,433,902,993	3.69	8,184,525,267	3.15	9,034,313,546	1.69	6,892,528,600	1.20	12	14	11	10	5
	76212	Radio-broadc..	543,006,180	0.45	627,664,343	0.24	849,197,162	0.16	1,233,125,910	0.21	12	12	15	12	5
	77812	Electric accu..	3,655,404,358	3.04	10,122,126,908	3.89	25,643,092,737	4.81	33,069,515,786	5.76	16	13	13	13	6
	77823	Sealed-beam..	228,957,682	0.19	346,536,321	0.13	510,683,453	0.10	339,335,819	0.06	17	11	14	14	6

Annex 4 – Infomap model

Infomap multilayer algorithm

The module detection method, introduced by Rosvall and Bergstrom (2008, 2011), is based on information theory: to detect modules in complex networks, the method minimises the length of the two-level description of a simulated flow circulating through the network. The first level of description concerns the nodes between which the flow moves, the second the sub-areas of the network, i.e. modules, in which the flow tends to circulate for a long period before exiting. Therefore, each detected module maximises the probability of a considered random walker remaining within its boundaries before moving into another module. This method is implemented in an algorithm called 'Infomap'[1] extended by De Domenico et al. (2015) to run over a multilayer—or multiplex—networks. We run our data with version 0.21 of Infomap.

The Infomap multilayer algorithm: (a) considers in each layer only one specific type of relationship to determine intra-layer connections; (b) connects all the projections (i.e. state-nodes) of the same node (physical-nodes) with inter-layer connections. Finally, overcoming the limits of the first-order Markov model that "suffers of memory loss and washes out significant dynamic patterns" (Edler et al., 2017, p. 1), the Infomap multilayer algorithm (c) implements recursive computation of a random walker[2]. The mathematical machinery that underlies the working of the Infomap algorithm is derived from information theory and reported in De Domenico et al. (2015) to which we refer the interested reader.

Definition of the weight variables

To produce the .net file, to be used as input for Infomap, it was necessary to define the weight to be assigned to the individual relationships between the nodes across layers. Specifically, for each year, we used the percentage weight of the value of each transaction on the total amount of the transaction value (i.e. for all components and parts) in the year[3]

Table A9 - Parameters of the distribution of the percentage weight of export transactions on the total export per year

year	Count	Mean	st.Dev.	Min	1st Qu.	Median	3st Qu.	Max
1993	22749	0.00440	0.05192	4.17E-07	8.22E-06	0.00005	0.00043	3.26843
2003	32645	0.00306	0.03569	3.84E-10	2.34E-06	0.00002	0.00026	2.36051
2013	36550	0.00274	0.02421	1.88E-10	1.87E-06	0.00002	0.00034	1.63069
2017	36620	0.00273	0.02497	1.74E-10	1.50E-06	0.00002	0.00032	2.22185

Based on the information provided by mapequation.org (Edler, Eriksson, and Rosvall) at https://www.mapequation.org/infomap/#InputMultilayerIntra, an extract from the structure of the .net file for export in 2017 is therefore:

```
*Vertices 42
1 "ARE"
2 "ARG"
3 "AUS"
. . .
41 "GBR"
```

1 Infomap solves the main problems with Newman and Girvan (2004) in identifying modules of very different sizes and, in addition, it allows for detection of overlapping modules (Fortunato & Hric, 2016), so that each agent/node can belong to more than one of them.

2 We implemented the module detection with 1500 trials.

3 Gorgoni, Amighini, and Smith (2018) use a different weight: "For each of the auto components examined, a value is given to the trade relationship (i.e. tie) between any two pairs of countries [ij] according to the value of their bilateral trade flow [wij] over the world's total for that good in a specific year. "

```
42 "US"
*Intra
# layer_id node_id node_id weight
1 1 3 0.000436500580796818
1 1 4 8.43163640725565e-06
1 1 5 0.00019459248198603
    ...
```

Identification of optimal relax rate

To determine the optimal relax-rate over the four years (for import and export), the procedures developed by Mangioni et al. (2018) have been implemented with Python.

The information loss values have been calculated for centesimal values of the relax rate, with number of trials equal to 1000, 1500 and 3000, using the following command to run Infomap:

```
for rate in 1E-6 $(seq -w 0.01 0.01 $max); do
 printf "Running for relax rate %.2f ...\r" "$rate"
 # Generate the .map file for the alluvial plot generator each .2
 increment
 case $rate in
  1E-6|0.20|0.40|0.60|0.80|1.00)
   map="--map"
   ;;
  *)
   map=""
   ;;
 esac
 infomap/Infomap --multiplex-relax-rate "$rate" \
  --include-self-links --num-trials 1000 --seed 1234 --two-level –d \
  --input-format multiplex --out-name "relax$rate" --expanded --clu "$map" \
  --silent "$@" "$network_data" "$dest"
 printf "Running for relax rate %.2f ... DONE\n" "$rate"
done
```

Figure A3 – Export and Import – Normalized Information Loss

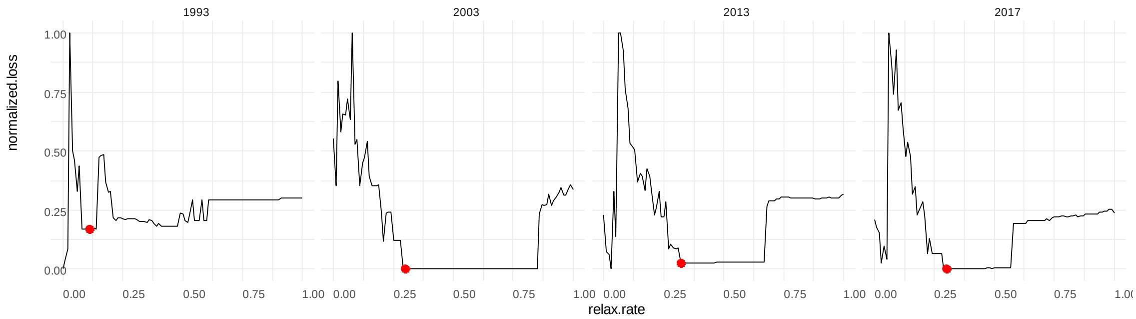


Table A10 – Optimal relax rate for import export share trade flows

year	Optimal relax.rate	Number of modules
1993	0.11	37
2003	0.30	16
2013	0.32	16
2017	0.30	17

Annex 5 - Infomap output files under analysis to study the flow between clusters

For each state-node, we integrate the following Infomap output file .flow, containing enter flow and exit flow from each state-node

```
# flow in network with 2446 memory nodes (from-to) and 4264276 links
(1 1) (flow: 0.000281759, enter: 0.000281759, exit: 0.000300978)
 --> (1 3) (8.02382e-06)
 --> (1 4) (1.54992e-07)
 --> (1 5) (3.57703e-06)
 --> (1 8) (9.2298e-08)
...
 <-- (1 3) (3.16565e-08)
 <-- (1 5) (3.78119e-09)
 <-- (1 6) (8.53595e-08)
```

...

with:

- cluster of the origin state-node and cluster of destination state-node;
- shares of export and import for each state-node pair;
- the flow type: within if the flow is inside the same cluster (cluster.from=cluster.to), between if the flow is between different clusters.

cluster.from	cluster.to	country.from	country.to	SITC.from	SITC.to	trade_flow.from	trade_flow.to	flow.type	flowIN	flowOUT	share_Exp	share_Imp
2	2	ARE	AUS	6251	6251	Export	Export	within	3.17E-08	8.02E-06	4.37E-04	6.31E-07
2	1	ARE	AUT	6251	6251	Export	Export	between		1.55E-07	8.43E-06	
2	1	ARE	BEL	6251	6251	Export	Export	between	3.78E-09	3.58E-06	1.95E-04	7.49E-07
2	3	ARE	CAN	6251	6251	Export	Export	between	2.58E-06	9.23E-08	5.02E-06	3.36E-04
2	1	ARE	CHE	6251	6251	Export	Export	between		7.51E-08	4.08E-06	
2	1	ARE	DEU	6251	6251	Export	Export	between	1.74E-05	2.01E-06	1.09E-04	4.83E-03

...

Data is in csv files: flowIE1993.csv, flowIE2003.csv, flowIE2013.csv and flowIE2017.csv.

Year	n. records
1993	3601034
2003	4922170
2013	5195240
2017	5172892

Annex 6 - Infomap flow, by meso-level, state node and country, by year

Table A11 – Cumulative Infomap flow for the top 10 clusters, by year

cluster	1993	2003	2013	2017
1	0.533048	0.544083	0.500620	0.513119
2	0.902337	0.789892	0.740408	0.747934
3	0.929383	0.964174	0.934148	0.952513
4	0.953401	0.983507	0.973042	0.979670
5	0.963814	0.999952	0.999590	0.999715
6	0.974028	0.999988	0.999923	0.999887
7	0.983266	0.999996	0.999975	0.999967
8	0.991939	0.999998	0.999991	0.999991
9	0.998700	0.999999	0.999994	0.999994
10	0.999592	0.999999	0.999997	0.999996

❁ **Figure A4 – Names of clusters and countries by cluster**

Names of clusters (Country | layer) are listed in decreasing value of Infomap flow; countries with flow greater than zero are listed in alphabetic order.

