Trade agreements and the geography of motor vehicle production in North America and Europe

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Abstract: This paper describes changes in the geography of the production of vehicles and sourcing of powertrains in both North America and Europe between 2000 and 2016. During that time period, new trade agreements in both regions resulted in larger economic geographies within which vehicle and parts producers could organise production. We show that as trade relationships encompassed larger geographies, powertrain sourcing and vehicle assembly diffused across countries within each region. At the same time, trade agreements did not alter the traditional forces affecting regional integration patterns within the industry, rather they changed their geographical reach at a subregional level.

Keywords: Europe; North America; vehicle production; engine; transmission; trade agreements; geography.

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1 Introduction

This article compares the vehicle production regions of North America and Europe, two regions that feature rather similar footprints and that have been shown to have been shaped by agglomerative forces in similar ways (see Klier and Rubenstein, 2015). Specifically, it documents changes in the geography of production of vehicles and sourcing of powertrains within North America and Europe between 2000 and 2016, capturing a time period during which the implementation of trade agreements in both regions–the North American free trade agreement (NAFTA) and the enlargement of the European Union (EU)–resulted in a larger economic geography within which vehicle and parts producers could organise production.

In North America, the implementation of NAFTA in 1994 brought Mexico into a free-trade zone that had been created by Canada and the US back in the 1960s. The five carmakers with production facilities in Mexico prior to the ratification of NAFTA were given preferential treatment for the first decade of the agreement (Iliff, 2016). Vehicle production increased rapidly in Mexico during the second decade of the agreement, once other carmakers were allowed to benefit from NAFTA provisions. Mexico's share of North American light vehicle production rose from 10.8% in 2000 to 19.7% in 2016.

In Europe, ten countries joined the EU in 2004, the largest single expansion in EU history. Most were former Communist countries in Central and Eastern Europe. Included were five with some vehicle production: Czechia, Hungary, Poland, Slovakia, and Slovenia. Romania, also a former Communist country with a history of vehicle production, joined the EU in 2007.

While global in nature, today's motor vehicle industry is highly integrated within specific regions (Layan, (2000), p.122; Head and Mayer, 2019). Underlying the location decisions in the industry are enduring economic geography principles of agglomeration and economies of scale. The paper asks if trade agreements have altered the relevance of these principles in location decisions.[1] We find that at a regional scale the traditional forces shaping the industry still prevail: there was little change to the share of either vehicles or powertrains imported from outside the region in both North America and Europe subsequent to the enlargement of both economic geographies.

Within both North America and Europe, trade agreements have shaped the subregional-scale distribution of production facilities. In both regions, the countries added relatively recently to the regional trade agreements have gained as production locations. Despite differences between North America and Europe regarding the industry footprint as well as in the specific features of the trade agreements, observed changes in the two regions' geographic sourcing patterns display more similarities than differences, noticeably a greater reliance on multiple countries within each region. Financial incentives, such as tax abatement, support for worker training, and infrastructure construction, play an important role in location decisions at a local or community scale, but not at the regional and subregional scales, which are the focus of this paper (Appel-Molot, 2005; Rubenstein, (1992), pp.213–231).

The paper is structured as follows. Section 2 reviews economic geography principles that help to explain the distribution of auto industry, namely agglomeration and economies of scale. In Section 3 we discuss the source of our data. Section 4 presents evidence of changes to the distribution of production between 2000 and 2016 at the regional scale. Section 5 offers similar evidence of geographic change at the subregional or subarea scale. In both cases we focus on changes in the geography of both vehicle

production and engine and transmission sourcing for vehicles produced in both regions. Section 6 provides a summary discussion.

2 Principles underlying the distribution of vehicle production

Two economic geography factors underlie the distribution of motor vehicle production: agglomeration economies and economies of scale. Trade agreements have not altered the importance of these factors.

2.1 Agglomeration

Today's motor vehicle industry, while global in nature, is highly integrated within specific regions (Layan, (2000), p.122; Head and Mayer, 2019). For example, most vehicles sold in North America are assembled at plants in North America, with the principal components–notably engine and transmission–also produced in the same region. Similarly, most vehicles sold in Europe are assembled in Europe, with engines and transmissions typically made in Europe. Enduring economic geography principles, notably agglomeration economics, underlie the pattern of assembling most vehicles in the same region as they are sold (Klier and Rubenstein, 2015, 2017).

According to Brincks et al (2018)

> "Motor vehicle production is highly agglomerated because it is a good example of what Weber (1929) called a bulk-gaining industry. A bulk-gaining industry is characterised by a fabricated product that is heavier and occupies a greater volume than its inputs [Rubenstein, (1992), p.11]. To minimise the aggregate costs of bringing in raw materials and shipping out finished products, final assembly in a bulk-gaining industry, such as motor vehicles, tends to locate near consumers [Klier and Rubenstein, (2015), p.205]."

