Are automotive global production networks becoming more global? Comparison of regional and global integration processes based on auto parts trade data

Frigant, Vincent and Zumpe, Martin

GREThA, CNRS, UMR 5113

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Vincent FRIGANT [1, 2]

&

Martin ZUMPE [1]

[1] GREThA, CNRS, UMR 5113; University of Bordeaux, Bordeaux, France
[2] GERPISA-International Networks, ENS6Cachan, Cachan, France

Abstract:

In this paper, we examine the evolution of international exchanges of auto parts over the 2000-2012 period. The first part of our study proposes an analysis of the organisation of automotive supply chains based on the *global production networks* framework. We give details about this approach by stating the nature of trade flows that occur in these networks, and by highlighting the importance of intra-firms flows. The second part poses the question of reasons for an eventual increase of intercontinental flows at the expense of intra-continental flows. In the third part, we evaluate the assumptions made in this context. On the basis of *Chelem* data about auto parts exchanges, we examine in a comparative way the evolution of intra-continental and intercontinental flows for nine zones of regional integration that cover the world's entire set of countries. Our results highlight the heterogeneity of situations and of trajectories in the different zones. We explain this state of affairs by the history and the trajectory of the industrial actors, by institutional opportunities/constraints, and by the balance of power between the industries engaged in the setting up of automotive production networks.

Keywords: Global Production Networks; Automotive; Auto parts industry; Globalisation; Regionalisation; International economics

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Corresponding author:

Vincent FRIGANT
GREThA UMR CNRS 51113
University of Bordeaux
France
vincent.frigant@u-bordeaux.fr

Introduction[1]

Since the 1990s, intermediate goods exchanges represent an increasing proportion of international goods trade (Feenstra, 1998). This evolution is nowadays widely recognized as being a result of the impressive development of the international fragmentation of production processes (Berger, 2006; Milberg, Winkler, 2013; UNCTAD, 2013; OECD, 2013). This fragmentation finds its roots in three phenomenons: the movement towards vertical disintegration of large industrial firms that rely increasingly on outsourcing; international labour division set up by these large industrial (and commercial) firms; the insertion of new spaces into world trade, starting with China.

Somehow at odds with this general tendency towards increasingly internationalized productive processes, there are numerous studies highlighting the existence of factors likely to dampen this movement. Not all kinds of activities are suitable -- from the firm's point of view -- for fragmentation and/or outsourcing; not all kinds of fragmented activities are likely to be executed remotely (because of cognitive and contractual coordination constraints); and all kinds of remotely executed production processes may not be suitable for far-distance fragmentation (due to issues of productive coordination). The questions of the setting-up of the different spatial scales of activity localisation, of their mutual imbrications and of how they mutate and reconstruct themselves, are at the heart of two research agenda: the global value chain approach (Gereffi, Sturgeon, Humphrey, 2005) and the global production networks approach (Coe, Dicken, Hess, 2008; Henderson et al., 2002). Despite of their analytical differences (Bair, 2008), these two approaches agree on one crucial point of their diagnosis of the movement towards increasing international labour division: both of them explain this tendency by the structural internationalization of the supply networks (set-up and organized by large industrial and commercial firms).

Our paper aims at contributing to this research agenda by adding the perspective and the experiences of the automotive industry. We will first synthesize the burgeoning literature about the spatial organization of the automotive value chain; in a further step, we will raise the question whether this organization is likely to internationalize over far distances; finally, we will propose a quantified measure of this movement.

The automotive industry is rather well suited to raise this question of an international extension of the value chain; in fact, this industry was traditionally shaped on a regional basis. Carmakers are indeed organized according to an integration pattern corresponding to a continental scale, both from the commercial viewpoint (i.e. the characteristics of marketed car models) and from the productive one (plants organized in order to provide a whole continent with very few intercontinental trade flows) (Carrillo, Lung, van Tulder, 2004; Freyssenet, Lung, 2000). This pattern seems to be highly stable, but what about the supply networks? Have the powerful movement of vertical disintegration of carmakers (Herrigel, 2010; Withford, Enrietti, 2005; Veloso, Kumar, 2002) and the consecutive increase in power of mega-suppliers (Donovan, 1999; Frigant, 2009) led to a growth of intercontinental exchanges of auto parts, and thus to a weakening of the traditional clustering of the automotive industry? Before proposing a spatial analysis aiming at responding to this question, we have to explain the transformation of the sector's industrial organization via the *global production networks* approach.

Section 1 reviews the literature about the geography of the automotive value chain, thereby establishing our analytical framework, based on the Global Production Networks theory. In a second section, we expand reasons for an eventual growth of intercontinental auto parts exchanges over the recent years. Section 3 proposes measures of the evolution of intercontinental flows, based on

[1] The present study has been carried out under the auspices of the Open-Lab *Competitive Intelligence* (Peugeot Citroën Automobile / GREThA UMR CNRS 5113), working out of the University of Bordeaux.

Chelem data. The last section synthesizes our main propositions and offers suggestions for empirical improvements.

1. Global automotive production networks' general spatial patterns

The geography of the automotive industry is probably one of the most scrutinised topics in academic literature, whether by geographers, economists, sociologists or management specialists. There seem to be three particular explanations for this interest.

Firstly, the automotive industry plays a crucial role in countries that host carmakers, having developed in a way that brings a number of economic, sociological and political factors into play. The issues raised often break down along territorial lines, due to the enormous weight that carmaker and supplier plants carry at the local level. Secondly, the automobile is a complex product requiring many parts and ancillary activities, in a mass production context governed by the principles of lean management. Researchers have viewed this as an excellent field of analysis where all different kinds of complexities intersect: technological; organisational; and institutional. Lastly, there is constant innovation in this field, whose constant technological transformation regularly leads to the emergence of new industries and actors (such as electric vehicles or onboard entertainment systems). Alongside of this, there is the shifting balance of power in automotive value chains, whose organisational models have also changed over time, as witnessed by the invention of the Fordian assembly line; the rise of lean manufacturing (Womack, Jones, Roos, 1990); or, closer to the focus of the present paper, modularisation (McDuffie, 2013). This twofold technological and organisational transformation has altered supply networks, hence the geography of the automotive business, if only because all these changes affect carmakers' level of vertical integration and lend themselves to the emergence of new relationships with new suppliers who, after all, need to locate somewhere.

The present article starts with the postulate that production networks' geographical transformation has been technologically and organisationally caused by changes in the way that automobiles are being manufactured. Such changes are driven by technological and organisational innovations that have appeared or developed as a result of the strategic actions taken by actors (carmakers and increasingly suppliers) and because of the influence exercised by certain institutions[2]. Against this background, the geography of the automotive industry is itself undergoing perpetual change, so that the challenge for researchers is to formulate theoretical models apprehending the spatial dynamics underlying all of these movements. Hence the suggestion made in section 1.2 of an interpretive framework that is rooted in Global Production Networks (GPN) theory and tries to account for the four stylised facts highlighted in literature.

1.1. Four robust stylised facts about automotive parts production

Despite the multitude of relationships between design and production activities, the two fields have traditionally been analysed separately from one another. This is because R&D activities tend to be located for relatively autonomous reasons, relating to the materialisation of carmakers and suppliers' research networks (Pavlinelk, 2012; Cabigiosu, Zirpoli, Camuffo, 2013). The present text focuses on productive activities and the way linkages between input/output flows enable vehicle assembly operations. Recent applied literature in this area highlights four key points.

1.1.1. Stylised fact number 1: Resistance of forms of proximity

A first notable fact about the geography of the automotive industry is that ever since the sector's birth, suppliers and manufacturers have clustered together. Despite a number of recurring

[2] The simplest example is the introduction of new safety or environmental legislation causing product modifications. But there have also been changes in labour market rules or, closer to the present article's focus, international trade regulations (local contents requirement, customs tariffs, standardisation of norms, etc.).

shocks (Rutherford, Holmes, 2008) and major changes (Klier, McMillen, 2008), the formation/re-formation of clusters has long been a stylised fact. Indeed, the conditions under which automobiles are produced justifies the search for a greater or lesser degree of geographic proximity between carmakers and suppliers for three main reasons: delivery conditions; organisational learning; and access to information.

One significant moment in the identification of the need for proximity was the introduction of just-in-time (JIT). The first studies in this area (Estall, 1985) portrayed this as an organisational model based on a singular spatial geography. For instance, Fujita and Hill (1995) have shown that Toyota had a network of suppliers localised around its plants in a radiocentric formation, with Tier 1 suppliers being situated nearby, Tier 2 a little further away and Tier 3 at an even greater distance. Authors have largely described this type of organisation as reflecting the intensity of delivery flows, although they do recognise that Japan's particular geography (lack of room to build and ongoing congestion problems) offers another explanation. Similarly, Linge (1991) used the example of Australia to demonstrate that proximity constraints can be overcome if logistics are organised efficiently. The transfer of JIT to the USA when the Japanese transplants first moved there seems to corroborate this idea of a search for proximity, albeit on a larger scale. In turn, this suggests that the distance between firms - even if this is not a fully deterministic variable - constitutes a parameter that suppliers consider when making their location choices (Hill, 1989; Mair, Florida, Kenney, 1988).

Analysis of JIT's transfer to Europe should enable the identification of another important factor. This is due to the relative dearth of companies moving into this region. One explanation highlights transportation, given the smaller distances between European carmaker plants, and due to logistics providers' growing capabilities, which allows them to manage flows over longer distances (a development reinforced by future generations of 4PL four-party logistics firms, c.f Fulconis, Saglietto, Paché, 2007). Lung and Mair (1993) offer a second explanation, namely organisational learning. Their idea is that when European manufacturers and suppliers establish a JIT system, they are familiar with its functioning and therefore have a lesser need for proximity. This might explain why the arrival of modular production occurred in the late 1990s, alongside a new wave of co-locations (Lung et al, 1999) that dissipated as learning spread, except for certain kinds of production run out of suppliers parks (Larsson, 2002; Sako, 2005). Of course, suppliers parks were not only meant to resolve transport problems but also had an organisational justification insofar as they enhanced knowledge exchanges between organisations and helped to reduce the risk of opportunism stemming from certain site specificity factors (in Williamson's sense of the term) that the suppliers parks themselves brought into play – if only because the bilateral hostage-taking that they engendered helped to reduce the chance of opportunistic behaviour (Frigant, Lung, 2002).

Another noteworthy element is that clustering makes it possible to benefit from knowledge externalities even as it accelerates and facilitates the capture of information about carmakers' new needs. Thus, despite advances in large global suppliers' means and volumes of communication (which seem to have offered them a certain freedom to move as they saw fit), they continue to try to locate in carmakers' vicinity to better understand their expectations and establish closer relationships with decision-makers (Cabigiosu, Zirpoli Camuffo, 2013). This kind of advantage could also be found with SMEs – indeed, it is what ultimately allowed them to survive by maintaining their productive flexibility and rearranging their collaborative networks in such a way as to adapt to any changes in value chains and/or competition from mega-suppliers (Castelli, Florio, Giunta, 2011; Rutherford, Holmes, 2008; Herrigel, 2004).

All of these studies converge around the idea that geographic proximity is a necessity or an advantage ensuring the coordination of productive actions. The (complex) conditions of automobile production, especially where this is done on a mass basis and following the precepts of lean management, requires certain forms of proximity. At the same time, *the studies continue to assert that not all kinds of production are subject to this proximity imperative*. In this view, technological

and/or organisational variability preclude any sense of determinism. They claim there are powerful but not entirely determinant centripetal forces.

One empirical objection might be that the observed clusters reflected suppliers' geographic inertia. But for two reasons, this would only be partially true. Firstly, because analysis of the new plants that manufacturers build in relatively virgin territories demonstrate that they were still attractive. Carmakers' investments in Eastern Europe led to the development of powerful automotive clusters in countries like the Czech Republic (Pavlinek, Janak, 2007) or Poland (Domanski, Gwosdz, 2009) – even if the older clusters tended to survive (Holl, Pardo, Rama, 2010) despite relocation pressures (Kim, 2005; Lampon, Lago-Penas, 2013). Secondly, observed changes over time in the different suppliers' factories show that they tended to track carmaker plants' changing geography (Klier, Rubenstein, 2011; Klier, McMillen, 2013).