Clusters "names", years: 1993-2017

"name": "Country | layer" with the highest Infomap flow in the cluster

	year			
cl..	1993	2003	2013	2017
1	DEU | 78439_imp	DEU | 78439_imp	DEU | 78439_imp	DEU | 78439_imp
2	USA | 78439_exp	USA | 78439_exp	CHN | 78439_imp	CHN | 78439_imp
3	CHN | 78421_exp	JPN | 78439_imp	USA | 78439_exp	USA | 78439_exp
4	BRA | 76212_imp	UKR | 78421_exp	RUS | 78439_exp	RUS | 78439_exp
5	JPN | 71321_imp	BRA | 78439_imp	BRA | 78439_exp	BRA | 78439_exp
6	CZE | 78435_exp	ZAF | 78421_exp	PHL | 78436_exp	PHL | 78436_exp
7	KOR | 62591_imp	BRA | 78421_exp	RUS | 69961_imp	ZAF | 78421_exp
8	CHN | 69961_imp	IND | 82112_imp	RUS | 62592_imp	RUS | 76212_imp
9	SGP | 69961_exp	ZAF | 77823_imp	BRA | 77823_imp	UKR | 76211_exp
10	IDN | 77833_exp	TUR | 62592_exp	CHE | 76211_imp	ZAF | 69915_imp
11	TUR | 78421_exp	DNK | 71321_imp	IRL | 71322_imp	ARE | 78425_imp
12	IND | 76212_exp	ARG | 62593_imp	SWE | 71321_imp	CHE | 62591_imp
13	SGP | 82112_imp	ROU | 76212_imp	UKR | 78431_imp	SVN | 76211_imp
14	RUS | 76212_imp	ARE | 62591_exp	ARE | 78425_imp	IRL | 71321_exp
15	ARE | 76211_imp	ARE | 71322_exp	ARG | 62592_exp	ARG | 77823_imp
16	AUS | 7841_imp	ARE | 78425_exp	BRA | 62592_exp	BLR | 78421_imp
17	SVK | 76212_imp			UKR | 71321_imp
18	CHN | 62551_exp			
19	FIN | 76212_imp			
20	IND | 76211_exp			
21	ARG | 62593_imp			
22	IDN | 82112_imp			
23	TUR | 76211_imp			
24	THA | 62551_exp			
25	IRL | 71323_imp			
26	SVK | 76211_imp			
27	ARE | 82112_imp			
28	SVN | 76211_imp			
29	RUS | 6251_exp			
30	ZAF | 62551_exp			
31	BLR | 62559_exp			
32	RUS | 62559_exp			
33	ZAF | 62592_exp			
34	ARE | 76212_exp			
35	ARE | 77831_exp			
36	BLR | 77834_exp			
37	RUS | 78433_exp			

Countries by cluster

(filtered by flow IN > 0)

clust..	1993
1	ARE AUT BEL BLR CHE CZE DEU DNK ESP FIN FRA GBR ···
2	ARE AUS CAN CHN HKG IDN IND IRL JPN KOR MEX ···
3	ARE AUS CHN HKG HUN IDN IND JPN KOR MYS PHL ···
4	ARG BRA
5	ARG AUS AUT BEL BRA CAN CHE CHN CZE DEU DNK ···
6	BLR CZE IND IRL POL ROU SVK SVN
7	ARE ARG AUS AUT BEL BRA CAN CHE CHN DEU DNK ···
8	ARE ARG AUS AUT BEL BRA CAN CHE CHN CZE DEU ···
9	ARE AUS AUT BEL BRA CHE CHN CZE DEU DNK ESP ···
10	IDN PHL THA
11	ROU TUR
12	IND SVN

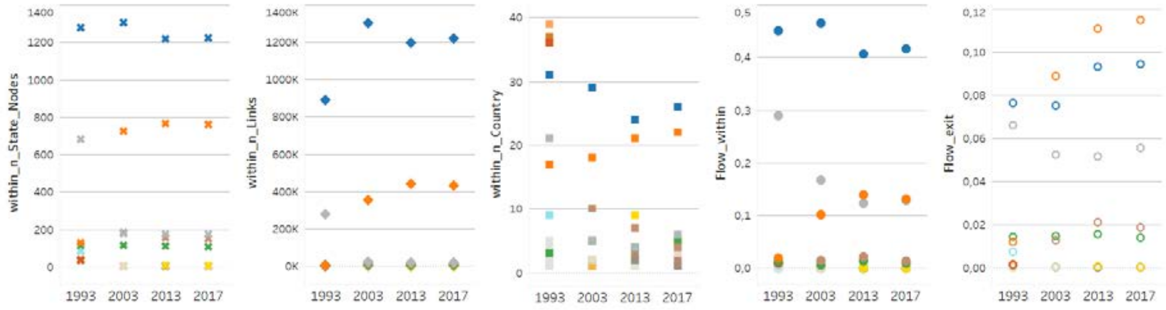
clust..	2003
1	AUS AUT BEL BRA CHE CZE DEU DNK ESP FIN ···
2	ARG CAN HKG MEX USA
3	ARE ARG AUS CHN HKG IDN IND IRL JPN KOR ···
4	BLR CZE IND KOR POL ROU RUS SVK TUR UKR
5	ARG BRA MEX TUR ZAF
6	ZAF
7	ARG BRA
8	IND
9	ZAF
10	TUR
11	DNK
12	ARG

clust..	2013
1	ARE AUT BEL CHE CZE DEU DNK ESP FIN FRA GBR ···
2	ARE ARG AUS BLR BRA CHN HKG HUN IDN IND JPN ···
3	CAN MEX USA
4	BLR CZE KOR POL RUS TUR UKR
5	ARG BRA KOR ZAF
6	PHL
7	BLR RUS UKR
8	BLR RUS
9	ARG BRA
10	CHE FIN
11	IRL
12	SWE

clust..	2017
1	ARE ARG AUT BEL CHE CZE DEU DNK ESP FIN ···
2	ARE ARG AUS BLR BRA CHN HKG HUN IDN ···
3	CAN FIN MEX USA
4	BLR KOR RUS UKR
5	ARG BRA KOR MEX ZAF
6	PHL
7	CAN HKG ZAF
8	BLR RUS
9	UKR
10	ZAF
11	ARE
12	CHE

Figure A5 - Clusters statistics: number of state-nodes, links and countries; flow within and exit flow

Only the first nine clusters are included in the graphs



Legenda: clusters by year are identified by the name: "country | SITC code"

1993_1_DEU | 78439_imp	2003_1_DEU | 78439_imp	2013_1_DEU | 78439_imp	2017_1_DEU | 78439_imp
1993_2_USA | 78439_exp	2003_2_USA | 78439_exp	2013_2_CHN | 78439_imp	2017_2_CHN | 78439_imp
1993_3_CHN | 78421_exp	2003_3_JPN | 78439_imp	2013_3_USA | 78439_exp	2017_3_USA | 78439_exp
1993_4_BRA | 76212_imp	2003_4_UKR | 78421_exp	2013_4_RUS | 78439_exp	2017_4_RUS | 78439_exp
1993_5_JPN | 71321_imp	2003_5_BRA | 78439_imp	2013_5_BRA | 78439_exp	2017_5_BRA | 78439_exp
1993_6_CZE | 78435_exp	2003_6_ZAF | 78421_exp	2013_6_PHL | 78436_exp	2017_6_PHL | 78436_exp
1993_7_KOR | 62591_imp	2003_7_BRA | 78421_exp	2013_7_RUS | 69961_imp	2017_7_ZAF | 78421_exp
1993_8_CHN | 69961_imp	2003_8_IND | 82112_imp	2013_8_RUS | 62592_imp	2017_8_RUS | 76212_imp
1993_9_SGP | 69961_exp	2003_9_ZAF | 77823_imp	2013_9_BRA | 77823_imp	2017_9_UKR | 76211_exp

We compare the characteristics of the clusters in the four years, in an overall time span of 25 years, by focusing on four main statistics: the number of state -nodes (i.e., the projections of each country in the trade networks of import and export for each SITC code, that are the layers in the multilayer model), the number of links and of countries; the connections generated by trades within the cluster (measured by the Infomap "flow within") and the connections of each cluster to all the other clusters (measured by the "exit flow"). These statistics are presented in Figure 6 with regard to the first nine clusters (colours represent the various clusters). The legend - with colours and names of the clusters by year - makes clear which is the leading country, i.e. the one having the highest Infomap flow in a layer (with the smallest clusters, starting from the 6th, having a different leading country characterized by a specific trade in each of the four years).

The large (only slightly declining) number of links and state nodes in the Germany-led cluster denotes the variety of export and import trades characterising this cluster. Both links and state node increase in the China-and-Japan-led cluster, while the US-led cluster has a lower number of state nodes, there being fewer countries in the cluster.

Focusing on the number of countries per cluster, in 1993 the three very small clusters 5, 7 and 8 involved trades with 35-40 countries. Since 2003, small clusters have involved a lower number of countries, which can be put down to the more focused specialisation in trade of smaller clusters and the growing importance of the largest clusters – led by Germany and by China (respectively, cluster 1 and cluster 2) - in terms of numbers of embedded countries.

Figure A6 – Infomap flow within and between clusters, by cluster and year. Top seven clusters

In each year, the total Infomap flow is equal to 1. Clusters are ranked by their total Infomap flow in each year

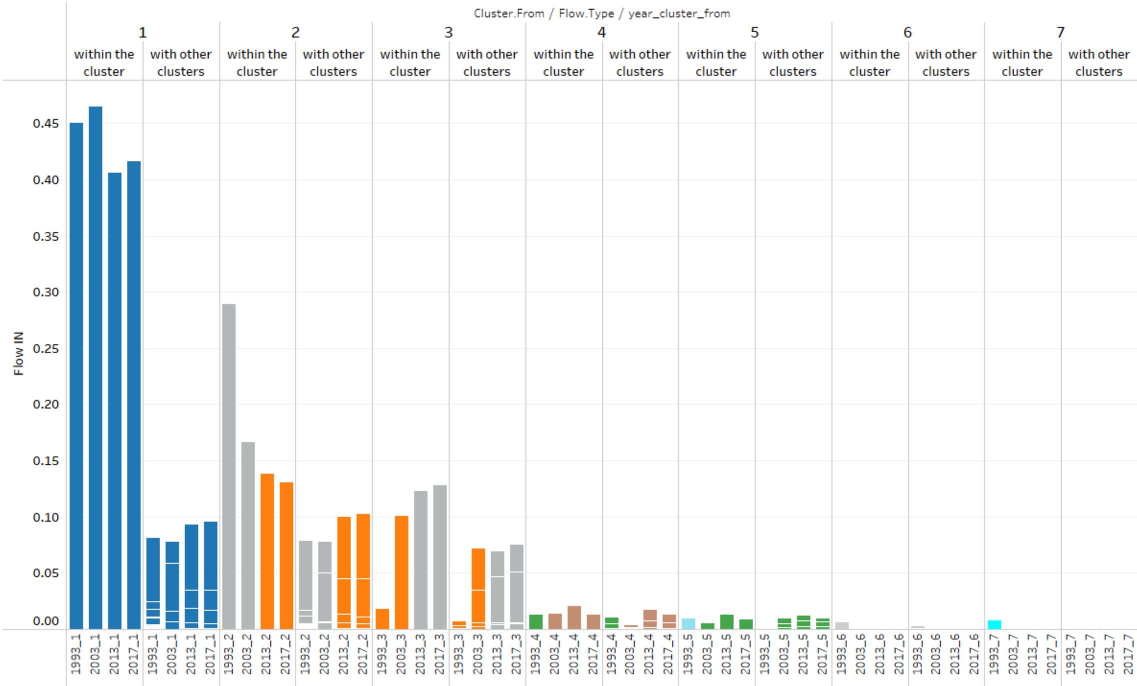


Figure A7 – Infomap flow within and between clusters, by country and year

In each year, the total Infomap flow is equal to 1. Countries are ranked by their Infomap flow in 1993