2.2 Regional trade agreements and trade

Although highly agglomerated, vehicle production facilities within North America and Europe are distributed among multiple countries. As a result, most vehicles sold in North America have been produced at engine, transmission, and final assembly facilities located in more than one North American country. Similarly, most vehicles sold in Europe have been produced at engine, transmission, and final assembly facilities located in more than one European country.

Economic geography provides a framework for understanding the impact of regional trade agreements on trade among members within a region as well as among regions (Viner, 1950). The formation or expansion of a trading block can result in trade creation and trade diversion. Trade creation, which is the increase in trade among member countries, occurs because the removal of trade barriers between member countries allows for greater specialisation according to comparative advantage. Trade diversion refers to the substitution of trade with low-cost producers outside the trading block with trade among countries within the trading block. Trade diversion typically results from the imposition of trade barriers between member countries and non-member countries.

However, regional trade agreements differ in terms of establishing common boundaries to non-member countries. A customs union, such as the EU, features trade

barriers that are common to its member states. On the other hand, NAFTA and its successor USMCA are not customs unions. Each member country can pursue trade agreements with other countries on its own.

2.3 Production sub-regions within North America and Europe

Consistent with the literature (see for example, Mordue and Sweeney, 2020; Pavlínek, 2018), we define three production sub-areas within North America and Europe, the two regions of interest in this paper–core, semi-periphery, and integrated periphery[2]:

- North America
  a Core: the US
  b Semi-periphery: Canada
  c Integrated periphery: Mexico.
- Europe
  a Core: France, Germany, Italy.
  b Semi-periphery: Austria, Belgium, Portugal, Spain, Sweden, the UK.
  c Integrated periphery: Czechia, Hungary, Poland, Romania, Serbia, Slovakia, Slovenia.

The US is classified as North America's core production subarea. Within the US, most production is clustered in auto alley, a north-south corridor between Michigan and the Gulf of Mexico and between the Appalachian Mountains and the Mississippi River. Powertrain production was highly concentrated in Southeastern Michigan and nearby states for most of the twentieth century.

Motor vehicle production clustered in or near Southeastern Michigan in the early twentieth century in part because expertise in manufacturing powertrain components was already there. Thus, Ford produced its engines and transmissions in Dearborn, and Chrysler in Detroit, while GM produced most of its engines in Flint and most of its transmissions in Saginaw and Toledo. After World War II, the Detroit 3 expanded powertrain production into other communities along the southern Great Lakes between New York State and Wisconsin (Klier and Rubenstein, 2008).

The emergence of auto alley as the home of most the US auto production in the late twentieth century reinforced the concentration of powertrain plants in the region. Since the emergence of the southern portion of auto alley during the late twentieth century, every assembly plant located in an East- or a West-coast State has been closed, with one exception.

Europe's core subarea is centered on western Germany and northern France (Jürgens and Krzywdzinski, 2008; Lung, 2004).[3] 'The internal combustion engine was first perfected in Germany and France' (Flink, (1990), p.11). Belgian mechanic Étienne Lenoir is credited with manufacturing in a Paris workshop the first commercially successful internal combustion engine (ICE), for which he received a French patent in 1860. Lenoir is also credited with operating motor vehicles with his engine in the early 1860s. An ICE built by Lenoir in 1861 is on display at the Musée des Arts et Métiers in Paris. During the 1890s and into the first few years of the twentieth century, Paris was the centre of motor vehicle production [Flink, (1990), p.15].

German manufacturer Nikolaus Otto began building ICEs in Cologne, Germany, 1861, at first based on Lenoir's specifications. Otto's company, established in 1864, was the first formed for the purpose of manufacturing ICEs. Otto is best known for developing the four-cycle ICE–intake, compression, power, and exhaust–still used today. The Otto engine was the basis for the development of Germany's modern motor vehicle industry in the 1880s by Gottlieb Daimler, Karl Benz, and their associates. Daimler's engine plants in the Stuttgart and Mannheim areas date back to around 1900.

Motor vehicle production developed independently elsewhere in Europe in prior to World War II, notably in the UK and Italy. The establishment of the Common Market in 1958, with its subsequent successors and expansions, promoted the establishment of assembly and powertrain plants outside the traditional production areas, such as southern Italy and Iberia.