1.1.2. Stylised fact number 2: Suppliers' move to low-cost countries

The desire to follow carmakers was not the only factor influencing suppliers' relocation strategies. The auto parts industry also moved en masse to low-cost countries situated in zones on the periphery of the traditional big automotive countries.

Mexico was the first major destination to hit the headlines, back in the late 1970s (Carrillo, Contreras, 2007). This process accelerated as the prospect of NAFTA became a reality, coinciding as well with an acceleration in carmakers' outsourcing tendencies. In turn, this justified suppliers' search for new locations, if only because their markets were expanding, forcing them to set up new production units. From the 1970 onwards, a number of German companies were signing cooperation agreements with Eastern European companies, although it was not until the Iron Curtain came down and the prospect of European integration took shape that the process accelerated. By the 2000s, however, Eastern European countries had become major auto parts production centres. Analysis of output and employment in this sector, and of European countries' sectorial specialisation indexes, reveals the magnitude of the industry's growth in the East and decline in the West (Frigant, Miollan, 2014). Where the rise of the auto parts industry in Mexico was basically driven by greenfield investments, Eastern Europe saw numerous acquisitions of local companies at the beginning of the period in question, creating in turn a certain impression of neo-colonialism (Havas, 2000)[3]. Some of the facilities built in these low-cost countries were meant to supply the new plants that manufacturers had built locally. Having said that, analysis of national trade balances shows that much of their output was meant to be be exported back to Western Europe (Frigant, Miollan, 2014) or North America (US Department of Commerce, 2011).

These import/export flows suggest the possibility that what was involved here was the reorganisation of the division of labour on a continental scale. More monographic studies have confirmed this finding, whether for North America (Klier, Rubenstein, 2008 and 2011; Carrillo, 2004); Europe, where Central and Eastern European countries played this role (Pavlinek, Domanski, Guzik, 2009; Jürgens, Krzywdzinski, 2009); the Magrebian and North African countries (Layan, Lung, 2007); and Turkey (Ozatagan, 2011). All of these studies converge in one respect, namely that mega-suppliers became the key drivers of this international production fragmentation process. Certainly, they were moving some of their production segments to low-cost countries.

1.1.3. Stylised fact number 3: A division of labour driven first and foremost by mega-suppliers – modularisation's winners

Since the 1980s, Western carmakers have engaged in a vertical disintegration process (Lamming, 1993) similar to what their Japanese counterparts had done previously (Cusumano, 1989).

[3] A process found in several countries like India or Brazil (Humphrey, 2000; Humphrey, Salerno, 2000) where Western suppliers who had been forced to follow their carmaker customers ended up partially destroying the local suppliers fabric.

There was an acceleration from the late 1990s, however with the advent of modular production (MacDuffie, 2013; Sako, 2003; Veloso, Kumar, 2002). Coupled with carmakers' increasing interest in outsourcing, automobiles' increasingly modular design caused major changes in carmakers' procurement, with a sharp decline in subcontracting accompanied by the growing purchase of more complex modules/subassemblies - themselves resulting from the aggregation of components, the so-called macro-components (Volpato, 2004) - designed, developed and produced by suppliers who were being asked to deliver all of these parts to their carmaker customers' plants. This led in turn to a major recomposition of suppliers, with fewer working with manufacturers directly on a Tier 1 basis – even if several chosen companies did become global oligopolies and began working with most of the world's main carmakers (Frigant, 2011; Frigant, 2009; Klier, Rubenstein, 2008; Sturgeon, Florida, 2001), becoming trailblazers in an era subsequently referred to as "the dawn of the mega-supplier" (Donovan, 1999).

These mega-suppliers were the key drivers behind the new international division of labour, organised on a continental scale. There were three reasons for this.

- ✓ Firstly, they had to develop their productive apparatus and technological competencies in a severely competitive context, causing them in turn to opt for mergers and acquisitions. Each acquisition led to their integrating a number of units that would then have to be rationalised both in terms of their productive function within the business's general organisation and also as regards their location. This translated into many plants being closed, opened and re-qualified. As an example, between 2001 and 2006, the French mega-supplier Valeo closed 59 plants, opened 29, sold 26 sites and acquired 13 others
- ✓ Secondly, even in the absence of any major acquisitions, mega-suppliers had to restructure their own value chains. For a long time, being a supplier meant delivering simple components to a few special carmakers running operations in just a few countries. Henceforth they would have to organise long value chains making complex parts based on their mobilisation of many external suppliers but also in-house units. This production was aimed at a growing number of carmaker customers worldwise, who were themselves running a growing number of assembly plants. The carmakers would then organise the different models' production along continental lines (Freyssenet, Lung, 2000; Carrillo et al., 2004), the end result being that the mega-suppliers would generally organise their productive geography on a basis similar to the carmakers, i.e. continentally.
- ✓ Thirdly, the market was not sufficiently concentrated for mega-suppliers to be particularly strong in market power terms. Temporarily at least, and for most of their models, the carmakers were able to maintain their domination using avoidance strategies (exclusivity contracts, rotating suppliers from one model to another, maintaining in-house supply subsidiaries, etc.). They try to escape to an Intel Inside syndrome, and they succeed in because mega-suppliers' profitability remains fairly weak due to strong downwards pressure on prices (Jacobides, MacDuffie, Tae, 2012; Frigant, 2009). To restore their margins, one of the strategies they adopted was to move to low-cost countries.

From the late 1990s onwards, Sadler (1998; 1999) started writing about the connection between all of these different movements. In this view, the rise of outsourcing, which mainly benefited a particular category of suppliers (so-called mega-suppliers) and happened in a context defined by European integration, culminated in a hollowing out process characterised by massive relocations from Eastern to Western Europe. Things more or less took place as expected, although the spatial reality seems somewhat more complex insofar as proximity needs actually did help to maintain a number of large clusters in the West (including the USA and Canada) - if only because certain processes that began to emerge in local institutional contexts revived some spaces' dynamism (Rutherford, Holmes, 2008; Herrigel, 2010). This latter movement was often led by SMEs.

1.1.4. Stylised fact number 4: SMEs still active up and down the supply chains

The dawn of mega-suppliers does not capture the entirety of this history. SMEs continued to play a major role in the value chains, sometimes even operating at the top of the supply pyramid. Herrigel (2004) was skeptical about the extent to which the rise of modular production would transform cars into a game of Lego where "big" suppliers would be the only parties producing "big components" assembled in manufacturers' assembly plants. Although mega-suppliers continued to operate at the very top of the supply pyramids, many SMEs would still worked as Tier 1 suppliers. In a study covering a sample of 696 French SMEs, Frigant (2011) demonstrated that although 30.4% operated exclusively in Tier 2 and 14% in Tier 3, 12.9% said that they were working in Tier 1. Furthermore, 12.5% were operating in tiers 1 and 2 simultaneously, and 4.3% in tiers 1, 2 and 3. The supply pyramid was less static than is often described (strict separation between tiers). Nor was the summit as closed to SMEs as some observers inferred.

This is because the automobile is not a perfectly modular product (Cabigiosu, Camuffo, Zirpoli, 2013; MacDuffie, 2013). Carmakers still need to purchase simple parts, call upon subcontractors, organise maintenance operations, turn to engineering SMEs, etc. In addition, mega-suppliers sometimes refuse to follow carmakers overseas when they feel that the profit opportunities are insufficient and/or when the cars need local adaptations to satisfy consumers' national preferences. The end result is that some auto parts have had to be redesigned and built for a single factory. In both of these cases, carmakers have had to find local suppliers replacing the mega-suppliers. This has not necessarily involved "exotic" factories built in very distant countries, one example being Dacia's Romanian factory, whose supply networks ranged from local businesses (Romanian SMEs) to the whole of Europe and other international mega-suppliers (Jullien, Lung, Midler, 2013).

Outside of Tier 1, SMEs obviously maintained a major presence up and down the supply chain. Mega-suppliers relied on a large number of SMEs to carry out their activities. What is worth emphasizing at this level is the discovery revealed in several studies, namely SMEs' internationalisation, which tended to go down two routes. On one hand, some SMEs started creating their own productive units in low-cost countries and/or in automotive clusters because they wanted to get closer to their customers (carmakers or big or small suppliers). A study carried out in France showed, for instance, the 14% of French SMEs working in the automotive sector had overseas subsidiaries for the following purposes: 1) low production costs, 2) access to the local market, 3) customer demand (OSEO, 2011). In addition, SMEs would also export some of their output. In the same study, 40.9% of SME respondents stated that they were involved in export activities, with 24.3% saying that exports accounted for more than 10% of their revenues (OSEO, 2011). Although there is probably a European specificity at this level (compared to North America and Asia) in the sense that the European automotive industry is more geographically and economically integrated (if only because of the single currency), these figures demonstrate that the internationalisation of SMEs working in the automotive sector is a factor to be reckoned with (for an Italian example, see Castelli, Florio, Giunta, 2011; Bacchiocchi, Florio, Giunta, 2014).

These studies have the merit of showing that SMEs' local automotive productive systems have not disappeared. They also suggest that, methodologically speaking, analysis of the international trade in auto parts can help to enhance understanding of production networks' changing geography.

1.2. An interpretive framework rooted in Global Production Networks theory

The four aforementioned stylised facts are areas where authors converged. The question then becomes how they are interlinked and what kinds of logic they respond to. To answer these questions, an analytical representation of buyers/suppliers' relationships in space is necessary.

1.2.1. Why stylised facts support a GPN framework

In recent years, conceptualisation of interfirm relationships in space (and in relation to space) have been profoundly renewed through so-called Global Commodity Chains/Global Value Chains

approaches (Gereffi, Korzeniewicz, 1994; Gereffi, Sturgeon, Humphrey, 2005) and Global Production Networks approaches (Coe and al, 2004; Coe et al, 2008; Henderson et al, 2002) that tried to break with the centre/periphery vision. These orientations were also at odds with international economics that, despite fine-tuning these schools of thought and explaining rising vertical trade (e.g. Baldwin, Venables, 2013) remained very embedded in factor endowment and country-centric reasoning. The general idea is to reconstruct firms' supply networks via two methodological principles:

1) A reticular conception of interfirm relationships. Firms are apprehended here as functional nodes that are interconnected for economic reasons (exchange relationships). Hence the need to study the spatial structure of these interconnections, which are simultaneously local and international.
2) The firms' network must be studied in light of a particular product/service. This is something of a reverse approach where one starts with the final product and reconstitutes the supply network to determine its functional logic and historic trajectory (the latter point being the crux of GPN analyses).

Significant analytical differences remain between GVC and GPN, making it difficult to find any compatibility between the two theorisations (Bair, 2008; Coe et al 2008). Given the aforementioned stylised facts and other elements developed below, there are three kinds of reasons to model the automotive industry's geography using a GPN framework.

GVC studies try to categorise typical governance forms implemented by anchor firms whose spatial embeddedness needs to be characterised. In terms of the aforementioned stylised facts, however, this approach raises two problems. In their desire to develop a useful typology demonstrating the coexistence of several kinds of value chains, the corpus adopts a static approach neglecting the depth and variety of chains within one and the same sector. In relation to this latter point, empirical work carried out by Sturgeon et al (2008) has recognised that automobiles can lend themselves to several forms of governance (including relational and captive). Having said that, detailed empirical studies have shown that the whole five types of governance can be observed in the auto sector, and even for one and the same carmaker. Carmakers can purchase several types of service from distinct actors (electronic components bought off-the-shelf; modules co-designed and co-produced with mega-suppliers; SME subcontracting arrangements, etc.). This variety problem comes with a depth problem in the sense that Tier 1 might feature one form of governance with other forms being present in other tiers. One example might be a relational form of governance applied for the purchase of a cockpit made by mega-suppliers calling upon subcontractor SMEs working under captive governance conditions. This dual problem is further complicated when we analyse networks not in terms of the final producer (carmaker) but at some intermediary point : a supplier can adopt one form of governance when relating to one carmaker but another form for another one.