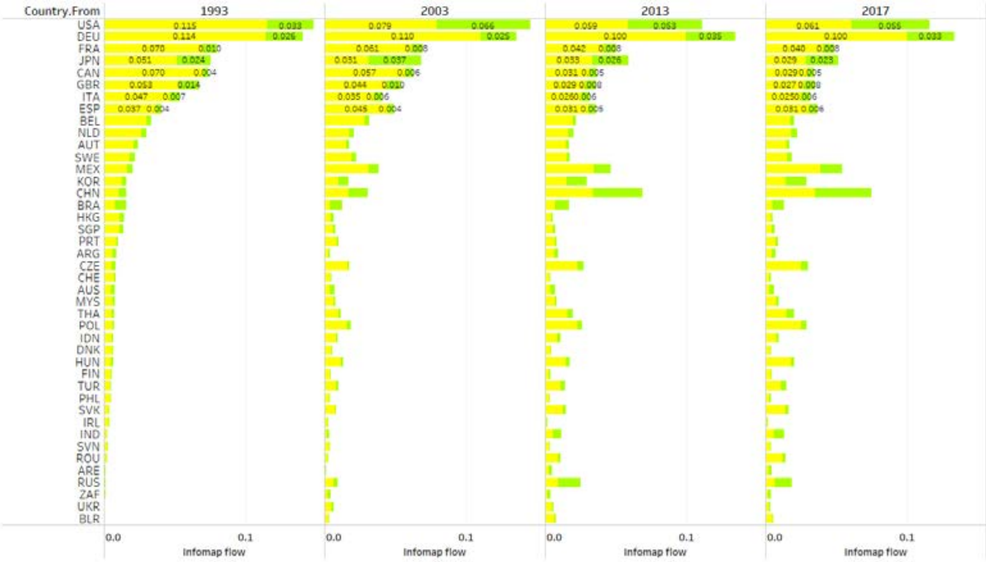
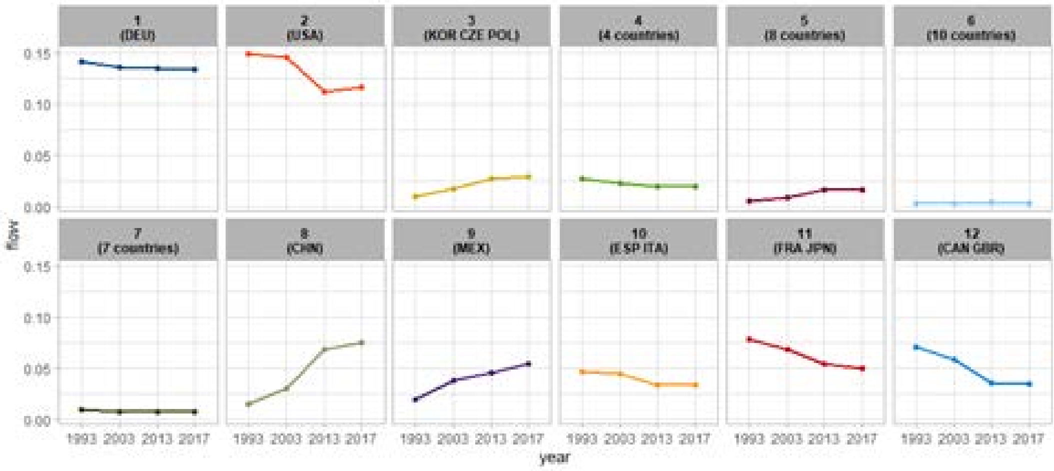


Figure A8 – Dynamics of change in the contribution of countries in determining the meso-level entities over the years

(a) Clusters of countries' Infomap flow in the four years



(b) Clusters of countries' trade shares in the four years

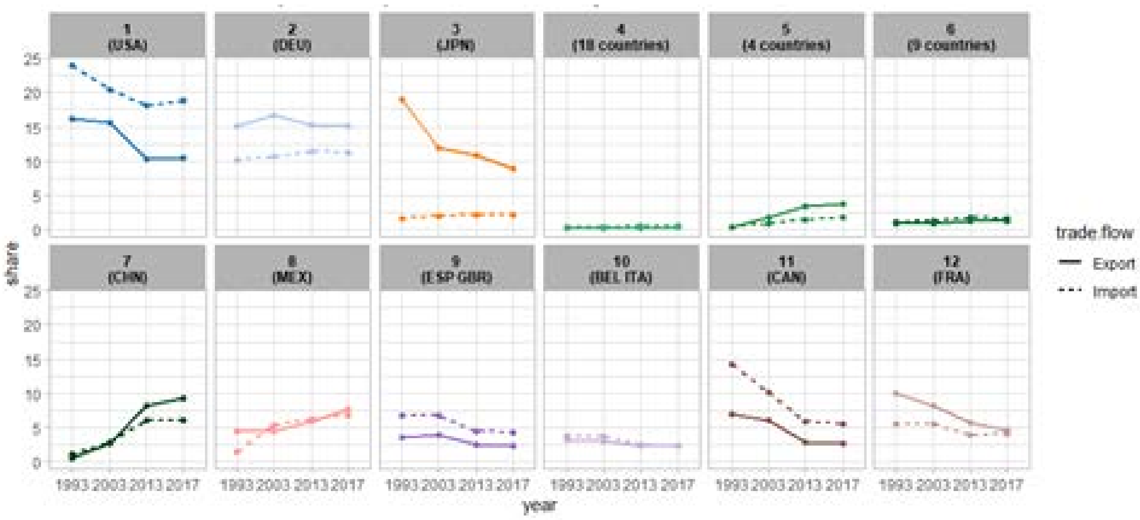


Figure A9 – Infomap flow by cluster, country and layer

Figures refer to Infomap flow IN
Panel (a): Infomap flow by year and cluster.
All the other panels, Infomap flow percentage by year and by cluster, respectively,
Panel (b): by country, panel (c): by SITC code; panel (d): by trade flow.

(a)

(b)

(c)

(d)

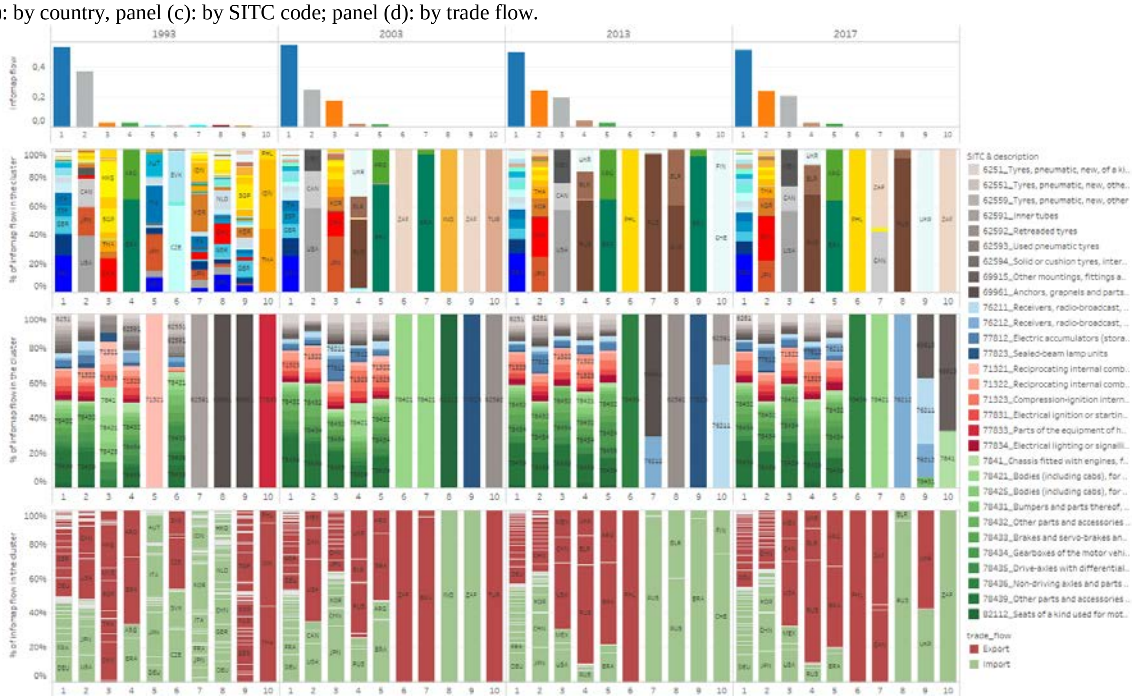


Figure A9 shows that, while in 1993 clusters were characterised by an array of countries and components, since 2003, only the biggest three clusters have been characterised by a variety of countries and a mix of all automotive components and parts, while the smaller clusters comprise only a few countries mainly or solely exporting or importing a few components and parts.

Focusing on the Infomap flow by country (panel b), we observe that while in 1993 there was a significant presence of the main countries in more than one cluster, this feature was no longer significant in the following years, when more distinct clusters appeared. On looking at the Infomap flow generated by export and by import, by cluster and by country (panel d), we are able to single out the different emergent characteristic of clusters over the years.

In 1993, the two top clusters, US & Japan-led and the Germany-led clusters, were more balanced on export and import of a variety of bilateral trades; the Brazil-led cluster (cl-4) had a relatively greater importance for the world exporting countries, while for the Czech-led cluster (cl-6) the opposite held true. The smaller clusters were either exporters or importers in a few specific trades. Since 2003, the Germany-led has been balanced between export and import; the China&Japan-led cluster was more important as an exporter, the US-led cluster as an importer.