Production facilities in both North America and Europe have been increasingly located in subareas identified in previous studies as the integrated periphery, which comprise Mexico in North America and several former Communist countries in Central Europe (Brincks et. al., 2018; Chanaron, 2004; Domański and Lung, 2009; Humphrey and Oeter, 2000; Jürgens, 2004; Jürgens and Krzywdzinski, 2008; Ludger and Dehnen, 2009; Lung, 2000; Mordue and Sweeney, 2020; Pavlínek, 2002, 2014, 2018). In both North America and Europe, the countries in the integrated periphery are the ones brought into the enlarged trade areas around 2000. By 2016 the integrated peripheries of Europe and North America had become home to similar numbers and shares of regional production for final assembly, engine, and transmission plants.

2.4 Economies of scale

In addition to agglomeration, the current geography of final assembly operations and powertrain sourcing is influenced by the legacy of vertical integration and underlying variations in economies of scale. A key element of a vehicle, the engine remains an almost exclusively vertically integrated part: Only 5% of engines are outsourced to independent suppliers in North America and 1% in the European assembly plants included in our study. For transmissions, the degree of vertical integration is not quite as strong yet remains substantial; while independent producers have captured double-digit shares of transmission sourcing in both regions, the extent of vertical integration remains high (77% in Europe and 88% in North America). The substantial extent of vertical integration observed in powertrain production suggests that location decisions concerning vehicle assembly and powertrain production are made within the same corporate entity.

Economies of scale influence how many plants are needed for assembly operations and for powertrain production (Cedillo-Campos et al., 2006; Klier and Rubenstein, (2015), p.104; Lung, 2004; Truett and Truett, 1996, 2001, 2003; Wynn-Williams, 2009). Important in the context of this paper is that economies of scale in powertrain production are substantially larger than those in vehicle assembly. For example, Husan (1997, p.40) cites studies conducted in the 1970s that identified annual economies of scale ranging from 400,000 to 2 million for pressing body panels, from 250,000 to 1 million for powertrain fabrication, and from 200,000 to 300,000 for final assembly. According to Rhys (1977), "motor industry sources put the car assembly optimum output in the range of 200,000 to 300,000 units per year on a two-shift basis, with that for powertrain manufacture being 500,000 identical units" (p.316).

As a result, carmakers can manufacture in powertrain plants more blocks, heads, gears, and other parts to go into engines and transmissions than they can assemble finished vehicles in a given time period. A single line in a final assembly plant can turn out approximately one vehicle per minute, whereas a single line at a powertrain plant can turn at least twice that number (Glynn, 2018). According to Rhys (2005, p.264), the optimum scale of engine casting is 1 million units per year, nearly twice as large as that of engine machining and assembly (approximately 600,000 units). Thus, one casting operation can support several engine machining and assembly lines.

Table 1 supports findings from the earlier literature about different magnitudes in economies of scale between vehicle assembly and powertrain production. It summarises data underlying the paper.

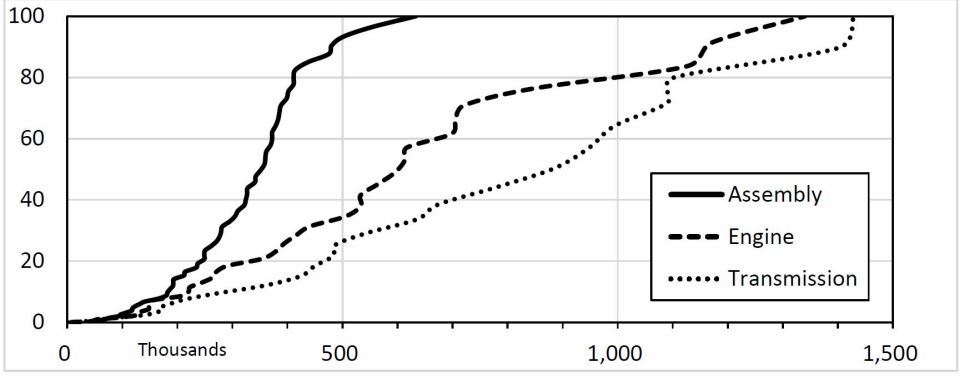
Table 1 Number and output of final assembly and powertrain plants in North America and Europe, 2016

	Assembly		*Engine*		*Transmission*	
	N.Am.	*Europe*	*N.Am.*	*Europe*	*N.Am.*	*Europe*
Number of included plants	63	75	37	40	27	35
Est. mean plant production [000 units]	281	241	421	522	526	560

Notes: The table excludes vehicle assembly plants that produced less than 50,000 units in 2016, as well as assembly plants performing contract work for carmakers. The estimated mean includes production at engine and transmission plants known to be shipped to assembly plants in Europe and North America and an estimate of the number shipped to the rest of the world.