These problems are easier to apprehend using the GPN approach that, more pragmatically, considers the need to specify bilateral relationships according to the activities actually being conducted. This particularly applies (especially further down pyramids that are necessarily unstable and changing, see stylised fact number 4) to firms working with several customers in several sectors (i.e. automobile but also aircraft). Spatially, this is an important point since it also assumes the need to build networks compatible with different customers' requirements. Another crucial point is if the goods being delivered are subject to significant economies of scale and delivery time constraints (stylised fact number 1). Clearly, carmakers exercise a certain attraction but cannot be considered flagship firms given that suppliers belong to several value chains – a diversity of membership better apprehended using GPN's more holistic approach (Ernst, Kim, 2002).

Another key aspect of GPN is the institutional dimension of inter-firm relationships, especially the importance of multi-dimensional embeddedness processes (Henderson et al, 2002[4]). In the automotive business, these issues affect two levels: macro-economic; and local.

In terms of the former, studies of the transfer of productive automotive models (Boyer, Freyssenet, 2002) have shown that from one institutional space to another, firms have had to adapt to national regulations, norms and practices (Boyer et al, 1998), i.e. it is a myth to say that there is some kind of transnational or stateless organisational model that is dominant in all institutional contexts (Freyssenet et al 1998). Clearly, there is a question here whether regional integration processes, specifically in Europe where they are very advanced, might have glossed over some of these national specificities. One example might be a multi-scalar regulatory system (Coe et al 2008, p.11-14) where harmonisation processes are expected to maximise convergence. Recent studies show that European automotive sector public policy is basically incomplete because firms remain embedded in their national settings and because nation-states still try to define supranational regulatory frameworks reflecting domestic manufacturers' interests (Jullien, Pardi, Ramirez, 2014). On the other had, as noted by Lagendijk (1997: 14) "On the sociopolitical front, the attachment of carmakers to their home country is still a pervasive factor that seems to fetter the transition to a European production system". National sites are closed less frequently than sites located in other European countries. It is also harder for carmaker to abandon a failing domestic supplier (especially when the case has been widely publicised) and easier to abandon a foreign supplier. The European Union has also helped to transform automotive GPN along continental lines by subsidising carmakers' new investments in Eastern Europe (and co-funding mass redundancy programmes in the West). By so doing, it helps to encourage an exploitation of institutional differences between EU member-states, despite the fact that the European customs union (and monetary union for 11 member-states) has created a unified commercial space. National differences in production coincide here with commercial unification. The two ingredients are exactly what is needed to create an international division of labour on a continental scale. The effects are not equally distributed throughout Europe, however, since a modicum of local embeddedness still exists.

The GPN approach clearly argues in favour of including findings from regional science studies (Coe et al, 2004). The approach's relational perspective highlights the effects of territorialisation (Dicken, Malmberg, 2001). Reflecting the degree of political decentralisation, the interactions of local actors (firms or institutional bodies) or their territorial embeddedness (Hess, 2004), productive resources are being developed and reproduced in many ways. Where stylised fact number 4 evokes SMEs' strategic responses, it is worth noting that these are based on a mobilisation of interfirm networks (territorialised or not) and on the mobilisation of local institutional infrastructures, whose density explains local strategies' effectiveness (Amin Thrift, 1993; Bailey et al, 2010). Automotive cluster case studies have all found similar phenomena to varying degrees (Herrigel, 2004; Rutherford, Holmes, 2008; Whitford, Enrietti, 2005). Even multinationals mobilise (and transform) local resources (Dicken, Forsberg, Malmberg, 1994), as demonstrated by the mega-supplier Delphi in Mexico (Carillo, 2004) or complexes built by (or organised) around carmaker plants in other places.

Another aspect is the power games that parties play when developing such networks. One consequence of the automobile's modularisation is the complication of market power. Succinctly, during the pre-modular era, relations between carmakers and suppliers corresponded to a Fordian model of descending domination, in both functional and decisional terms, i.e. it was a schema where carmakers dominated suppliers and subcontractors both technologically and economically (Chanaron, 1995). Although national models could be distinguished (Sako, Helper, 1995), power remained asymmetrically distributed, benefiting carmakers who became the real focal points for

[4] We know this is a terrible simplificiation but there is no room here for real discussion. To deepen understanding of the relationship between GPN, institutional concepts and forms of embeddedness, see Bair (2008) and Hess (2004).

product definition, and around whom there was a convergence of products coming from suppliers who remained largely dependent on historic carmaker customers. With the rise of modularisation, mega-suppliers partially freed themselves from this dual dependency, since they now had the key technologies that carmakers no longer controlled, or at least not sufficiently (Morris, Donnelly, 2006). Monopolistic competition tightened around several module series (Sutherland, 2005). The ensuing internationalisation broadened their customer portfolios. The end result was that depending on a carmaker's size and growth or decline trajectory (i.e., Hyundai vs. Fiat); depending on the potential market for a particular vehicle model (i.e. niche versus mass); and depending on the size and location of factories requiring supplies (i.e. a plant making 400,000 vehicles annually located at the heart of Europe versus another calibrated for 100,000 vehicles located in a country where the carmaker was the only operator) - the ability of a given carmaker to negotiate with mega-suppliers could be quite variable. This relativity in the balance of power between carmakers and mega-suppliers determined how value creation, and enhancement broke down between firms (Henderson et al, 2002). It also influenced the spatial organisation of interfirm networks.

1.2.2. A heuristic mapping of material flows in the automotive industry: focus on intra- and inter-firms flows and the depth of the supply pyramid

The GPN framework is useful because it helps to apprehend the many different dimensions of interfirm networks (material but also immaterial, like power and information). It does this by reasoning on several levels, ranging from the local to the global (cf. Figure 1, in Coe et al, 2008). Although we feel that this duality (multi-level and material/immmaterial) is essential and should be used to hypothesize and explain changes in intercontinental trade, the organisation of supply networks is so complex that we have come up with a simplified framework that only incorporates material input/output flows. The aim is to have a heuristic framework that can then be used to formulate hypotheses about the international trade in auto parts. As such, it neglects immaterial flows as well as dimensions that do not directly relate to trade (mainly institutional) but also, amongst material flows, suppliers of capital goods or services companies specialising in areas such as engineering, maintenance or logistics.

This choice can be justified by the need to increase the complexity of the representations habitually found in literature in both of these areas. Authors studying the automotive industry from a GPN/GVC perspective focus rarely on the differences between intra- and interfirms flows (see Coe et al, 2008, p.7-8). They also tend to neglect the depth of the supply pyramid.

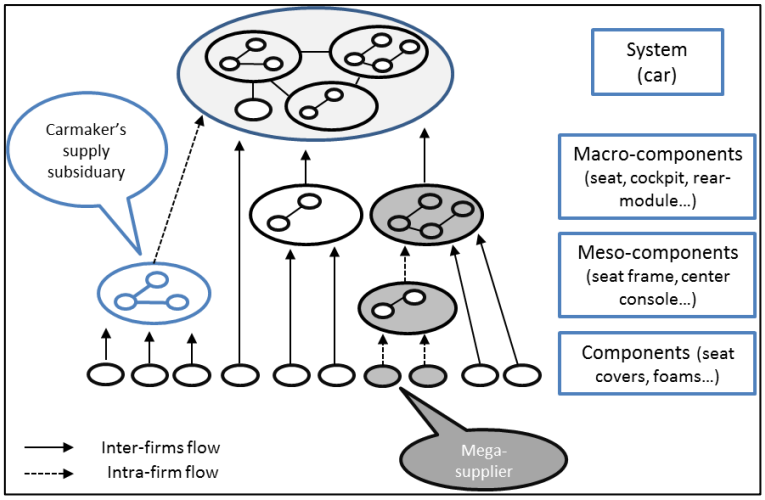
With regards to this latter point, recent studies of automotive modularisation have mobilised the notion of complex product architecture, with products being viewed as an interconnected hierarchy of different systems (Murman Frenken, 2006). Despite certain characteristics, automobiles are imperfectly modular (MacDuffie, 2013) yet automotive engineers still try to modularise them (Cabigiosu and al, 2013) with the help of mega-suppliers (Frigant, 2011). A linear and sequential view would describe the automotive value chain schematically as a pyramid interlinking three levels of parts, with the assembly plant located at the top of this pyramid. Carmakers buy 1) macro-components, which accounts for most of their procurement; 2) meso-components[5] when, for strategic reasons (like engines) or because they have no choice (i.e. local contents requirement) they maintain a high degree of vertical integration; and 3) components. The different levels then purchase meso-components and components from another, as illustrated in Figure 1.

After this technical breakdown of the production process, the next question relates to its organisational materialisation (Colfer, Baldwin, 2010; Campagnolo, Camuffo, 2010; Frigant, 2011).

[5] Meso-components are kinds of platforms on which macro-components can be built. The goal is to create economies of scale since each macro-component is specific to particular carmaker and usually a specific model. Another kind of meso-component is huge mechanical equipment like engines or transmissions which can be delivered to different car models (See Frigant, Layan, 2009 for more details).

Modularisation has forced mega-suppliers to increase their vertical integration (Klier, Rubenstein, 2008; Frigant, 2009). If their goal is to design, produce and sell macro-components, this means that they are already making many of their macro-components' constituent parts. In addition, in their bid to generate economies of scale, they tend to build units specialising in the production of meso-composants. Elementary parts, which we call components here, are either manufactured in-house or purchased from subcontractors. This generates two types of flows (respectively, intra-firm and inter-firm). Lastly, despite this vertical disintegration trend, carmakers are still responsible for making some of their key macro-components, like engines, gearboxes, etc. Figure 1 expresses this as intra-firm flows. One particularity of these kinds of production is that they are often at a distance from assembly plants. Hence the need to transpose this model along spatial lines.

Figure 1. Translating the concept of modularity to the automotive industry

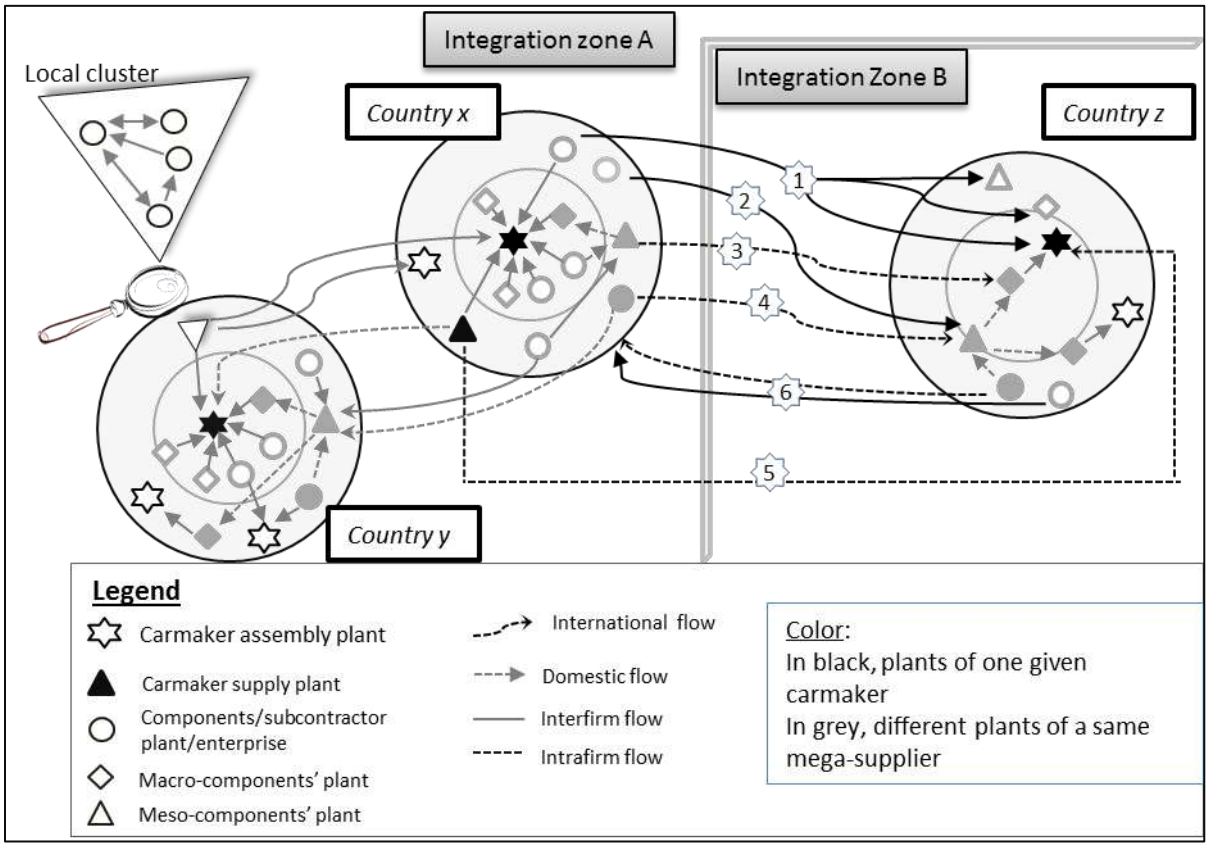


Source: authors

Figure 2 offers a representation of automotive production networks in space. In line with lessons drawn from GPN research, it highlights supply networks' multi-level spatial interconnectedness, starting with the local and going towards the global. The present paragraph focuses on the left-hand side of the figure. The right-hand side is dealt with in the section below.