Annex 7 - Top six clusters, by year

Table A12 - Percentage of Infomap flow and of trade shares generated within and between clusters by year, in the top six clusters

Infomap flow

	1993			2003			2013			2017		
Cluster	**within**	**between**	**Total**	**within**	**between**	**Total**	**within**	**between**	**Total**	**within**	**between**	**Total**
1			53.3			54.4			50.1			51.3
2			36.9			24.6			24.0			23.5
3			2.7			17.4			19.4			20.5
2+3			39.6			42.0			43.4			43.9
4			2.4			1.9			3.9			2.7
5			1.0			1.6			2.7			2.0
6			1.0			0.0			0.0			0.0
Total			97.4			100.0			100.0			100.0

Tade shares

	1993			2003			2013			2017		
Cluster	**within**	**between**	**Total**	**within**	**between**	**Total**	**within**	**between**	**Total**	**within**	**between**	**Total**
1	40.6	7.0	47.6	45.3	7.8	53.1	38.1	12.0	50.1	39.0	10.8	49.9
2	41.1	7.7	48.8	23.1	3.1	26.2	11.2	17.8	29.0	10.3	17.7	28.0
3	1.0	0.4	1.5	6.5	12.6	19.1	16.3	2.8	19.1	17.3	3.5	20.8
2+3			50.3			45.3			48.1			48.8
4	0.8	0.9	1.7	0.3	0.0	0.3	0.3	0.2	0.5	0.3	0.2	0.5
5				0.3	1.0	1.3	0.8	0.5	1.3	0.4	0.4	0.8
6	0.1	0.2	0.3	0.0	0.0	0.0	0.0		0.0	0.0		0.0
Total	83.6	16.3	99.9	75.5	24.5	100.0	66.7	33.3	100.0	67.4	32.6	100.0

Table A13 - Percentage of export shares between the top six clusters, by year

For each year, clusters are embracing bilateral trades of specific pairs of country-SITC codes

1993

Cluster.From	Cluster.To					
	1	**2**	**3**	**4**	**5**	**6**
1	80.85	11.98	0.27	1.45	0.00	0.24
2	13.54	83.40	0.74	0.62		0.02
3	0.36	0.07	1.02	0.01		0.00
4	0.57	1.27	0.02	1.53		0.00
5					0.78	
6	0.33	0.03	0.01	0.00	0.00	0.25

2003

Cluster.From	Cluster.To					
	1	2	3	4	5	6
1	90.66	8.60	5.27	0.63	1.16	0.00
2	3.05	46.12	2.74	0.04	0.36	0.00
3	8.47	15.93	13.10	0.28	0.42	0.00
4	0.08	0.00	0.01	0.47	0.00	0.00
5	0.64	1.21	0.20	0.00	0.53	
6	0.00	0.00	0.00			0.00

2013

Cluster.From	Cluster.To					
	1	**2**	**3**	**4**	**5**	**6**
1	76.30	10.26	7.80	3.92	2.02	
2	10.31	22.44	19.42	3.71	2.15	
3	1.91	2.70	32.60	0.43	0.55	
4	0.24	0.03	0.04	0.59	0.01	
5	0.23	0.16	0.59	0.03	1.54	
6						0.00

2017

Cluster.From	Cluster.To					
	1	**2**	**3**	**4**	**5**	**6**
1	[redacted]	9.86	7.85	2.70	1.27	
2	11.80	[redacted]	19.43	2.66	1.57	
3	2.63	3.34	[redacted]	0.35	0.69	
4	0.29	0.02	0.04	[redacted]	0.00	
5	0.22	0.10	0.46	0.01	[redacted]	
6						[redacted]

Table A14 – Share of export by country and cluster, by year

Legend: "0.0" indicates percentage shares below 0.5%. Countries are ranked according to their total export share in world trade in 1993

year / Cluster.From

1993

Co..	1	2	3	4	6	9	10	11	12	13	18	20	24	29	30	31	32	33	34	35	36	37	T..
JPN		17.7	1.3			0.0																	19.0
USA		16.2																					16.2
DEU	15.1					0.0																	15.1
FRA	9.9					0.0																	9.9
CAN		7.0																					7.0
MEX		4.4																					4.4
ITA	4.3					0.0																	4.3
GBR	3.9					0.0																	3.9
ESP	3.2					0.0																	3.2
AUT	2.4					0.0																	2.4
SWE	2.4					0.0																	2.4
BEL	2.2					0.0																	2.2
NLD	1.5					0.0																	1.5
BRA				1.4		0.0																	1.4
KOR		1.1	0.0			0.0						0.0											1.1
PRT	0.8					0.0																	0.8
CHN		0.6	0.0			0.0					0.0												0.7
MYS		0.4	0.0			0.0																	0.4
SGP		0.4	0.0			0.0																	0.4
CHE	0.4					0.0																	0.4
ARG				0.3																			0.3
AUS		0.3	0.0			0.0																	0.3
DNK	0.3					0.0																	0.3
IRL	0.2	0.0			0.0	0.0																	0.2
HUN	0.2		0.0			0.0																	0.2
CZE	0.1				0.2	0.0																	0.2
HKG		0.2	0.0			0.0																	0.2
FIN	0.2					0.0																	0.2
PHL	0.0	0.1	0.0			0.0	0.0																0.2
THA		0.1	0.0			0.0	0.0						0.0										0.2
IDN	0.1	0.1	0.0			0.0	0.0																0.2
SVN	0.1				0.0	0.0			0.0														0.1
SVK	0.0				0.1	0.0																	0.1
TUR	0.1					0.0		0.0															0.1
POL	0.1				0.0	0.0																	0.1
ZAF	0.1	0.0	0.0	0.0		0.0									0.0			0.0					0.1
IND	0.0	0.1	0.0			0.0				0.0		0.0											0.1
RUS	0.0		0.0			0.0								0.0			0.0					0.0	0.1
ROU	0.0		0.0			0.0		0.0															0.0
ARE	0.0	0.0	0.0			0.0						0.0							0.0	0.0			0.0
BLR	0.0				0.0											0.0					0.0		0.0
UKR	0.0	0.0	0.0		0.0																		0.0

2003

Co..	1	2	3	4	5	6	7	10	14	15	16	T..
JPN			11.9									11.9
USA		15.6										15.6
DEU	16.6											16.6
FRA	8.3											8.3
CAN		6.1										6.1
MEX		4.4										4.4
ITA	4.1											4.1
GBR	4.0											4.0
ESP	3.9											3.9
AUT	1.7											1.7
SWE	2.3											2.3
BEL	1.9											1.9
NLD	1.3											1.3
BRA					1.1		0.0					1.1
KOR			1.7	0.0								1.8
PRT	0.9											0.9
CHN			2.7									2.7
MYS			0.4									0.4
SGP			0.2									0.2
CHE	0.4											0.4
ARG	0.0	0.0			0.2		0.0					0.2
AUS			0.2									0.2
DNK	0.2											0.2
IRL	0.1											0.1
HUN	2.0											2.0
CZE	1.7			0.0								1.7
HKG		0.0	0.1									0.1
FIN	0.2											0.2
PHL			0.3									0.3
THA			0.7									0.7
IDN			0.5									0.5
SVN	0.2											0.2
SVK	0.5			0.0								0.5
TUR	0.5			0.0				0.0				0.5
POL	1.8			0.0								1.8
ZAF	0.3		0.0			0.0						0.3
IND			0.2	0.0								0.2
RUS				0.2								0.2
ROU	0.2			0.0								0.2
ARE	0.0		0.0			0.0			0.0	0.0	0.0	0.0
BLR				0.0								0.0
UKR	0.0			0.1								0.1

2013

Co..	1	2	3	4	5	6	15	16	T..
JPN		10.9				0.0			10.9
USA			10.2			0.0			10.2
DEU	15.2					0.0			15.2
FRA	5.6					0.0			5.6
CAN			2.9						2.9
MEX			6.0						6.0
ITA	3.4								3.4
GBR	2.3								2.3
ESP	3.0								3.0
AUT	2.0								2.0
SWE	1.8								1.8
BEL	1.4								1.4
NLD	1.2								1.2
BRA					1.0			0.0	1.0
KOR		5.2		0.0	0.0	0.0			5.3
PRT	0.8								0.8
CHN		8.3				0.0			8.3
MYS		0.4				0.0			0.4
SGP		0.2				0.0			0.2
CHE	0.3								0.3
ARG			0.0		0.3		0.0		0.3
AUS		0.1							0.1
DNK	0.2								0.2
IRL	0.1								0.1
HUN	2.3								2.3
CZE	3.1			0.0					3.1
HKG		0.1							0.1
FIN	0.1								0.1
PHL		0.3							0.3
THA		1.9							1.9
IDN		0.7							0.7
SVN	0.4								0.4
SVK	1.8								1.8
TUR	1.1			0.0					1.1
POL	3.1			0.0					3.2
ZAF	0.0	0.2							0.2
IND		0.9							0.9
RUS				0.2					0.2
ROU	1.1								1.1
ARE		0.0							0.0
BLR				0.1					0.1
UKR	0.0	0.0		0.1					0.1

2017

Co..	1	2	3	4	5	6	7	9	14	T..
JPN		8.8				0.0				8.8
USA			10.4							10.4
DEU	15.1									15.1
FRA	4.7									4.7
CAN			2.7				0.0			2.7
MEX			7.7							7.7
ITA	3.3									3.3
GBR	2.0									2.0
ESP	2.8									2.8
AUT	2.0									2.0
SWE	1.8									1.8
BEL	1.3									1.3
NLD	1.2									1.2
BRA			0.0		0.6					0.6
KOR		5.0		0.1	0.0					5.2
PRT	0.8									0.8
CHN		9.2				0.0				9.2
MYS		0.4								0.4
SGP		0.2				0.0				0.2
CHE	0.3									0.3
ARG	0.0		0.0		0.2					0.2
AUS		0.1								0.1
DNK	0.2									0.2
IRL	0.1								0.0	0.1
HUN	2.6	0.0								2.6
CZE	3.5									3.5
HKG		0.1				0.0	0.0			0.1
FIN	0.1									0.1
PHL	0.0	0.3								0.3
THA		2.0								2.0
IDN		0.6								0.6
SVN	0.4									0.4
SVK	1.8									1.8
TUR	1.1									1.1
POL	3.5									3.5
ZAF		0.1					0.0			0.1
IND		1.0								1.0
RUS				0.2						0.2
ROU	1.4									1.4
ARE	0.0	0.1								0.1
BLR				0.1						0.1
UKR	0.0			0.0				0.0		0.0