Starting with interfirm flows (bold font in Figure 2), a first major interconnection node can be found amongst those clusters that last over time and are regenerated in time and space, as indicated in the first stylised fact and confirmed by automotive studies formulated in GVC (Sturgeon et al, 2008) and GPN (Coe et al, 2004) terms. Supplier clusters tend to found on a narrow perimeter surrounding automakers' plants, whether units belonging to mega-suppliers or SMEs. The second level is national, characterised by very dense connections with one particular point, namely the fact that the spaces in question can feature a dense fabric of suppliers without being located in a carmaker's immediate vicinity (see the 'local cluster' box in Figure 2). This can be witnessed, for instance, in Southeast France where automotive suppliers constitute a territorialised productive system from where they supply plants that can be quite far away. In these clusters (and similar to the clusters found around carmakers' factories), supplier relationships are dense and not necessarily linear. Depending on which customers a company wants to deliver, it can either act as an order-giver or as a subcontractor, even collaborating on specific projects while competing on others (Chanarron, 2013). Such companies are not even necessarily working only in the automotive sector, and certainly not just for one manufacturer. Some of them - potentially SMEs (stylised fact number 4) – are export-oriented and deliver their output either to mega-suppliers (when they operate in tiers 2 or 3) or directly to carmakers (when they operate in Tier 1). These exports are the flows between countries X and Y seen in Figure 2, which is relatively sparse to show that local and national trade densities are greater. Indeed, it is more through this kind intrafirm trade and large companies' organisation of an internal international division of labour that import/export flows can be forged.

Figure 2. Schematic representation of the automotive Global Production Networks



Note: This figure ignores the existence of logistics platforms comprising intermediary nodes linking different kinds of plants.
Source: authors

Two kinds of intrafirm flows feature on this figure. The first are internal to carmakers. This is because assembly plants are not the only productive units they possess. Most still have plants they use to produce mechanical assemblies (transmission, clutch, etc.) and/or driving systems (mainly engines). They will, however, run relatively few of these units, if only because they are trying to achieve economies of scale. Historically, these meso-component factories were located in carmakers' countries of origin and used to supply some of their other plants (Bordenave, Lung, 1996). The regional integration process means, however, that some carmakers built new meso-component plants in low-cost countries. Examples include Volkswagen and Opel, both of whom built major engine factories in Hungary, or else Daimler in Romania. Output from these factories was distributed macro-regionally to carmakers' different assembly plants.

The figure details the example of mega-suppliers. Stylised fact number 2 showed that they were at the heart of the international production fragmentation process. According to Frigant and Layan (2009), suppliers' dominance strategy has mainly consisted of fragmenting their production into three main phases corresponding grosso modo to the breakdown shown in Figure 1.

1. Plants or workshops dedicated to the final assembly of macro-components. Such units labour under lean management constraints. Their output is also hard to transport, meaning that they are very much influenced by proximity constraints. Typically, they are found in suppliers parks (Larsson, 2002; Sako, 2005) or in the immediate vicinity thereof.
2. The second category of units produce meso-components. The strategic goal here is to isolate this kind production in dedicated units in order to maximise economies of scale. Such plants tend to be few and far between and are ideally located at the centre of the different macro-component plants that they are supposed to be supplying - even if mega-suppliers' historic locations turn this optimisation model into something of a theoretical ideal.

3. The third type of units involves plants manufacturing components that can be used either to make meso- or macro-components, or else components to be delivered directly to a carmaker. In spatial terms, these units are the most footless. They are less subject to proximity constraints since they operate at a more upstream part of the value chain. They are also less subject to JIT constraints, their output is easier to transport and their flows can therefore be regulated via logistics platforms (something not illustrated on Figure 2). The need for interactions between users/producers is less intense here, meaning that they have no great need of working in proximity to suppliers or carmakers' R&D centres (Frigant, Layan, 2009).

GPN approaches also intimate a need to look at connectivity. Because of their degree of centrality (characterised by the number of connections they have and by the number of different actors with whom they are connected), some firms play key role in building up an overall network structure and in developing its specific projections. Two kinds of firms can be isolated here.

Clearly, carmakers are central to the equation since, quantitatively, the greatest number of flows converges around them. They also have connections to the largest number of suppliers. But the point we want to make here is actually a different one, highlighting carmakers' power to replicate supply networks in different countries. The reason is because their purchasing practices tend to promote follow sourcing. They encourage mega-suppliers (mainly) to duplicate their productive apparatus in countries where they have established operations. On our scheme, this can be seen in the formal duplication of networks centring around the carmaker's two plants (portrayed in bold font) in countries X and Y. This was perfectly true when similar models were manufactured in several plants on a continental scale. It is a kind of strategy that has tended to disappear to be replaced by the idea of having a single production site for each model. But, on the contrary, the advent of modular platforms, with the same types of modules or parts being used for several models, implies that these modules/parts need to be delivered to several plants. This particularity is one of the key points explaining the rise of intercontinental flows of automotive parts.

Mega-suppliers have also been characterised by a strong degree of centrality, something first witnessed at the intra-firm level since they tended to own a very large number of units (cf. Frigant, 2009). This results from the fragmentation strategies that they pursued; their merger/acquisition-based development trajectory, meaning that they inherited numerous sites; and their response to follow sourcing. They managed a major volume of intra-firm flows that were largely organised on a continental basis, replicating carmakers' regional integration logic (stylised fact number 3). In addition, these mega-suppliers called upon external suppliers themselves and, like carmakers, tried to continue working with their customary suppliers on all of their different sites. Sometimes Tier 2 or 3 suppliers would accompany them overseas but more often, the connection would be maintained via exports. This was especially the case when the goal was to conquer exotic and very distant markets situated on other continents.

2. Intercontinental exchanges of auto parts: which inventory? Why are they likely to grow?

In the automotive industry, intercontinental exchanges take a rather special form. With respect to strategy issues, firms consider themselves as global players, but from a commercial and productive point of view, they are stilled organized according to the so-called multi-multiregional scheme (Bélis-Bergouignan, Bordenave, Lung, 2000). The commercial space is most relevantly defined at the level of regional integration areas: inside an area, sold cars are relatively homogeneous, but cars sold in different continents are quite heterogeneous. There are of course similar products sold over all continents, but this is only the case of products belonging to small market segments (for each continent). There are also lots of seemingly similar car models that are in

reality closely tailored to local preferences, standards and use constraints.[6] This state of affairs largely explains why carmakers have sharpened their production facilities according to the continental scheme just mentioned. Another explanation is that car exportations over long distances are expensive because of the risk of materiel damage. For these raisons, macro-regional integration is dominant in the automotive industry (Carrillo, Lung, van Tulder, 2004)

With this in mind, we consider that auto parts exchanges « spontaneously » tend towards some macro-regional organization scheme. The existence of intercontinental trade flows is thus the result of a real effort in terms of strategy, based on 1) the exploitation of competitive advantages; 2) adaptation to institutional opportunities and constraints; 3) the nature of inter-firm relations.

2.1. A typology of intercontinental trade flows

Figure 2 illustrates the main flows that we have to explain.

Arrow 1 represents inter-firm flows which result from the specific nature of the production of the component manufactured by the supplier: of-the-shelf purchasing, production by suppliers which are not directly affiliated to the automotive value chain. This is e.g. the case for some electronic components: they are manufactured in factories characterized by high fixed costs and huge economies of scale, and they are not very exposed to logistical constraints. The double disaster of Fukushima and major floods in Thailand have highlighted in a dramatic way that carmakers and suppliers make use of such kinds of components delivered to destinations all over the world.

A second scenario is that of far-distance exchanges that result from anchoring in specific areas: either productions rely on particular know-how and/or on important knowledge externalities, indicating some kind of territorial effect; or they are anchored by resource scarcity. Anchorages may be artificially created by means of exportation restrictions applied in the host country. China for example set up measures in order to restrict rare-earth exports, so that companies that make use of this resource have to establish themselves in China, and then export the processed products[7] (Canis, Morrisson, 2013).

Arrow 2 reflects a mega-supplier driven strategy of international following without setting up of production facilities in the host country. This strategy namely applies to simple elements that are weakly affected by transportation constraints (i.e. they are easy to transport and characterized by low exposure to flow tensions). There are several reasons that may push carmakers to maintain their traditional rank 2 supplier: reduction of transaction costs (search for alternative suppliers); financial advantages linked to supplier-based economies of scale; reliability and high quality production of the traditional suppliers. These suppliers are typically much smaller and thus incapable of setting-up abroad production facilities; as long as there are no restrictions to exports, intercontinental exports are the most convenient solution, at least at the beginning, i.e. when the market size has not yet reached the point where local production facilities become profitable.

Flows 3 and 4 correspond to a rationale very close to that of intra-firms flows of mega-suppliers. Depending on eventual trade barriers and on the degree of implication of the mega-supplier in zone B, there are two distinct configurations. In both of them, the mega-supplier follows his customer (i.e. the carmaker) and sets up a factory where takes place final assembly of macro-components. However, this production facility may be provided with meso-components in two different ways. The first scenario is that of a customer-carmaker's assembly plant with a low

[6] Due to the frequent recourse to drivers, cars sold in China are lengthened in order to provide added legroom to the back seats ; heating systems are removed in India ; cars sold in Brazil are characterized by reinforced suspensions and high ground clearances (because of the bad state of the roads).

[7] "Rare earths are important in a number of automobile uses, including the manufacture of permanent magnets for hybrid and electric vehicle motors (…) restrictions include quotas, export taxes, production limits, and minimum export prices" (Canis, Morrisson, 2013: 18).

production level, and which is isolated in country Z: in this case, the mega-supplier provides its macro-components factory with meso-components produced in country X (arrow 3). In the second scenario, the factory of the customer-carmaker is of large size and/or there is another customer-client localized in country Z; this is precisely the moment where a process of duplication of the production facilities begins: the factories producing macro-components are now supplied by a meso-components' factory localized in country Z, and only some other components are imported from country X (arrow 4). In case of sufficient market size and favourable local conditions (skilled work force, respect of intellectual property rights), the mega-supplier may set up a factory in country Z that produces almost all necessary components (grey circle starting from arrow 6).

Carmakers choose a similar strategy of production facilities duplication. Initially, the factory localized in country Z is provided with meso-components which are typically produced in the carmaker's origin country (arrow 5[8]). In some cases, namely when the targeted market is too small, the assembly plant is only in charge of *Complete Knock Down* (henceforth: CKD), inducing thus high-valued trade flows (*cf.* the case studies of BMW in Coe et al., 2004, and Dacia in Jullien et al., 2013). This type of flows may last over time when the market remains on low levels; in case of growth of the targeted market (as in China), the best established carmakers join meso-components factories to their assembly plants, implying the decrease of the intercontinental flows in question.

The last kind of trade flows reflects a rationale clearly different from the preceding ones, which all rely on the idea of an international extension of the production networks established in the zone of origin of the carmaker/supplier. We now have to illustrate offshoring for reasons of costs compression. In order to highlight the distinctive nature of these flows, we reversed the direction of the arrows (arrow directions are of course unimportant in this schematic representation). We can identify two configurations. The first one concerns inter-firms relationships and corresponds to a situation where components are produced by a supplier localized in country Z. The second configuration concerns intra-firm relationships and reflects a rationale of international production fragmentation organized by a mega-supplier. The represented example is the following: a mega-supplier has set up a factory destined to provide a local production facility with meso-components, and he reimports towards country X a part of the production of this factory. It is not by accident that we pay attention to this scenario: in the last few years, several mega-suppliers have increased their production capacities in China in order to supply their local plants. However, when the 2008/2009 crisis seriously affected North America and Europe, some of their factories localized in these latter areas moved beyond the plant-closing threshold and were shut down; the mega-suppliers in question rely nowadays on their local factories (typically localized in China) in order to supply the production in their countries of origin (OTM, 2012). In our scheme, these flows are not associated to a specific arrival point in country x. They are indeed likely to provide either component suppliers, or mega-supplier production facilities for components or meso-components, or carmaker's factories. They also may provide the aftermarket parts. We have indeed to account for the fact that cars are durable goods; estimations of the proportion of auto parts destined to the aftermarket range from one quarter to one third. The associated trade flows go to auto parts stores and independent service outlets.

2.2. Assumptions about the dynamics of intercontinental flows in the 2000s

The six flow types discussed in the above typology have experienced profound transformations in the first decade of the 21th century, a decade marked by increased outsourcing in a context of growing modularization, by the emergence of mega-suppliers, by trade liberalization and some degree of standard harmonization, and by the integration of emergent countries into international trade, namely the emergence of a continent-country like China ; at the same time, differentials in

[8] Just one example: more than 70% of the Peugeot Citroen's automatic transmissions (model AL4) produced in France (Valenciennes) are exported to Peugeot's Chinese plants.

production costs, in exchange rates, and in national and territorial institutional specificities remained wide, inducing a consolidation of the differentiation of places. Against this background, how have intercontinental auto parts flows evolved?

The first flow type has probably increased. The growing complexity of cars has indeed induced a rise in the number of non-specific elements incorporated into cars, involving by the way a strong specificity of human and physical assets (in the sense of de Williamson, 1985). The producers of these components are providing many sectors and customers, so they are not incited to localize next to one of them; their choice of localization is governed by consideration that have nothing to do with bilateral supplier-customer relationship (economies of scale and quality in the case of electronics, proximity to rare resources in other cases)[9]. Note that at the same time, the factors for anchoring remained relevant: industrial and commercial policies, applied on a national or regional level in order to support and protect local producers, helped to consolidate the localization choices of these companies (*see* the case of Chinese rare-earth policies discussed in subsection 2.1).

At first sight, one could think that flows 2, 3 and 4 have largely augmented, because they are associated to economic players having experienced the highest growth rates over the last decade; at the same time, these players were engaged into a process of growing internationalization. However, the crucial question is that of the scale on which occurred the essential part of the process of mega-suppliers' internationalization. Empirical studies indeed suggest that they organized their production facilities on a continental scale, implying that this latter is the relevant scale for the fragmentation of the production process (stylized fact 3). The entry of new countries into the huge areas of regional integration offered new places enabling them to exploit production costs differentials, and to benefit in parallel from the ease of access favoured by commercial liberalization. Against this background, the growth of intercontinental flows carried by these firms is directly linked to their faculty of building macro-regional production facilities. A crucial point for the emergence of intercontinental flows is the maintenance of commercial regulations and production standards in far-distant located target countries. Some countries impose *local requirement contents* to carmakers (and their suppliers) who want to establish production sites in these countries. Note that in the case of small market sizes, carmakers will build low-level production facilities destined to reach the fixed thresholds, importing other components needed for production. This state of affairs highlights the importance of a second factor referring to the density (number of factories and volumes produced in each factory) of carmakers established in the targeted zone. *Ceteris paribus* (namely regulatory constraints) high densities of established carmakers incite suppliers to build important production facilities, implying significant contractions of intercontinental flows.[10] One should expect that, according to the degree of advancement of macro-regional integration of the different zones and to the density of local assembly plants, the empirical results will vary over the different zones.

Similar contrasting effects are relevant for carmakers' intra-firm flows. Without specific regulatory or tariff restrictions, carmakers tend to supply small markets by means of the construction of CKD or *Semi Knock Down* (henceforth: SMD) assembly plants, inducing important intercontinental flows. However, in the presence of regulation and of a market size sufficiently large to cover the break-even point, carmakers may build greater production facilities. We observe this kind of scenario

[9] OTM (2012) created the term « Tier 8 supplier» for those invisible, but crucial, suppliers.

[10] This dynamics can be observed in ASEAN. The policies in favour of the development of the Thai automotive industry (established in the 1960s) are based on the attraction of carmakers and on restrictions to parts imports; these two policy aspects aimed at fostering the emergence of a powerful supply industry destined to provide local carmakers. The signing of the Brand to Brand Complementation scheme at the end of the 1980s and the ASEAN Industrial Cooperation Organization in 1998 enabled suppliers to act more and more on a macro-regional scale (Lecler, 2002). On the ASEAN-level, a macro-regional division of labour set up, to which European and North-American mega-suppliers perfectly adapted when they started targeting this zone at the beginning of 2000s (Shimokawa, 2004).

in South America during the massive wave of implementation in the 2000s, and in Europe where several Asian carmakers established or reinforced production facilities. However, meso-components like certain engine or transmissions types are generally provided from the carmakers' origin countries. Against this general framework, China is somehow atypical: having become in 2009 the world's greatest car market, China constitutes a continental market on its own. Nevertheless, carmakers are positioned at different points of the trajectory of local implementation. The whole decade was the stage of a high speed chase between local demand and set up of supplementary production capacities. As a consequence, intercontinental exchanges driven by carmakers should have increased in a significant manner over this period.

The same holds true for intra-firms and inter-firms exchanges of components associated to a rationale of cost-compression (arrow 6); in this context, it is worth noting that the period in question was characterized by a reduction of far-distance exchange costs[11]. However, we should again expect important differences between the different zones of regional integration. There are in fact three kinds of reasons likely to induce pronounced differences between the three major macro-regions (North America, Europe, and Asia). First of all, each zone disposes of its own "outsourcing reserve". In Europe, the integration of Eastern European and Mediterranean countries implied new opportunities in terms of low production cost localizations. This effect was reinforced by aggressive attracting policies applied by these countries during the period in question (investment subsidies, profit tax credits, work force education and training programs …). Second, according to the rationale of global production networks, the density of trade flows is all the more important when the connection between the different spaces is ensured by national firms. We already highlighted that the high presence of North American suppliers in China is an explanation for the sustained growth of auto parts flows towards the United States (OTM, 2012). Finally, trade tensions/agreements explain pronounced changes in inter-zone flows; bilateral monetary fluctuations may also explain rather brutal reorientations of trade flows (intra-regional versus intercontinental flows)[12]. Overall, these flows are expected to have experienced a strong growth at a worldwide level, but with quite significant disparities over zones and sub-periods.

All in all, it seems difficult to make use of general reasoning in order to answer the question whether intercontinental exchanges have significantly increased over the period in question. Indeed, the arguments discussed above may cross each other with respect to zones, and the identified mechanisms may induce contradictory effects in the different spaces. For example, the relaxing of auto parts importation restrictions may provoke an increase of intercontinental imports, or rather the opposite, a decrease in case of a simultaneous process of macro-regional integration. Against this background, section 3 aims at evaluating the respective evolution of these two types of flows; the idea is to highlight which type evolves in the most dynamic way: intercontinental or intra-continental trade flows?

3. The 2000-2012 evolution of intercontinental auto parts trade: an empirical investigation

A modern car comprises more or less 10,000 elementary parts, such a way it is quasi impossible to map all the global production networks. But a frequently neglected source of information is exports/imports parts. If these data can not allow to describe precisely the network(s), they allow to catch the general trend and to answer to our question: are the auto global production networks becoming more intercontinental or macro-regional? For answering to this question, we

[11] Exchange costs break down into three elements: transportation costs which decreased over the 2000s (a little bit faster for long distances), exchange rates, and coordination costs that dropped drastically thanks to information and communication technologies.

[12] For an example on tire industry, see Canis, Morrison (2013).

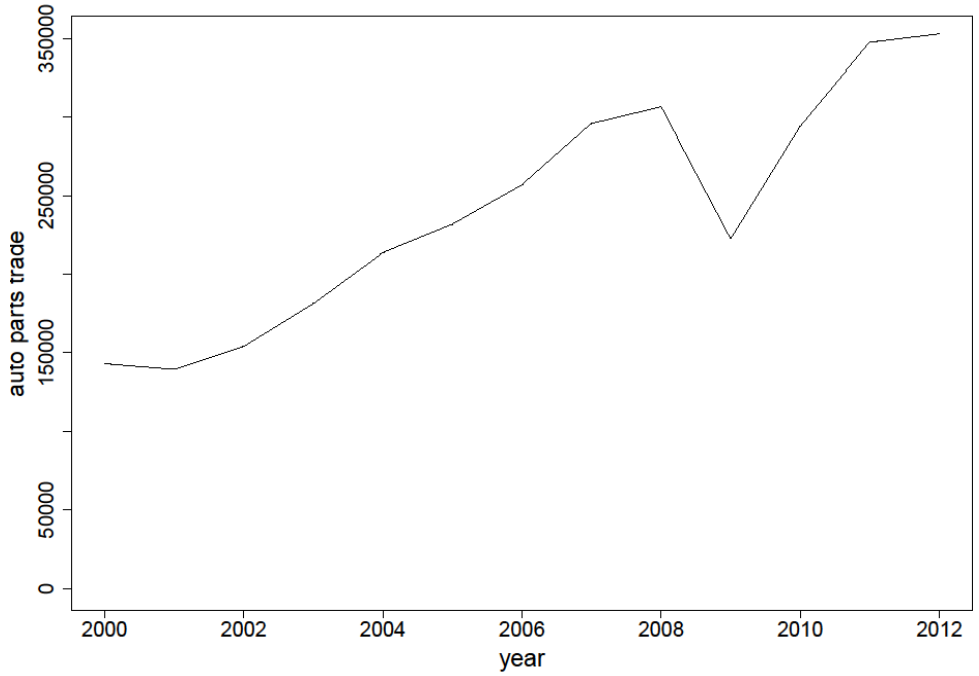
propose to build a specific index comparing the respective growth of far-distance and near-distance imports. The section 3.1 is going to explain how we collect the data, and why and how we built a particular index.

3.1. Data and methods

3.1.1. Data

Data used in this paper comes from *OICA* (Organisation Internationale des Constructeurs d'Automobiles) and from the *Chelem CIN Database*. More precisely, we make use of OICA data about the automobile production of nine large economic zones, and of international trade figures from 2000 to 2012 concerning the product category "auto parts" (designed by the acronym *FS* in the Chelem categorization). Note that Chelem international trade figures are given in millions of current US Dollars, i.e. in nominal terms.

Figure 3. Evolution of worldwide international auto parts exchanges (in million US Dollars) from 2000 to 2012.



Source: authors from Chelem database

We chose 2000-2012 data because of the profound mutations experienced by the automotive industry during this period. In fact, the production practices have been deeply impacted by the emergence of modularization and of vertical disintegration, giving rise to the appearance of mega-suppliers and to a genuine international division of labour (*see* stylized fact 3 in section 1). The 2000-2012 period has also witnessed a significant acceleration of regional integration: setting up (1999) and enlargements (2001, 2007, 2008, 2009, 2011) of the euro zone, entry of China into the World Trade Organization (2001), and enlargements of the European Union towards East and Central Europe in 2004 and 2007 (*see* stylized fact 2).