Table A15 – Share of import by country and cluster, by year

Legend: "0.0" indicates percentage shares below 0.5%. Countries are ranked according to their total export share in world trade in 1993

year / Cluster.From

1993

Co..	1	2	4	5	6	7	8	13	14	15	16	17	19	21	22	23	25	26	27	28	
USA		23.5		0.3		0.0	0.0														23.9
CAN		13.8		0.0		0.0	0.0														13.8
DEU	10.1			0.0		0.0	0.0														10.2
GBR	8.1			0.0		0.0	0.0														8.1
FRA	5.5			0.0		0.0	0.0														5.6
ESP	5.3			0.1		0.0	0.0														5.4
BEL	4.5			0.0		0.0	0.0														4.5
ITA	3.0			0.0		0.0	0.0														3.1
NLD	2.4			0.0		0.0	0.0														2.5
SWE	1.7			0.0		0.0	0.0														1.7
AUT	1.6			0.0		0.0	0.0														1.6
JPN		1.6		0.0		0.0	0.0														1.6
MEX		1.3		0.0		0.0	0.0														1.3
AUS		1.2		0.0		0.0	0.0				0.0										1.2
THA		1.0		0.0		0.0	0.0														1.0
KOR		1.0		0.0		0.0	0.0														1.0
PRT	1.0	0.0		0.0		0.0	0.0														1.0
SGP	0.0	0.9		0.0		0.0	0.0	0.0													0.9
HKG	0.0	0.9		0.0		0.0	0.0	0.0													0.9
BRA			0.9	0.0		0.0	0.0														0.9
IDN		0.9		0.0		0.0	0.0								0.0						0.9
CHN		0.8		0.1		0.0	0.0														0.8
ARG			0.8	0.0		0.0	0.0							0.0							0.8
CHE	0.8			0.0		0.0	0.0														0.8
TUR	0.6	0.0		0.0		0.0	0.0									0.0					0.6
FIN	0.6			0.0		0.0	0.0						0.0								0.6
DNK	0.5			0.0		0.0	0.0														0.5
POL	0.3	0.0		0.0	0.0	0.0	0.0					0.0									0.3
MYS		0.2		0.0		0.0	0.0	0.0			0.0										0.3
SVN	0.2			0.0		0.0	0.0					0.0								0.0	0.2
IRL	0.2	0.0		0.0		0.0	0.0										0.0				0.2
CZE	0.0			0.0	0.2		0.0					0.0									0.2
HUN	0.2			0.0		0.0	0.0														0.2
PHL		0.1				0.0	0.0														0.1
IND	0.0	0.1		0.0	0.0	0.0	0.0	0.0		0.0											0.1
SVK	0.0				0.1		0.0					0.0						0.0			0.1
ROU	0.0				0.0	0.0	0.0		0.0	0.0											0.0
ARE	0.0	0.0				0.0	0.0			0.0											0.0
ZAF																					
UKR																					
RUS																					
BLR																					

2003

Co..	1	2	3	4	5	8	9	11	12	13	T..
USA		20.4									20.4
CAN		10.1									10.1
DEU	10.6										10.6
GBR	6.8										6.8
FRA	5.5										5.5
ESP	6.7										6.7
BEL	4.9										4.9
ITA	2.7										2.7
NLD	2.0										2.0
SWE	1.8										1.8
AUT	1.8										1.8
JPN			1.9								1.9
MEX		5.3	0.0		0.0						5.3
AUS	0.0		0.9								0.9
THA			1.0								1.0
KOR			1.0								1.0
PRT	1.0										1.0
SGP			0.7								0.7
HKG	0.0		0.7								0.7
BRA	0.0				0.9						0.9
IDN			0.5								0.5
CHN			2.9								2.9
ARG			0.0		0.3						0.3
CHE	0.5										0.5
TUR	1.1				0.0						1.1
FIN	0.4										0.4
DNK	0.4							0.0			0.4
POL	1.0										1.0
MYS			0.4								0.4
SVN	0.3										0.3
IRL	0.2		0.0								0.2
CZE	1.2										1.2
HUN	0.7										0.7
PHL			0.2								0.2
IND	0.0		0.2			0.0					0.2
SVK	0.9										0.9
ROU	0.1		0.0							0.0	0.1
ARE			0.0								0.0
ZAF	0.3		0.0		0.0		0.0				0.3
UKR	0.0		0.0	0.1							0.1
RUS				0.3							0.3
BLR				0.0							0.0

2013

Co..	1	2	3	4	5	7	8	9	10	11	12	13	14	T..
USA			18.1											18.1
CAN			5.8											5.8
DEU	11.3													11.3
GBR	4.6													4.6
FRA	3.9													3.9
ESP	4.3													4.3
BEL	2.9													2.9
ITA	2.0													2.0
NLD	1.8													1.8
SWE	1.3										0.0			1.3
AUT	1.3													1.3
JPN		2.2												2.2
MEX		0.0	6.1											6.1
AUS		1.1												1.1
THA		1.8												1.8
KOR		1.1												1.1
PRT	0.7													0.7
SGP		0.6												0.6
HKG		0.6												0.6
BRA		0.0			2.0			0.0						2.1
IDN		0.9												0.9
CHN		6.1												6.1
ARG		0.0			1.0			0.0						1.0
CHE	0.4								0.0					0.4
TUR	1.6	0.0												1.6
FIN	0.3								0.0					0.3
DNK	0.3													0.3
POL	1.6													1.6
MYS		0.7												0.7
SVN	0.2													0.2
IRL	0.1									0.0				0.1
CZE	2.2													2.2
HUN	1.2	0.0												1.2
PHL		0.1												0.1
IND		1.1												1.1
SVK	1.6													1.6
ROU	0.7													0.7
ARE	0.0	0.9											0.0	0.9
ZAF	0.0	0.4			0.0									0.4
UKR	0.0	0.0		0.1		0.0						0.0		0.2
RUS		0.0		3.6		0.0	0.0							3.6
BLR		0.0		0.1		0.0	0.0							0.1

2017

Co..	1	2	3	4	5	8	9	10	11	12	13	15	16	17	T..
USA			18.9												18.9
CAN			5.5												5.5
DEU	11.3														11.3
GBR	4.3														4.3
FRA	4.1														4.1
ESP	4.3														4.3
BEL	2.2														2.2
ITA	2.3														2.3
NLD	2.2														2.2
SWE	1.4														1.4
AUT	1.3														1.3
JPN		2.2													2.2
MEX		0.0	6.7		0.0										6.7
AUS		0.8													0.8
THA		1.5													1.5
KOR		1.2													1.2
PRT	0.7														0.7
SGP		0.4													0.4
HKG		0.6													0.6
BRA		0.0			1.4										1.4
IDN		0.8													0.8
CHN		6.1													6.1
ARG		0.0			0.7							0.0			0.7
CHE	0.4									0.0					0.4
TUR	1.8														1.8
FIN	0.5		0.0												0.5
DNK	0.3														0.3
POL	2.0														2.0
MYS		0.7													0.7
SVN	0.3										0.0				0.3
IRL	0.1	0.0													0.1
CZE	2.6														2.6
HUN	1.5														1.5
PHL		0.1													0.1
IND		1.2													1.2
SVK	1.9	0.0													1.9
ROU	0.8														0.8
ARE		0.6							0.0						0.6
ZAF	0.0	0.4			0.0			0.0							0.4
UKR	0.0	0.0		0.1			0.0							0.0	0.1
RUS		0.0		2.5		0.0									2.5
BLR		0.0		0.1		0.0							0.0		0.1

Table A16 – Germany-led cluster: overall export shares and composition by group of countries, by year, and by orientation of export

		year / Flow.Type											
		1993			2003			2013			2017		
country_ from_ clust_DEU..	country_ from_ clust_DE..	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total
DEU	DEU	12.3	2.9	15.1	12.6	4.0	16.6	9.4	5.8	15.2	10.0	5.2	15.1
	Total	12.3	2.9	15.1	12.6	4.0	16.6	9.4	5.8	15.2	10.0	5.2	15.1
Western countries	ESP	2.8	0.3	3.2	3.5	0.4	3.9	2.3	0.6	3.0	2.3	0.5	2.8
	FRA	8.7	1.2	9.9	7.4	0.9	8.3	4.7	1.0	5.6	4.0	0.7	4.7
	GBR	3.2	0.7	3.9	3.3	0.6	4.0	1.7	0.5	2.3	1.4	0.5	2.0
	ITA	3.5	0.8	4.3	3.5	0.6	4.1	2.6	0.7	3.4	2.6	0.7	3.3
	Total	18.2	3.1	21.3	17.7	2.5	20.2	11.4	2.9	14.2	10.3	2.4	12.7
CEE countries	CZE	0.0	0.0	0.1	1.6	0.1	1.7	2.7	0.4	3.1	3.0	0.5	3.5
	HUN	0.2	0.1	0.2	1.9	0.1	2.0	2.0	0.3	2.3	2.2	0.4	2.6
	POL	0.1	0.0	0.1	1.7	0.1	1.8	2.8	0.4	3.1	3.2	0.3	3.5
	SVK	0.0	0.0	0.0	0.5	0.0	0.5	1.4	0.4	1.8	1.5	0.3	1.8
	Total	0.4	0.1	0.5	5.8	0.3	6.1	8.8	1.5	10.3	9.8	1.6	11.4
Others	Others	9.7	1.0	10.7	9.3	1.0	10.2	8.6	1.8	10.4	9.0	1.6	10.6
	Total	9.7	1.0	10.7	9.3	1.0	10.2	8.6	1.8	10.4	9.0	1.6	10.6
Grand Total		40.6	7.0	47.6	45.3	7.8	53.1	38.1	12.0	50.1	39.0	10.8	49.9

Table A17 – Germany-led cluster: overall import shares and composition by group of countries, by year, and by orientation of export

		year / Flow.Type											
		1993			2003			2013			2017		
country_ from_ clust_DEU..	country_ from_ clust_DE..	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total	within the cluster	with other clusters	Total
DEU	DEU	8.3	1.9	10.2	9.5	1.1	10.6	9.9	1.4	11.3	9.5	1.7	11.3
	Total	8.3	1.9	10.2	9.5	1.1	10.6	9.9	1.4	11.3	9.5	1.7	11.3
Western countries	ESP	4.9	0.5	5.4	6.4	0.3	6.8	4.1	0.3	4.4	3.9	0.5	4.3
	FRA	4.8	0.7	5.5	4.9	0.6	5.5	3.3	0.6	3.9	3.4	0.7	4.1
	GBR	6.6	1.6	8.1	5.4	1.4	6.8	3.6	1.0	4.6	3.4	0.9	4.3
	ITA	2.8	0.3	3.1	2.4	0.3	2.8	1.7	0.4	2.0	1.9	0.5	2.3
	Total	19.1	3.0	22.2	19.2	2.7	21.9	12.7	2.2	14.9	12.6	2.5	15.1
CEE countries	CZE	0.0	0.0	0.0	1.1	0.1	1.2	1.8	0.4	2.2	2.2	0.4	2.6
	HUN	0.2	0.0	0.2	0.6	0.1	0.7	1.1	0.1	1.2	1.3	0.2	1.5
	POL	0.3	0.0	0.3	0.9	0.1	1.0	1.4	0.2	1.6	1.7	0.3	2.0
	SVK	0.0	0.0	0.0	0.9	0.0	0.9	1.3	0.3	1.7	1.6	0.3	1.9
	Total	0.5	0.1	0.6	3.5	0.4	3.9	5.6	1.0	6.6	6.8	1.2	8.0
Others	Others	12.3	2.4	14.7	13.1	2.0	15.1	10.0	1.7	11.7	10.2	2.0	12.1
	Total	12.3	2.4	14.7	13.1	2.0	15.1	10.0	1.7	11.7	10.2	2.0	12.1
Grand Total		40.3	7.4	47.6	45.3	6.1	51.5	38.2	6.3	44.5	39.0	7.5	46.5