Figure 2 confirms that during the 2000s, the international exchanges of auto parts grew sharply. At the same time, the 2008/2009 crisis was clearly visible since the worldwide exchanges droped dramatically in 2009. Since this year, the auto parts exhanges knew a new growth and joined the previous trend. But, for our study, we need to break these global data by zones because the previous section suggested that the results will be different between macro-regions. So, we created 9 different economic zones defined as follows:

1. **Europe and its economic backyard** (henceforth noted ***EUR*** in equations, tables and graphics): *Europe (with exception of Russia, Ukraine, Belarus, Moldavia and former Soviet Caucasian states), Turkey, and North Africa (Algeria, Egypt, Libya, Morocco and Tunisia)*.
2. **The Commonwealth of Independent States** (henceforth noted ***CIS***) with exception of the Baltic States.
3. **Sub-Saharan Africa** (henceforth noted ***SSA***): *all African States with exception of Algeria, Egypt, Libya, Morocco and Tunisia.*
4. **Near and Middle East** (henceforth noted ***NME***): *Bahrain, Kuwait, Lebanon, Iran, Iraq, Israel, Jordan, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen.*
5. **East Asia** (henceforth noted **EAS**): *China, Cambodia, Hong Kong, Indonesia, Japan, Laos, Malaysia, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.*
6. **South Asia and Pacific** (henceforth noted ***SAP***): *Bangladesh, India, Pakistan, Sri Lanka and some small economies in Asia and Oceania.*
7. **Australia and New Zealand** (henceforth noted ***ANZ***).
8. **North America** (henceforth noted ***NAM***): *Canada, Mexico, and the United States of America.*
9. **South and Central America** (henceforth noted SAM): *all American States, excepted Canada, Mexico, and the USA.*

Trade flows between two states belonging to the same economic zone will be considered as "near-distance" exchanges; flows between states located in different zones will be regarded as "far-distance" exchanges, even in case of geographical neighbourhood of the states concerned, e.g. Poland (*EUR*-zone) and Ukraine (*CIS*-zone). Thanks to this binary distinction, we can attribute to each observed trade flow either a near-distance or a far-distance status. Applying this treatment to Chelem auto parts trade data, we get table 1.[13]

Table 1. Far and near-distance imports in 2000 and 2012 (in millions of current USD) and automobile production levels (number of produced cars)

	Far-distance imports		**Near-distance imports**		**Automobile production**		***Growth rate***
	2000	2012	2000	2012	2000	2012	*2000-2012*
EUR	6921.8	16478.1	56878.5	128074.2	19472902	17462745	*-0,1032*
CIS	448.4	14718.6	338.5	850.4	1269109	2472198	*0,9480*
SSA	1695.4	5295.8	48.7	204.6	357364	539424	*0,5095*
NME	1513	5798.1	9.4	45.2	277985	1013561	*2,6461*
EAS	4146.4	17739.6	6281.6	36174.1	16684737	38179642	*1,2883*
SAP	679.8	5784.9	59.9	138.8	801360	4145194	*4,1727*
ANZ	1542.3	2961.2	39	109.6	347122	209730	*-0,3958*
NAM	17346	43254.6	39145.4	53884.8	17697020	15794590	*-0,1075*
SAM	3949.6	13747.6	1096	4779.3	1681517	3342617	*0,9879*
WLD	38242.7	125778.5	103897	224261	58374162	84100167	*0,4407*

Source: authors from Chelem database and OICA database

3.1.2. Pitfalls of international trade figures… and how to avoid them: a useful data decomposition

First of all, we would like to address here the matter of how to interpret correctly the data assembled in table1. Interpretations are indeed likely to be misguided by two aspects of Chelem data:

i) Trade figures are given in nominal terms; changes over time of these trade figures thus may simply reflect variations in auto parts prices.

[13] Note that *WLD* refers henceforth to world data.

ii) Trade figures do not take into account the evolution of the automobile production; changes over time of auto parts imports of a given zone thus may simply reflect the fact that the zone's production level has changed.

With respect to these two potential sources of data misinterpretation, we propose the following decomposition of Chelem trade figures, henceforth noted $X_t^{i\to j}$:

$$X_t^{i\to j} \equiv P_t^{i\to j} \times x_t^{i\to j} \qquad (1)$$

where $X_t^{i\to j}$ stands for zone i's auto parts export earnings from zone j in year t (in millions of USD); $x_t^{i\to j}$ is a quantity index that describes the volume of auto parts exported from i to j in t, and $P_t^{i\to j}$ is the associated auto parts price index. Auto parts price changes mentioned under i) are now captured by $P_t^{i\to j}$-changes.

To the best of our knowledge, there is unfortunately no price index proposed by statistical offices corresponding closely or remotely to the auto parts index $P_t^{i\to j}$. There are of course national importation price inquiries, but only in a minority of countries (those endowed with the most efficient statistics institutes). What is more, these inquiries usually do not break down prices over the different origins of imports. These inquiries can thus be considered as reliable proxies for $P_t^{WLD\to j}$, but they do not enable us to decompose further in order to get proxies for $P_t^{EUR\to j}$, $P_t^{CIS\to j}$, …, $P_t^{SAM\to j}$, which are essential for our research approach.

The absence of a reliable proxy for $P_t^{i\to j}$ induces major difficulties to handle with this auto parts price index, especially when it comes to take into account for index evolutions over time (e.g. comparisons between $P_t^{i\to j}$ and $P_{t-k}^{i\to j}$ with $k > 0$). In this context, it is worth noting the following two points:

- $P_t^{i\to j}$ may or may not be affected by exchange rate variations. In fact, trade contracts denominated in dollars are not influenced by fluctuations of exchange rates (because Chelem trade data itself is dollar-denominated). On the contrary, trade contracts denominated in other currencies induce dependence of $P_t^{i\to j}$ with respect to variations between the dollar and the currencies in question. There is every raison to believe that both situations apply in one and the same price index, but in *a priori* unknown proportions.
- $P_t^{i\to j}$ depends heavily on composition effects: the structure of internationally traded auto parts evolves indeed rather quickly.

Under these circumstances, even the most prudent and reasonable assumptions about $P_t^{i\to j}$ are likely to be excessively hazardous. *A priori*, one could be tempted to assume that the index is characterized by a long-term downwards trend (thanks to productivity gains and cost-compressing international labour division). Now take for example a euro-denominated trade contract between some German carmaker and its Slovakian supplier. Even if the exchanged quantities of auto parts and the contracted exchange prices remain perfectly stable, this exchange relation would give rise to an increase of the price index $P_t^{SVK\to DEU}$ in case of an appreciation of the euro against the dollar, *ceteris paribus*.

Composition effects are probably even more disturbing. Imagine that the price of each individual auto part exported from Slovakia to Germany has decreased, but that at the same time, the proportion of expensive auto parts (e.g. car radios) has drastically increased. In this case, one may observe a $P_t^{SVK\to DEU}$-increase despite the overall auto parts deflation.

In spite of these difficulties, we will have to formulate working assumptions about the behaviour and the evolution of $P_t^{i\to j}$ in order to make practical use of decomposition (1).

We now account for the impact of automobile production levels in order to deal with data aspect ii).

Recall in this context that we address in our paper the issue whether *far-distance* auto parts exchanges (noted henceforth "far" in equations, tables and graphics) are becoming increasingly important. So one might be tempted to evaluate whether there is $x_t^{far \to j}$-growth. Now remark that pure observations of $x_t^{far \to j}$-growth are not necessarily very helpful when it comes to answer our research question: for example, $x_t^{far \to EUR}$-growth may simply reflect an increase in the European automobile production, leaving unchanged the average quantity of far-distance imported auto parts used to build each individual automobile. But a scenario where European carmakers continue to import the same quantity of far-distance auto parts *per produced automobile* can hardly be regarded as a manifestation of an increasing importance of far-distance imports.

In order to control for the evolution of the automobile production, we propose to introduce a *per automobile* version of the auto parts quantity index, noted $G_t^{i \to j}$:

$$G_t^{i \to j} \equiv \frac{x_t^{i \to j}}{y_t^j} \qquad (2)$$

where y_t^j is zone j's automobile production in t (i.e. the number of produced automobiles) and where $G_t^{i \to j}$ measures the *per automobile volume* of auto parts exported from i to j (i.e the number of auto parts from i incorporated in the "average" automobile produced in zone j).

With this index per automobile, we get for equation (1) :

$$X_t^{i \to j} \equiv P_t^{i \to j} \times y_t^j \times G_t^{i \to j} \qquad (3)$$

3.1.3. A formalization of our research question

With data decomposition (3), we are now able to formalize our research question. Recall that we wanted to know to which extend the internationalization of the automotive global production networks has an impact on far-distance auto parts exchanges (henceforth noted "far" in equations, tables and graphics). Is intercontinental auto parts trade becoming increasingly important, i.e. do far-distance exchanges grow faster than near-distance exchanges (henceforth noted "near")?

In order to capture an eventual increase of the proportion of far-distance exchanges, we propose to compare $\frac{G_t^{far \to j}}{G_{t-k}^{far \to j}}$ and $\frac{G_t^{near \to j}}{G_{t-k}^{near \to j}}$, i.e. the gross growth rates from t - k to t of the far-distance and the near-distance $G_t^{i \to j}$-indexes. The easiest way of proceeding is to built the ratio

$$\delta_{t-k,t}^{far/near \to j} \equiv \frac{\frac{G_t^{far \to j}}{G_{t-k}^{far \to j}}}{\frac{G_t^{near \to j}}{G_{t-k}^{near \to j}}} = \frac{\frac{X_t^{far \to j}}{X_{t-k}^{far \to j}}}{\frac{X_t^{near \to j}}{X_{t-k}^{near \to j}}} \times \frac{\frac{P_{t-k}^{far \to j}}{P_t^{far \to j}}}{\frac{P_{t-k}^{near \to j}}{P_t^{near \to j}}} \times \frac{\frac{y_{t-k}^j}{y_t^j}}{\frac{y_{t-k}^j}{y_t^j}} = \frac{\frac{X_t^{far \to j}}{X_{t-k}^{far \to j}}}{\frac{X_t^{near \to j}}{X_{t-k}^{near \to j}}} \times \frac{\frac{P_{t-k}^{far \to j}}{P_t^{far \to j}}}{\frac{P_{t-k}^{near \to j}}{P_t^{near \to j}}} \qquad (4)$$

for each zone of the nine economic zones mentioned in subsection 3.1.1, and for the entire world. Ratio $\delta_{t-k,t}^{far/near \to j}$ interprets best as a relative growth index: superiority to unity indeed reflects that from t –k to t, far-distance imports to zone j have grown faster than near-distance imports.

Due to the absence of a trustworthy proxy for the auto parts price index $P_t^{i \to j}$, we have to rely on the working assumption that

$$\pi_{t-k,t}^{far \to j} = \pi_{t-k,t}^{near \to j} \qquad (5)$$

i.e. we assume that the inflation rate of far-distance auto parts imports $\pi_{t-k,t}^{far \to j} = \frac{P_t^{far \to j} - P_{t-k}^{far \to j}}{P_{t-k}^{far \to j}}$ is equal to that of near-distance imports. In this case, equation (4) simplifies to

$$\delta_{t-k,t}^{far/near\to j} \equiv \frac{\frac{G_t^{far\to j}}{G_{t-k}^{far\to j}}}{\frac{G_t^{near\to j}}{G_{t-k}^{near\to j}}} = \frac{\frac{X_t^{far\to j}}{X_{t-k}^{far\to j}}}{\frac{X_t^{near\to j}}{X_{t-k}^{near\to j}}} \qquad (6)$$

i.e. we get rid of the double price ratio on the right hand sight of equation (4). Assumption (5) is of course rather strong, but there is no other obvious way of dealing with the considerable uncertainty about far-distance and near-distance auto parts prices, and about their relative evolution.

Note that the production level denominator y_t^j of the *per automobile* quantity index $G_t^{i\to j}$ (*see* equation (2)) has vanished from the relative growth index $\delta_{t-k,t}^{far/near\to j}$, because the associated numerator and denominator terms are identical (*see* equation (4)). This is problematic because production levels have much varied over the 2000--2002 period, and these variations are likely to explain a lot of the growth-differentials between far-distance and near-distance imports. In order to reintegrate this dimension into our analysis, we build the zone comparison index $\delta_{t-k,t}^{far\to m/n}$, which allows for direct zone-to-zone comparisons, and, most importantly, for zone-to-world comparisons:

$$\delta_{t-k,t}^{far\to m/n} \equiv \frac{\frac{G_t^{far\to m}}{G_{t-k}^{far\to m}}}{\frac{G_t^{far\to n}}{G_{t-k}^{far\to n}}} = \frac{\frac{X_t^{far\to m}}{X_{t-k}^{far\to m}}}{\frac{X_t^{far\to n}}{X_{t-k}^{far\to n}}} \times \frac{\frac{P_{t-k}^{far\to m}}{P_t^{far\to m}}}{\frac{P_{t-k}^{far\to n}}{P_t^{far\to n}}} \times \frac{\frac{y_{t-k}^m}{y_t^m}}{\frac{y_{t-k}^n}{y_t^n}} \qquad (7)$$

A ratio higher than 1 highlights that the number of far-distance imported auto parts (per produced automobile) has risen faster in zone m than in zone n between periods t-k and t. Numerical assessments of ratio (7) require the working assumption $\pi_{t-k,t}^{far\to m} = \pi_{t-k,t}^{far\to n}$.

To complete the picture, we also evaluate the index $\delta_{t-k,t}^{near\to m/n}$

$$\delta_{t-k,t}^{near\to m/n} \equiv \frac{\frac{G_t^{near\to m}}{G_{t-k}^{near\to m}}}{\frac{G_t^{near\to n}}{G_{t-k}^{near\to n}}} = \frac{\frac{X_t^{near\to m}}{X_{t-k}^{near\to m}}}{\frac{X_t^{near\to n}}{X_{t-k}^{near\to n}}} \times \frac{\frac{P_{t-k}^{far\to m}}{P_t^{far\to m}}}{\frac{P_{t-k}^{far\to n}}{P_t^{far\to n}}} \times \frac{\frac{y_{t-k}^m}{y_t^m}}{\frac{y_{t-k}^n}{y_t^n}} \qquad (8)$$

designed to compare the relative growth of near-distance imports in the zones m and n.

3.2 Results

Before presenting the results for the indexes (4), (7) and (8), it is very instructive to compare the proportions of far-distance auto parts imports in the different economic zones. The far-distance shares reported in table 2 enable us to identify three groups:

- The "historical core" of the automotive industry: Europe, North America and East Asia. These zones are characterized by relative low shares of far-distance imports. This state of affairs is best explained by the presence of a dense and powerful network of suppliers localised in these zones. These suppliers provide the bulk of auto parts used by local carmakers, reducing mechanically the importance of far-distance originated supply flows.
- The "automotive periphery": Australia/New Zealand, Near/Middle East, South America, South Asia/Pacific and Sub-Saharan Africa. The automobile production of these zones corresponds essentially to assembly plants belonging to carmakers headquartered in the industry's "historical core". These assembly plants are largely (almost exclusively in the case of Australia/New Zealand, Near/Middle East and Sub-Saharan Africa) supplied by the mega-suppliers that are used to produce auto parts for the carmakers in question. As most of these mega-suppliers are localized in Europe, North America and East Asia, these auto parts deliveries are accounted for as far-

distance imports. Consequently, we observe fairly high far-distance shares (exceeding 75% in 2000 and remaining at similar orders of magnitudes up to 2012).

- The "special case" of the Commonwealth of Independent States: this zone is marked by a very impressive progression of the far-distance share. Situated in 2000 at an intermediate level of 57 %, it goes up to 94.5 % in 2012. This sharp increase reflects the fact that carmakers from the "historical core" set up assembly plants in this zone[14], whose auto parts procurements are essentially provided by far-distant located mega-suppliers.

Table 2. Share of far-distance imports and relative growth comparison indexes

	WLD	**EUR**	**CIS**	**SSA**	**NME**	**EAS**	**SAP**	**ANZ**	**NAM**	**SAM**
2000 share	0.269	0.109	0.570	0.972	0.994	0.398	0.919	0.975	0.307	0.783
2012 share	0.359	0.114	0.945	0.963	0.992	0.329	0.977	0.964	0.445	0.742
$\delta_{t-k,t}^{far/near \to j}$	**1.524**	**1.057**	**13.066**	**0.744**	**0.798**	**0.743**	**3.672**	**0.683**	**1.812**	**0.798**

On the basis of this preliminary overview, we now consider the outcomes for the relative growth index (4) reported in the bottom line of table 2. Importantly, we observe a world index which is clearly superior to unity ($\delta_{2000,2012}^{far/near \to WLD} = 1.524$) indicating that far-distance imports have grown faster than near-distance imports at a worldwide level. This global result breaks down into extremely heterogeneous local situations:

- There is a growth-differential in favour of far-distance imports in North America, South Asia/Pacific and in the Commonwealth of Independent States. This suggests an extension of auto global production networks at a more widespread scale.
- Far and near-distance growth rates are approximately the same in Europe ($\delta_{2000,2012}^{far/near \to EUR} \cong 1.524$). This suggests that Europe build its auto global production networks in an equilibrium way (the rhythm of integration of new countries (East and Africa) follows the growth of imports from far-distance countries).
- In East Asia and the remaining zones of the "automotive periphery" (Australia/New Zealand, Near/Middle East, South America and Sub-Saharan Africa), near-distance imports have grown faster than far-distance imports. This suggests the emergence of a regional integration process.

Recall that these results have to be handled with care, because they disregard production level variations. Table 3 presents the outcomes of the zone comparison indexes (7) and (8) that take explicitly account of these variations. In this context, we will concentrate on the first column that compares each zone's growth-rate with the world growth rate.

This change in perspective provides a better informed view of the dynamics of far-distance imports. In fact, first impressions relying on the relative growth index $\delta^{far/near \to j}$ may be literally upset by the supplementary information provided by the zone comparison indexes $\delta^{far \to m/n}$ and $\delta^{near \to m/n}$. This is for example the case of Australia/New Zealand, whose growth index of 0.683 a fairly sluggish evolution of far-distance imports. Table 3 clearly proves the contrary: the zone's growth index (1.392) is the second highest in the world (after the CIS)! Two elements explain this rather radical change of perception: the evolution of automobile production levels, and the dynamics of near-distance imports. In fact, the gross growth rate of far-distance nominal imports of the *ANZ*-zone is rather modest with respect to the world gross growth rate:

[14] If we consider the full owned passenger cars assembly plants: Renault established plant in 1998, Nissan in 2007, Hyundai in 2010, Toyota in 2007, Volkswagen (VW, Skoda and Audi) in 2007, PeugeotCitroën (with Mitsubishi) in 2010. We can also add some joint-ventures like GM-AvtoVAZ (2002) in Togliatti, the two plants of Ford-Sollers (2002 then 2011) but also domestic carmakers producing CKD or SKD cars (like Avtotor in Kaliningrad who produces Kia, Hyundai, Opel, Chevrolet, BMW passengers cars).

$$\frac{X_{2012}^{far\rightarrow ANZ}}{X_{2000}^{far\rightarrow ANZ}} = 1.920 < 3.289 = \frac{X_{2012}^{far\rightarrow WLD}}{X_{2000}^{far\rightarrow WLD}}.^{15} \quad (9)$$

We now introduce the fact that the automobile production has increased by 44 % on a worldwide level, but it decreased by nearly 40 % in the *ANZ*-zone (*see* the last column of table 1). We thus get the following gross growth rates *per produced automobile*:

$$\frac{G_{2012}^{far\rightarrow ANZ}}{G_{2000}^{far\rightarrow ANZ}} = 3.178 > 2.283 = \frac{G_{2012}^{far\rightarrow WLD}}{G_{2000}^{far\rightarrow WLD}}.^{16} \quad (10)$$

With this correction for automobile production levels, the dynamic of far-distance imports of the *ANZ*-zone appears much more vigorous.

Table 3. Zone comparison indexes of far-distance and near-distance imports

Far-distance imports $\delta_{2000,2012}^{far\rightarrow m/n}$										
	WLD	EUR	CIS	SSA	NME	EAS	SAP	ANZ	NAM	SAM
WLD	1	0.860	0.135	1.103	2.169	1.221	1.388	0.718	0.817	1.304
EUR	1.163	1	0.158	1.283	2.522	1.420	1.614	0.835	0.950	1.516
CIS	7.381	6.348	1	8.143	16.007	9.013	10.243	5.303	6.031	9.623
SSA	0.906	0.780	0.123	1	1.966	1.107	1.258	0.651	0.741	1.182
NME	0.461	0.397	0.062	0.509	1	0.563	0.640	0.331	0.377	0.601
EAS	0.819	0.704	0.111	0.903	1.776	1	1.136	0.588	0.669	1.068
SAP	0.721	0.620	0.098	0.795	1.563	0.880	1	0.518	0.589	0.940
ANZ	1.392	1.197	0.189	1.536	3.019	1.670	1.932	1	1.137	1.815
NAM	1.224	1.052	0.166	1.350	2.654	1.494	1.698	0.879	1	1.596
SAM	0.767	0.660	0.104	0.846	1.663	0.937	1.064	0.551	0.627	1
Near-distance imports $\delta_{2000,2012}^{near\rightarrow m/n}$										
	WLD	EUR	CIS	SSA	NME	EAS	SAP	ANZ	NAM	SAM
WLD	1	0.597	1.162	0.538	1.136	0.595	3.344	0.322	0.971	0.683
EUR	1.676	1	1.947	0.902	1.904	0.998	5.605	0.540	1.628	1.145
CIS	0.861	0.514	1	0.463	0.978	0.512	2.879	0.277	0.836	0.588
SSA	1.858	1.108	2.158	1	2.110	1.106	6.213	0.598	1.805	1.269
NME	0.880	0.525	1.023	0.474	1	0.524	2.944	0.284	0.855	0.601
EAS	1.680	1.002	1.951	0.904	1.908	1	5.618	0.541	1.632	1.147
SAP	0.299	0.178	0.347	0.161	0.340	0.178	1	0.096	0.290	0.204
ANZ	3.105	1.852	3.607	1.671	3.527	1.848	10.383	1	3.016	2.120
NAM	1.029	0.614	1.196	0.554	1.169	0.613	3.443	0.332	1	0.703
SAM	1.464	0.874	1.701	0.788	1.663	0.872	4.897	0.472	1.422	1

We then have to consider the impact of the dynamics of near-distance imports. The lower part of table 3 highlights that the *ANZ*-zone has experienced the highest growth of near-distance imports in the world. The rather low value of the relative growth index $\delta^{far/near\rightarrow ANZ}$ thus simply reflects the fact that the progression of near-distance imports was even more impressive than that of far-distance imports.

[15] Note that these two ratios are not directly available from our tables. They are computed on the basis of table 1 data : $\frac{X_{2012}^{far\rightarrow ANZ}}{X_{2000}^{far\rightarrow ANZ}} = \frac{2961.2}{1542.3} = 1.920$ and $\frac{X_{2012}^{far\rightarrow WLD}}{X_{2000}^{far\rightarrow WLD}} = \frac{125778.5}{38242.7} = 3.289$.