Table A18 – US-led cluster: overall export shares and composition by group of countries, by year, and by orientation of export

	year / Flow.Type											
	1993			2003			2013			2017		
country_fr..	within the cluster	with ot her clu sters	To..	within the cluster	with ot her clu sters	Total	within the cluster	with ot her clu sters	Total	within the cluster	with ot her clu sters	Total
JPN	13.4	4.3	17.7									
USA	14.5	1.7	16.2	13.0	2.6	15.6	8.1	2.1	10.2	7.9	2.6	10.4
CAN	6.9	0.1	7.0	5.9	0.3	6.1	2.7	0.1	2.9	2.6	0.1	2.7
MEX	4.0	0.4	4.4	4.2	0.3	4.4	5.5	0.5	6.0	6.9	0.8	7.7
Others	2.3	1.2	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	41.1	7.7	48.8	23.1	3.1	26.2	16.3	2.8	19.1	17.3	3.5	20.8

Table A19 – US-led cluster: overall import shares and composition by group of countries, by year, and by orientation of export

	year / Flow.Type											
	1993			2003			2013			2017		
country_fr..	within the cluster	with ot her clu sters	Total	within the cluster	with ot her clu sters	Total	within the cluster	with ot her clu sters	Total	within the cluster	with ot her clu sters	Total
JPN	0.96	0.62	1.58									
USA	19.69	3.87	23.56	9.54	10.82	20.37	7.51	10.62	18.12	8.59	10.31	18.90
CAN	13.74	0.45	14.19	9.29	0.90	10.18	4.70	1.22	5.92	4.42	1.10	5.52
MEX	1.12	0.25	1.37	4.23	1.15	5.38	4.09	2.09	6.18	4.29	2.48	6.77
Others	6.80	1.53	8.33							0.00	0.00	0.00
Grand Total	42.30	6.72	49.02	23.06	12.87	35.93	16.30	13.92	30.22	17.31	13.88	31.19

Table A20 – China&Japan-led cluster: overall export shares and composition by group of countries, by year, and by orientation of export

	year / Flow.Type											
	1993			2003			2013			2017		
country_fr..	withi..	with ..	Total	withi..	with ..	Total	withi..	with ..	Total	withi..	with ..	Total
JPN	0.91	0.39	1.30	3.55	8.39	11.94	4.58	6.28	10.86	3.63	5.19	8.82
KOR	0.01	0.01	0.02	0.67	1.08	1.75	1.77	3.44	5.21	1.56	3.48	5.04
CHN	0.01	0.01	0.03	0.90	1.85	2.75	2.41	5.87	8.28	2.71	6.48	9.19
THA	0.01	0.01	0.02	0.40	0.27	0.67	1.13	0.72	1.85	1.10	0.89	1.99
IND	0.00	0.00	0.01	0.03	0.20	0.22	0.18	0.69	0.87	0.21	0.81	1.02
IDN	0.00	0.00	0.00	0.26	0.27	0.54	0.37	0.29	0.66	0.36	0.29	0.64
MYS	0.00	0.00	0.01	0.26	0.17	0.42	0.25	0.12	0.37	0.28	0.15	0.43
Others	0.07	0.01	0.08	0.47	0.33	0.79	0.51	0.38	0.90	0.49	0.37	0.86
Grand Total	1.02	0.44	1.46	6.53	12.55	19.08	11.20	17.79	29.00	10.34	17.66	28.00

Table A21 – China&Japan-led cluster: overall import shares and composition by group of countries, by year, and by orientation of export

	year / Flow.Type											
	1993			2003			2013			2017		
country_fr..	withi..	with ..	Total	withi..	with ..	Total	withi..	with ..	Total	withi..	with ..	Total
JPN	0.00	0.01	0.01	0.80	1.12	1.92	1.45	0.71	2.16	1.51	0.70	2.22
KOR	0.03	0.04	0.07	0.62	0.39	1.00	0.67	0.45	1.12	0.68	0.50	1.18
CHN	0.15	0.26	0.41	1.54	1.37	2.91	3.00	3.12	6.12	2.79	3.33	6.12
THA	0.61	0.09	0.70	0.89	0.18	1.07	1.58	0.27	1.85	1.21	0.32	1.53
IND	0.00	0.01	0.01	0.14	0.09	0.23	0.70	0.40	1.10	0.78	0.41	1.19
IDN	0.07	0.24	0.31	0.43	0.05	0.48	0.79	0.08	0.87	0.76	0.05	0.81
MYS	0.02	0.07	0.09	0.35	0.05	0.40	0.59	0.10	0.69	0.58	0.12	0.70
Others	0.14	0.31	0.45	1.77	0.87	2.65	2.43	1.44	3.87	2.03	1.23	3.26
Grand Total	1.02	1.03	2.05	6.53	4.13	10.66	11.20	6.58	17.78	10.34	6.66	17.00

Annex 8 - Patterns of trade by cluster, countries and groups of products

THE GERMANY-LED CLUSTER

In Figure A10, the trade shares of Germany are compared with the main Western European and the four CEE countries. Export and import shares for each country refer to trading within the cluster and with other clusters (left panel) and with countries within the cluster and in other clusters (right panel). We observe that each country has a specific composition of trades by group of products and that their orientation towards other clusters remains essentially the same, even though there is an expansion toward Ukraine-led and Russia-led clusters through the CEE countries, mainly with respect of Miscellaneous parts.

While for most countries in the cluster there is an increase of exports and imports of miscellaneous products, for Italy, France, UK and Hungary, Czech Republic Engine and parts represent a significant and increasing share of exports. For Italy, where Fiat was located with several assembling plants, trades of Engines and Parts with Brazil are significant in 1993, while imports are reduced as early as 2003. UK and France have trade as early as 1993 with China-led cluster and particularly with China and Korea. All countries in the cluster export Electrical electric parts to the Ukraine-led (2003) and the Russia-led (2013) clusters, with a larger share of export for Spain.

All countries have significant and increasing trade relations, since 2003, with the China-led cluster, and mainly with China itself; while South Korea is the main partner for import of Czech Republic and Slovakia. It is worth noting that a significant share of trade, in 2013 and 2017, took place between countries in the Russia-led cluster, mainly Russia, in particular for the export of Slovakia in all groups of components but Rubber and Metal Part (for which the US is the main partner, with 46.5% of Slovakia's exports of those components).

With respect to imports, the relevance of the Germany-led cluster shows in the trade connection across several groups of components imported not only from Germany but also from the other countries in the Germany-led cluster.

THE US-LED CLUSTER

The four panels of Figure A11 show the trade shares of the three NAFTA countries by groups of components (with respect to export and import, with other clusters and with other countries).

In 1993, with Japan embedded in this cluster, the main trades outside the cluster were with the Germany-led cluster, for most components.

The trade patterns changed with the introduction of NAFTA and, by 2017, the largest share of export and import - for the three countries and for all the groups of components - were with the China-led cluster. Compared to 1993, in 2003 Mexico reduced its significant share of trade with Brazil: Engine and Parts, that in 1993 accounted for 16.2% of its import of that group of components, represented 3.3% in 2003 and only 2.3 in 2017. Since 2003, countries in the China&Japan-led cluster become the main partner of US and Canada, while for Mexico are the countries the Germany-led cluster relevant partners both in 1993 and in 2003.

THE CHINA&JAPAN-LED CLUSTER

In Figure A12, the detailed information on the China&Japan-led cluster. In 2017, Japan exported to the Russia-led cluster 12.6% of Rubber and Metal Parts, South Korea and China exported, respectively, 14% and 22.2% of Engines and Parts, and 9% and 6% of Miscellaneous Parts.

Figure A10 – Germany-led cluster: main Western European and CEE countries. Export and import shares within the cluster and with other cluster and with other countries, by year and groups of SITC codes

Selected countries, in the rows, are ranked by their export share in 1993

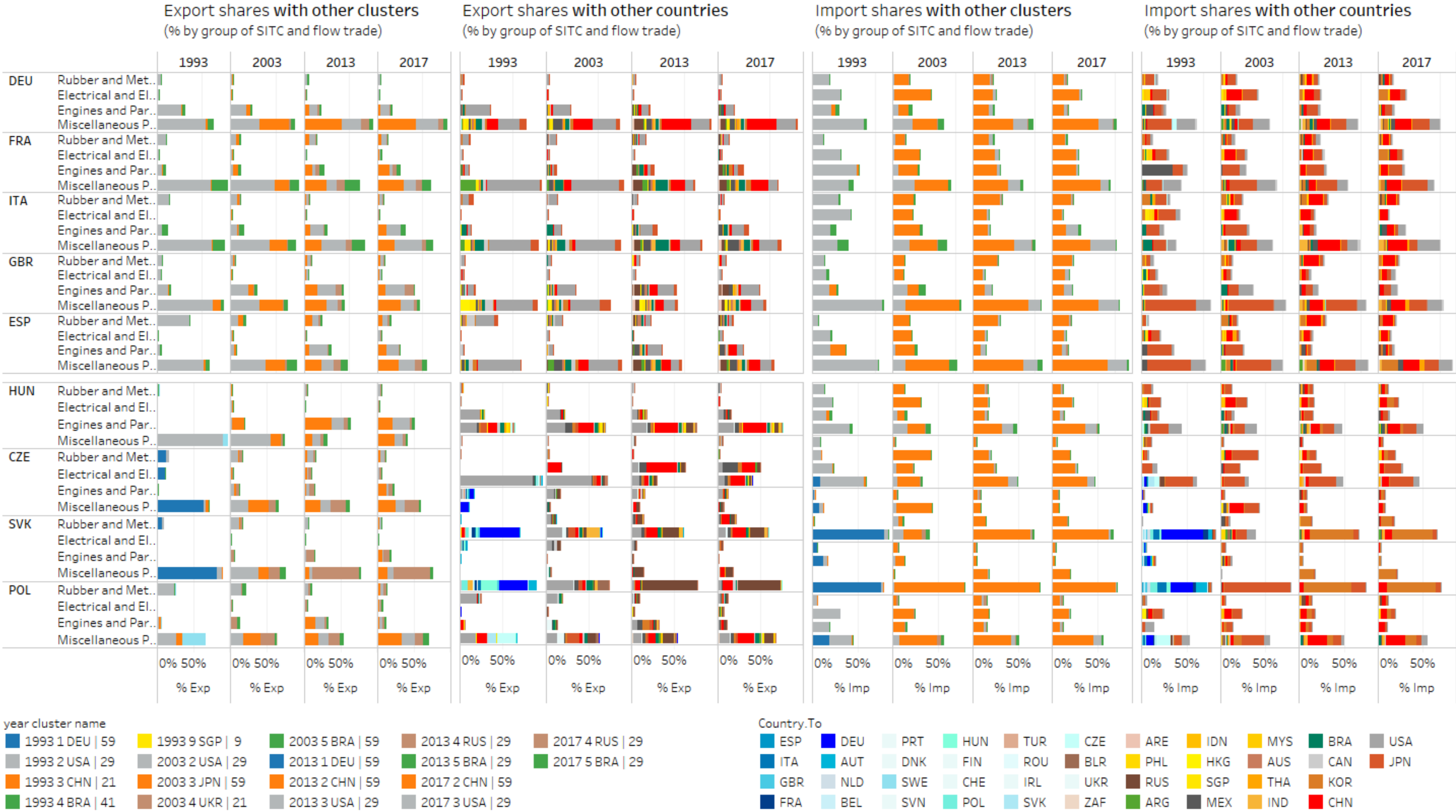


Figure A11 – US-led cluster - export and import shares, by year and groups of SITC codes