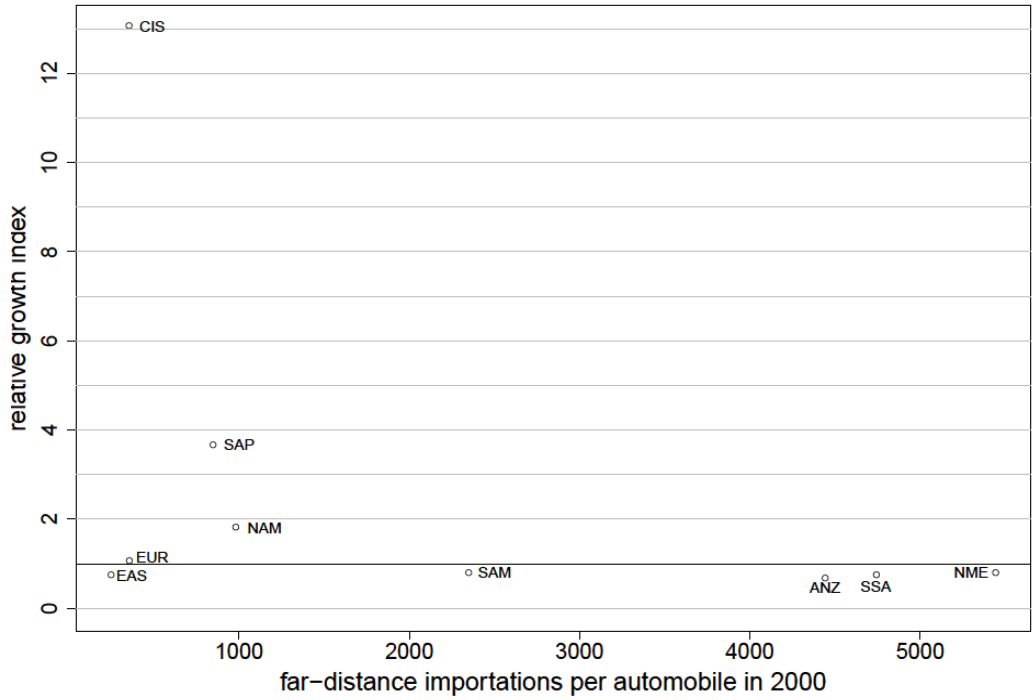
[16] These ratios are again computed on the basis of table 1 data: $\frac{G_{2012}^{far\rightarrow ANZ}}{G_{2000}^{far\rightarrow ANZ}} = \frac{X_{2012}^{far\rightarrow ANZ}}{X_{2000}^{far\rightarrow ANZ}} \times \frac{y_{2000}^{ANZ}}{y_{2012}^{ANZ}} = \frac{2961.2}{1542.3} \times \frac{347122}{209730} = 3.178$ and $\frac{G_{2012}^{far\rightarrow WLD}}{G_{2000}^{far\rightarrow WLD}} = \frac{X_{2012}^{far\rightarrow WLD}}{X_{2000}^{far\rightarrow WLD}} \times \frac{y_{2000}^{WLD}}{y_{2012}^{WLD}} = \frac{125778.5}{38242.7} \times \frac{58374162}{84100167} = 2.283$. Note that we find the zone comparison index $\delta_{2000,2012}^{far\rightarrow AUS/WLD} = 1.392$ (*see* table 3) by dividing $\frac{G_{2012}^{far\rightarrow ANZ}}{G_{2000}^{far\rightarrow ANZ}}$ by $\frac{G_{2012}^{far\rightarrow WLD}}{G_{2000}^{far\rightarrow WLD}}$.

The same reasoning applies to the European case. Table 2 could lead us to believe in a rather moderate progression of far-distance imports: the European relative growth index $\delta^{far/near \to EUR}$ is clearly inferior to the world index. However, we have to deal with the shrink of the European automobile production, as well as with its worldwide expansion. This is done by the zone comparison index $\delta^{far \to EUR/WLD}$. Table 3 shows without ambiguity that far-distance imports *per produced automobile* have grown faster in Europe than in the world.

South Asia/Pacific is an example of the opposite effect. The relative growth index $\delta^{far/near \to SAP}$ of 3.672 suggests a spectacular growth of far-distance imports, which is not confirmed by the zone comparison index $\delta^{far \to SAP/WLD}$ of 0.721. This sharp difference between the two indexes is due to the fact that the zone's automobile production increased more than eight-fold, whereas its far-distance imports increased fivefold. These two elements put together give rise to a decrease of far-distance imports *per produced automobile*. In the relative growth index $\delta^{far/near \to SAP}$, this slowdown was hidden by an even more pronounced slowdown of near-distance imports.

It is worth noting that for all other zones, the perception of far-distance imports dynamics is basically the same for the relative growth index $\delta^{far/near \to j}$ and the zone comparison index $\delta^{far \to m/n}$.

Figure 4. Scatter graph: 2000-level of per automobile far-distance imports (in USD) against the relative growth indexes $\delta^{\mathrm{far/near \to j}}$.



Note: Zones above the black line are characterized by $\delta^{\mathrm{far/near \to j}} > 1$, i.e. far-distance imports have grown faster than near-distance imports.

Finally, we address the question of how to interpret the heterogeneous imports dynamics observed in the different economic zones. In this regard, it is rather instructive to have a look on a scatter graph with the 2000-level of per automobile far-distance imports on the abscissa axis and the relative growth index $\delta^{far/near \to j}$ on the ordinate axis: indeed, figure 4 suggests a "catch-up" process. With exception of East Asia, far-distance imports have grow faster than near-distance importation in all zones where the 2000 level of per automobile far-distance imports was relatively low (say, inferior to 1000 dollar). The predominance of the growth of far-distance imports in these

zones seems thus to be due to some kind of "backlog" of far-distance imports, i.e. to their initial lowness with respect to the international standard.

Conclusion and discussions

In this paper we argued that inter-firm and intra-firm exchange networks govern the volumes and directions of international auto parts exchanges. These networks are mainly structured by carmakers and mega-suppliers. From this heuristic point of view, we aimed at qualifying different automotive zones, and to investigate whether the origins of import flows have significantly evolved over the 2000—2012 period. While more and more research papers are highlighting increasing interconnections, including on a global scale (Milberg, Winkler, 2013; UNCTAD, 2013; OECD, 2013), we wanted to examine the hypothesis that the automotive industry somehow resists "full" globalization. There is overall validation of this assumption; note that we have to account for some degree of heterogeneity between the economic zones under examination in this paper. We will make use of the global networks approach in order to explain this latter fact.

Indeed, our study shows that the degree of "intercontinentalization" of auto parts exchanges is very heterogeneous over the distinguished zones. Europe, East Asia and North America make use of relatively few far-distance imports. On the contrary, peripheral and/or emergent zones rely more heavily on far-distance imports. This first result seems to indicate that the three core zones of the automotive industry were able to organize a macro-regional division of labour. The European case is particularly striking: the proportion of far-distance imports (with respect to the entire set of imports flows) remains low, and the ratio between far- and near-distance imports is quite stable. This state of affairs suggests that despite of the implementation of new "exotic" carmakers (Hyundai, Geely, Kia, Suzuki …) and the temptations of outsourcing, suppliers of macro-, meso- and other components are massively implanted in broader Europe. Intra-European flows increased by 125.2% from 2000 to 2012, which nicely illustrates the widening of the European-scaled division of labour. This evolution enabled suppliers to discover new areas (in Eastern Europe and North Africa) in order to segment their production process on a larger scale and to take profit from the national differences which subsisted between countries (in terms of labour costs, labour legislation, implementation subsidies, labour force skill …). In the most peripheral zones – in the sense that their automotive industry is younger and less powerful - macro-regional integration is weaker and import flows tend to come from the "historical core" of the automotive industry. With respect to these peripheral countries, we can however distinguish two scenarios: The Commonwealth of Independent States and South Asia/Pacific seem to rely increasingly on importations from the historical core; on the contrary, we observe the setting up of some macro-regional integration in Sub-Saharan Africa, Near/Middle East, Australia/New Zealand and South America. The South American case (where US-American and European carmakers are heavily implanted since the 1990s, namely in Brazil and Argentina) accurately reflects the roles of carmakers' power and of import restrictions. A significant wave of assembly-plant implementation of carmakers has indeed taken place in a context of increasing modularization, putting pressure on suppliers to apply follow sourcing; at the same time, the need to adapt cars to local constraints made it necessary to redesign certain elements. Mega suppliers had to implement local engineering capacities, and to reproduce locally these elements. This transfer was particularly massive, because trade barriers between continents were high, but increasingly low on the regional scale thanks, to the creation of MERCOSUR (Humphrey, 2000; Humphrey, Salerno, 2000). Nevertheless, the intense volatility of local production[17], monetary uncertainty, and the possibility to transfer equipment with high-level economies of scale, imply some intermediate

[17] This high market and production volatility is a prominent feature of these "new carmaking countries" (Lung, 2000). Suppliers are exposed to an important risk of non-covering of fixed costs in case of a sudden downturn in the market. In the absence of regulatory devices (tariff and non-tariff barriers to entry, local standards …), they tend to postpone the most expensive investments.

position for the South American zone. In Sub-Saharan Africa, Near/Middle East and Australia/New Zealand, these forces are less powerful: from the carmakers' point of view, assembly-plants are of more accessory nature (so they are less able to require massive follow sourcing from their mega-suppliers); there are also clearly less trade barriers in these zones. As a consequence, production networks tend to expand over long distances.

In North America, on the contrary, the process of regional integration seems to have reached its limits. The share of elements coming from far-distant zones increases noticeably over the period in question (growing up to 44%), implying an index $\delta^{far \rightarrow NAM/WLD}$ that is greater than in the other zones of the historical heart of the automotive industry. Four issues may explain this. 1) some kind of exhaustion of the process of regional integration (suppliers' implementation started pretty early in Mexico[18] , see Carrillo, Contreras, 2007); 2) the integration of Asia into world trade, namely of China that joins in 2001 the World Trade Organization, offers new localization opportunities for low cost production of components (less exposed to proximity constraints) destined both to original car equipment and to the spare parts market (US Department of Commerce, 2011); 3) on a more isolated basis, the setting up of specific regulations (e.g. rare earth restrictions, Canis, Morrison, 2013) that compel certain production types to the areas where they are in force; 4) finally, and from a business cycle perspective, the crisis that impacts heavily the United States in 2008/2009, incites several suppliers to shut down their North American production sites just at the moment where they set up new production capacities in Asia (having become the world's leading market). With the economic recovery of the USA in 2010, these suppliers make use of their production capacities newly implemented in Asia (as well as of their Canadian and Mexican capacities) in order to provide the US market.

This latter explanation highlights the importance of trade flows primarily shaped by mega-suppliers. It also helps us to interpret the trajectories of peripheral countries that experienced a sustained growth of their car production. In fact, the implementation of new production capacities in the Commonwealth of Independent States (car production augments by 94.8% from 2000 to 2012) coincides with an important increase of far-distance importations. In an economy weakly endowed with suppliers satisfying to international standards, supply networks build up on the basis of the origin country of the carmakers localized in this economy (Renault, General Motors…See footnote 13). According to our framework, this phenomenon is best explained by the low density of the carmakers' production facilities that incite to implement macro-component factories (heavily impacted by proximity constraints), but not production facilities for meso- and other components, which remain, at least for now, in the country of origin of carmakers and mega-suppliers. If this analysis is correct, then we would join an important point of the GPN approach (Henderson et al., 2002, Coe et al., 2008): the weight of history. In fact, our results suggest that local production networks build up slowly, and that this building process is based on the implementation of a carmaker. As a first step, automotive production networks tend to extend from the historical national bases of carmakers and mega-suppliers in order to provide the new assembly-plants; as a second step, the implementation of other types of production (meso- and other components) gets possible in case of augmentation and solidification of national production levels.

When it comes to further supporting of this assumption, it would obviously be helpful to dispose of more precise data. In fact, data used in this study refers to the Chelem product category "automotive parts" that assembles quite heterogeneous elements: components, meso-components and macro-components. It would be appropriate to make use of more detailed statistical data in order to test the different assumptions presented in section 2 in a more exhaustive and precise way.

[18] Things are quite different in Europe, where this process only started at the end of the 1990s (Havas, 2000; Sadler, 1999; Lagendijk, 1997), and where implementation opportunities were constantly renewed thanks to EU enlargements and to agreements with African countries.

Furthermore, the problem of price movements needs to be addressed; in view of the imperfect availability of auto parts price data, concentration on a few countries seems unavoidable.

Recall in this context that we precisely aimed at painting an accurate picture of the current movements. Indeed, the GVC and GPN approaches are sometimes accused of being exclusively based on monographic studies (Sturgeon, Gereffi, 2009). This kind of methodology enabled to collect precise elements about the functioning of supply networks; but it may be criticised for the fact that as a matter of principle, the generalisation of the results is always questionnable. By observing the dynamics of intercontinental trade flow evolutions, we aim at contributing to this research agenda in an original manner. The different trajectories of the different zones distinguished in our paper are in fact better explained by GPN arguments than in terms of an approach of factor endowments of the areas in question, or by a centre/periphery rationale. We can give meaning to the observed evolutions by using the six flow types presented in figure 2. These latter are based on the nature of exchanged elements, on the economic actors who are carrying trade flows, on the moment where we take the photo of the situation, on the existence of institutional constraints/opportunities, and on the power exerted on suppliers by carmakers and mega-suppliers. These elements precisely form the core of the GPN research agenda, to which we hope our study has contributed in a useful way.

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