Main countries, in the rows, ranked by export share in 1993. Other 16 countries accounted in 1993 for about 3.5% of export share. Since 2003 the other two countries in the cluster accounted for a negligible share of export

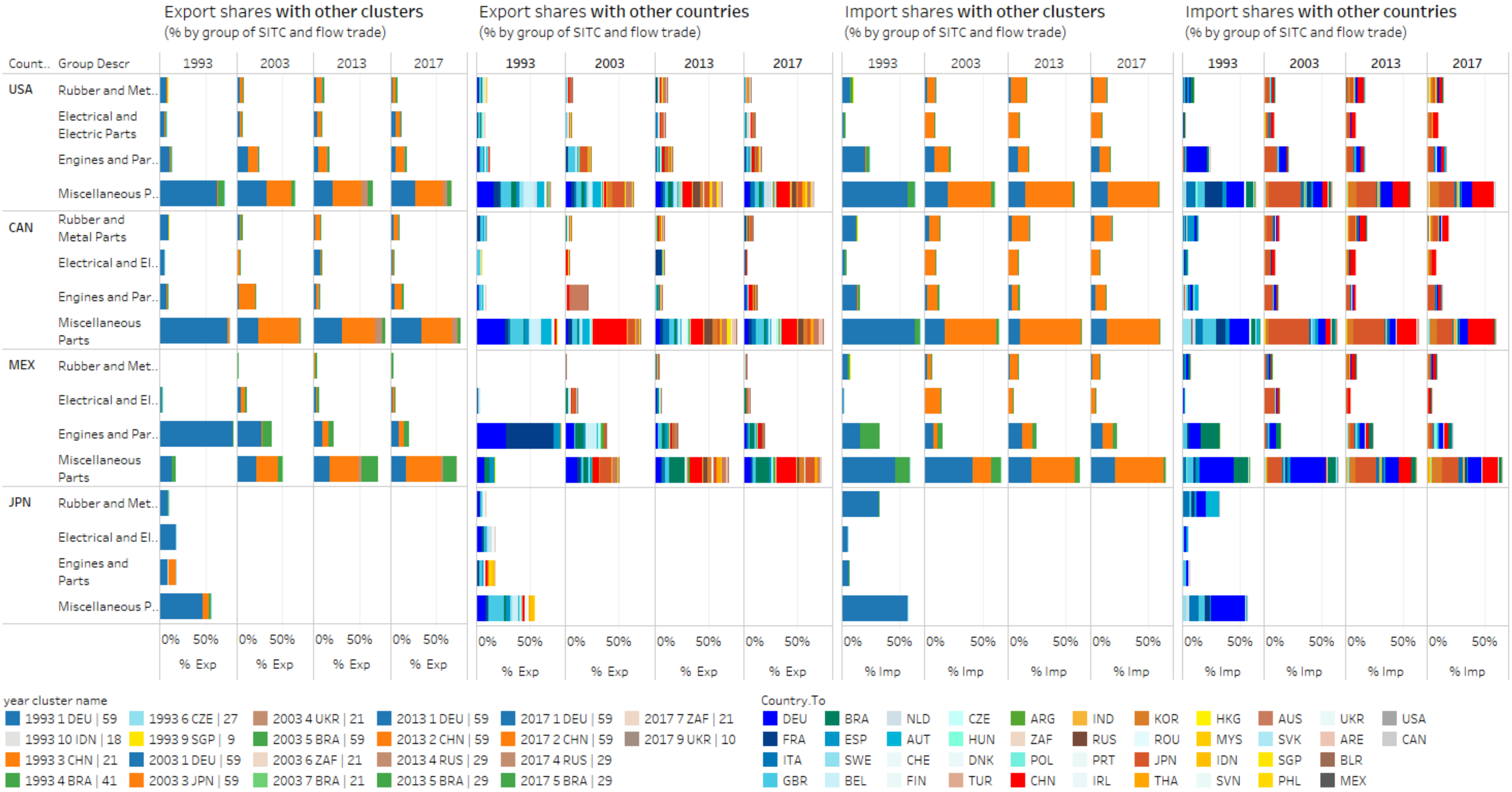
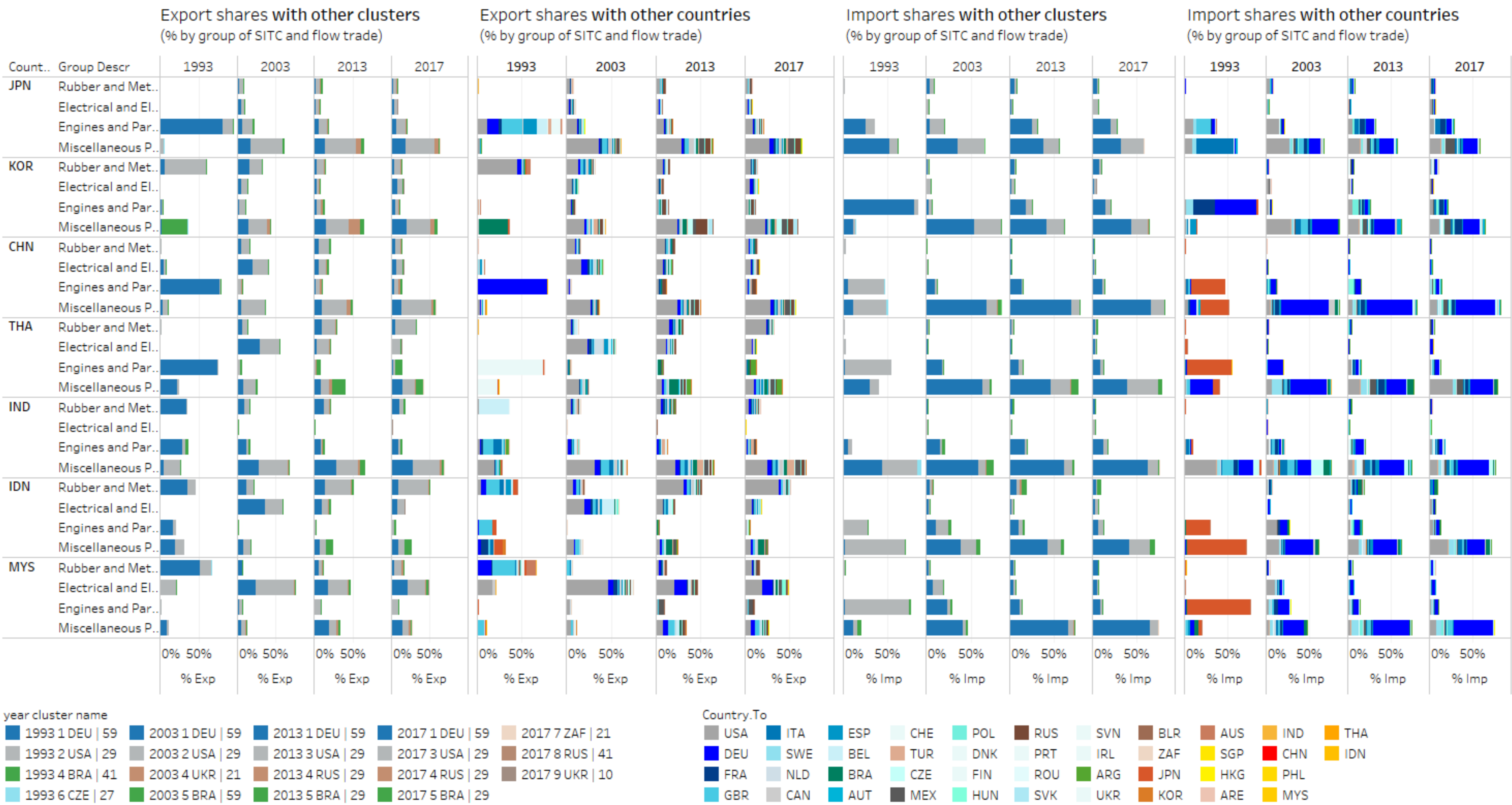


Figure A12 – China&Japan-led cluster. Export and import shares and groups of SITC codes, within the cluster they belong to and with other clusters

Main countries ranked by export share in 1993.



Annex 10 - – ICE

Table A22- Items classified in the SITC codes 713.21, 713.22 and 713.23

A list of components is available here: https://www.whichcar.com.au/car-advice/what-is-a-powertrain-or-drivetrain#:~:text=If%20the%20chassis%20is%20the,through%20to%20the%20rotating%20wheels

713.21	
	Engines, gasoline, internal combustion, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11, of a cylinder capacity not exceeding 1,000 cc
	Engines, petrol, internal combustion, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11, of a cylinder capacity not exceeding 1,000 cc
	Engines, piston, internal combustion, for motor cycles, of a cylinder capacity not exceeding 1,000 cc
	Engines, piston, spark-ignition, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11, of a cylinder capacity not exceeding 1,000 cc
713.22	
	Engines, gasoline, internal combustion, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11, of a cylinder capacity exceeding 1,000 cc
	Engines, petrol, internal combustion, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11, of a cylinder capacity exceeding 1,000 cc
	Engines, piston, internal combustion, for motor cycles, of a cylinder capacity exceeding 1,000 cc
	Engines, piston, spark-ignition, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11, of a cylinder capacity exceeding 1,000 cc
713.23	
	Engines, diesel, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11
	Engines, piston, compression-ignition, for vehicles of division 78, group 722 and headings 744.14, 744.15 and 891.11
	Engines, semi-diesel, for vehicles of division 78, group 722 and headings 744.11, 744.15 and 891.11

Table A23 - ICEs: Export shares by countries within and with other clusters, 2017

SITC codes: 713.21, 713.22, 713.23, 778.31, 778.33 and 778.34. Countries are ranked by total export share

	Grand	within the cluster						with other clusters																	
Cou..	Total	Total	1	5	4	3	2	Total	2	4	3	5	17	16	15	14	13	12	11	10	9	8	7	6	1
USA	4.817	3.972				3.972		0.845	0.431	0.041		0.063	0.000			0.000			0.000						0.310
DEU	4.359	2.694	2.694					1.665	0.410	0.188	0.986	0.082	0.000			0.000			0.000						
JPN	3.388	1.281					1.281	2.107		0.172	1.159	0.026	0.000			0.000			0.000						0.750
MEX	3.297	2.976				2.976		0.320	0.096	0.012		0.073	0.000						0.000						0.139
HUN	2.283	1.913	1.913					0.370	0.153	0.021	0.176	0.020							0.000						
CHN	2.276	0.615					0.615	1.661		0.367	0.776	0.060	0.000			0.000			0.000						0.457
AUT	1.747	1.344	1.344					0.403	0.065	0.005	0.330	0.003							0.000						
FRA	1.689	1.330	1.330					0.359	0.187	0.069	0.055	0.047				0.000									
GBR	1.411	0.990	0.990					0.421	0.089	0.101	0.226	0.005				0.000			0.000						
ESP	1.207	0.944	0.944					0.263	0.109	0.009	0.138	0.006							0.000						
ITA	1.160	0.740	0.740					0.420	0.140	0.010	0.214	0.056	0.000			0.000			0.000						
KOR	1.132	0.282		0.009			0.273	0.850	0.001	0.113	0.307	0.065	0.000						0.000						0.364
POL	1.102	1.032	1.032					0.070	0.021	0.020	0.027	0.002	0.000												
CAN	0.953	0.922				0.922		0.031	0.018	0.001		0.000				0.000			0.000						0.011
C.. Iı.	0.913	0.682	0.682					0.231	0.138	0.056	0.032	0.006	0.000												
SWE	0.906	0.788	0.788					0.118	0.071	0.031	0.011	0.004							0.000						
SVK	0.634	0.512	0.512				0.000	0.122	0.044	0.058	0.018	0.003	0.000												0.000
THA	0.570	0.339					0.339	0.231		0.006	0.048	0.135							0.000						0.041
ROU	0.398	0.314	0.314					0.084	0.030	0.035	0.009	0.010													
IND	0.305	0.092					0.092	0.214		0.012	0.041	0.012	0.000						0.000						0.148
TUR	0.280	0.238	0.238					0.042	0.008	0.016	0.014	0.004							0.000						
BRA	0.243	0.090		0.090				0.153	0.004	0.001	0.120								0.000						0.029
SVN	0.241	0.177	0.177					0.064	0.030	0.006	0.025	0.003	0.000												
NLD	0.202	0.184	0.184					0.018	0.010	0.001	0.003	0.003													
BEL	0.140	0.115	0.115					0.025	0.011	0.001	0.009	0.003													
IDN	0.130	0.096					0.096	0.034		0.004	0.012	0.008													0.011
RUS	0.075	0.036			0.036		0.000	0.039	0.002		0.001	0.001	0.000												0.034
MYS	0.070	0.040					0.040	0.030		0.000	0.026	0.000													0.002
PRT	0.066	0.053	0.053					0.013	0.006	0.001	0.006	0.000													
PHL	0.064	0.029					0.029	0.034		0.000	0.028	0.001													0.005
ARG	0.058	0.053		0.053				0.005	0.000	0.000	0.004														0.001
ZAF	0.058	0.043					0.043	0.015		0.001	0.010	0.000				0.000									0.004
SGP	0.048	0.041					0.041	0.007		0.000	0.004	0.001													0.002
CHE	0.046	0.043	0.043					0.002	0.001	0.000	0.001	0.000													
DNK	0.043	0.040	0.040					0.003	0.000	0.001	0.002	0.000													
FIN	0.040	0.021	0.021					0.019	0.005	0.001	0.013	0.000													
BLR	0.037	0.036			0.035		0.000	0.001	0.000		0.000	0.000	0.000						0.000						0.001
AUS	0.034	0.020					0.020	0.014		0.000	0.005	0.002				0.000									0.007
UKR	0.015	0.002	0.000		0.002			0.013	0.001		0.000	0.000													0.012
HKG	0.012	0.003					0.003	0.009		0.000	0.005	0.000	0.000												0.004
IRL	0.007	0.006	0.006					0.001	0.001	0.000	0.000	0.000													0.000
ARE	0.007	0.005					0.005	0.002	0.000	0.000	0.001	0.000													0.001
Total	36.461	25.134	14.160	0.153	0.073	7.871	2.878	11.327	2.084	1.363	4.839	0.707	0.000			0.000			0.000						2.333

Table A24- ICEs: Import shares by countries within and with other clusters, 2017

SITC codes: 713.21, 713.22, 713.23, 778.31, 778.33 and 778.34. Countries are ranked by total import share

	Grand	within the cluster						with other clusters																	
Cou..	Total	Total	1	5	4	3	2	Total	2	4	3	5	17	16	15	14	13	12	11	10	9	8	7	6	1
USA	6.99	3.55				3.55		3.44	1.78	0.00		0.00				0.00			0.00						1.66
DEU	4.65	4.19	4.19					0.46	0.32	0.02	0.11	0.01							0.00						
MEX	3.34	2.23				2.23		1.11	0.44	0.00		0.12													0.55
CAN	2.38	2.09				2.09		0.29	0.20	0.00		0.00				0.00									0.09
CHN	1.71	0.79					0.79	0.91		0.00	0.16	0.00													0.75
ESP	1.70	1.58	1.58					0.12	0.07	0.02	0.03	0.00													
RUS	1.31	0.04			0.03		0.00	1.27	0.66		0.04	0.00	0.00						0.00						0.57
TUR	1.24	0.98	0.98					0.25	0.21	0.00	0.02	0.02													
GBR	1.22	0.93	0.93					0.30	0.18	0.00	0.12	0.00													
FRA	1.15	0.87	0.87					0.28	0.26	0.00	0.02	0.00				0.00			0.00						
CZE	1.11	0.95	0.95					0.16	0.15	0.00	0.00	0.00	0.00												
JPN	0.83	0.44					0.44	0.39		0.00	0.09	0.00													0.30
BEL	0.79	0.76	0.76					0.03	0.02	0.00	0.01	0.00													
ITA	0.70	0.50	0.50					0.21	0.11	0.00	0.09	0.02							0.00						
HUN	0.70	0.61	0.61					0.09	0.08	0.00	0.01	0.00													
SVK	0.62	0.49	0.49				0.00	0.13	0.12	0.00	0.00	0.00													0.00
POL	0.61	0.54	0.54					0.08	0.06	0.00	0.01	0.00	0.00						0.00						
NLD	0.53	0.44	0.44					0.09	0.08	0.00	0.01	0.00				0.00			0.00						
THA	0.52	0.44					0.44	0.08		0.00	0.02	0.00													0.06
BRA	0.48	0.06		0.06				0.42	0.17	0.00	0.10														0.14
IND	0.41	0.27					0.27	0.14		0.00	0.04	0.00							0.00						0.11
KOR	0.39	0.18		0.00			0.18	0.21	0.00	0.00	0.06	0.00													0.15
ARG	0.38	0.09		0.09				0.29	0.14	0.00	0.03														0.12
ROU	0.29	0.27	0.27					0.02	0.01	0.00	0.00	0.00													
AUT	0.29	0.25	0.25					0.04	0.03	0.00	0.01	0.00													
IDN	0.29	0.27					0.27	0.01		0.00	0.01	0.00													0.01
SWE	0.24	0.20	0.20					0.04	0.03	0.00	0.01	0.00													
PRT	0.23	0.22	0.22					0.01	0.00	0.00	0.00	0.00													
AUS	0.22	0.08					0.08	0.14		0.00	0.08	0.00	0.00			0.00									0.06
MYS	0.21	0.18					0.18	0.03		0.00	0.01	0.00							0.00						0.02
FIN	0.18	0.16	0.16					0.01	0.01	0.00	0.00	0.00													
SVN	0.12	0.11	0.11					0.01	0.01	0.00	0.00	0.00													
ARE	0.11	0.07					0.07	0.05	0.00	0.00	0.02	0.00													0.02
SGP	0.10	0.03					0.03	0.07		0.00	0.05	0.00													0.02
BLR	0.09	0.03			0.03		0.00	0.06	0.01		0.01	0.00													0.05
ZAF	0.09	0.04					0.04	0.05		0.00	0.01	0.00							0.00						0.03
CHE	0.06	0.05	0.05					0.01	0.01	0.00	0.00	0.00				0.00									
PHL	0.05	0.05					0.05	0.00		0.00	0.00	0.00													0.00
DNK	0.05	0.04	0.04					0.01	0.01	0.00	0.00	0.00													
HKG	0.04	0.03					0.03	0.01			0.00														0.01
UKR	0.04	0.01	0.00		0.01			0.03	0.01	0.00	0.00	0.00													0.01
IRL	0.02	0.02	0.02					0.00	0.00	0.00	0.00	0.00													0.00
Total	36.46	25.13	14.16	0.15	0.07	7.87	2.88	11.33	5.19	0.05	1.20	0.18	0.00			0.00			0.00						4.71

Annex 11 - State-nodes and nodes in the multi-layer framework: an example

Figure A13 - Example of state-nodes and nodes (five countries) in the multi-layer framework (two layers)

This example refers only to a selection of five countries (CZE, DEU, JPN, MEX, USA) out of the 42 considered in the analysis, and only to two of the 30 layers of export in 2017 (items 71323 Compression-ignition engine (diesel or semi-diesel engines), and 78433 Brakes and servo-brakes and parts thereof).
The size of nodes is proportional to their overall weight in each of the two layers; the width of arcs is proportional to the trade flow between pairs of countries.
The vertical dotted lines indicate the state-nodes corresponding to the nodes (countries) represented in the example.