Source: Authors' calculations based on data from IHS Markit as of October 2017

Figure 1 Cumulative share of assembly, engine, and transmission plant output in North America, 2016

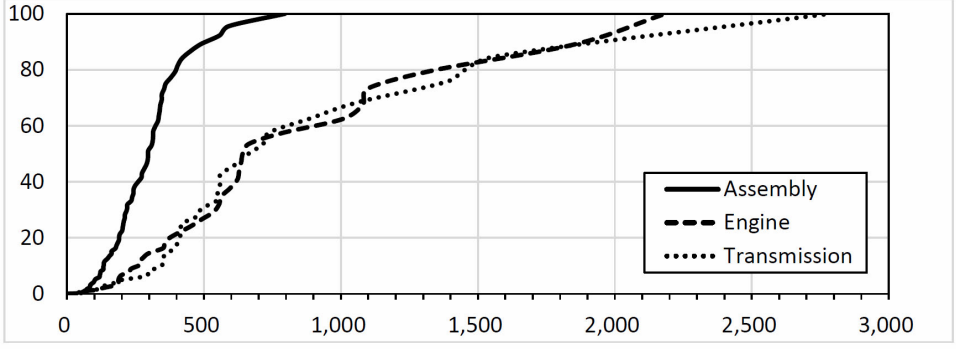


Source: Authors' calculations based on data from IHS Markit as of October 2017

The three types of plants display similar sizes in Europe and North America. In 2016, mean output at final assembly plants was 281,000 vehicles in North America and 241,000 in Europe, at engine plants 421,000 in North America and 522,000 in Europe, and at

transmissions plants 526,000 in North America and 560,000 in Europe. Figures 1 and 2 illustrate the differences in plant size with the cumulative distribution of assembly and powertrain plant production in 2016 for North America Figure 1 and Europe Figure 2. Except for the fact that Europe's largest powertrain plants are noticeably larger than those in North America, the distributions are quite similar across the two regions.

Figure 2 Cumulative share of assembly, engine, and transmission plant output in Europe, 2016



Source: Authors' calculations based on data from IHS Markit as of October 2017

A feature related to the differences in economies of scale in vehicle and powertrain production is that engines and transmissions are typically not unique to individual vehicle models but are shared across a range of models. This approach is common to all large volume vehicle producers, as engines and transmissions not only exhibit larger economies of scale than vehicle production, but also different, typically much longer, development and production cycles (Centre for Automotive Research, 2017).

3 Data

This paper relies primarily on proprietary data purchased from IHS Markit. IHS Markit data provide information at a much more detailed level than is available from government or United Nations data, which utilise the harmonised tariff schedule (HTS) classification. The data include information on the owner and location of the vehicle assembly plant, engine plant, and transmission plant for every vehicle assembled in Europe and in North America between 2000 and 2016.

Powertrain data are especially important for understanding the industry's sourcing geography, because it accounts for nearly the same share of the cost of vehicle production as final assembly (Cregger et al., 2012). Because each vehicle with an internal combustion engine features an engine and a transmission, the data show a 1:1 correspondence among assembled vehicles, engines, and transmissions.

The database also includes details concerning the volume of each specific vehicle, engine, and transmission models produced at each factory. However, information is limited to finished engines and transmissions, and does not extend to the origin of individual parts, such as pistons and gears.

This paper references only vehicles assembled with internal combustion engines, thus excluding all electric vehicle production. Also excluded are assembly plants with production of less than 50,000 vehicles in 2016, as well as plants owned by independent contractors that perform assembly operations for a variety of carmakers.[4] The included assembly plants produce cars and light trucks in North America and cars and light commercial vehicles in Europe; excluded are assembly plants that specialise in heavy-duty vehicles. The countries included in the assembly plant data are the three members of NAFTA and fifteen vehicle-producing members of the EU as of 2016. Europe includes the UK, which withdrew from the EU in 2020; also included in the fifteen is Serbia, which was granted formal candidate status by the EU in 2012. Assembly plants in Austria and the Netherlands qualify for inclusion in data for 2000, whereas none in Serbia qualify that year.

The data at our disposal include all engines and transmissions sourced by assembly plants in Europe and North America regardless of where they were produced. That enables us to achieve a precise 1:1 ratio between assembly operations and powertrain sourcing.

Note that our data do not include the number of engines and transmissions produced in Europe and North America for export to the rest of the world. Thus, for example, we know the number of engines and transmissions imported from Asia to Europe and North America, but we do not know the number exported to Asia from Europe and North America.

4 Regional integration and trade agreements

We stipulated earlier that vehicle production is highly integrated at the regional scale. This section discusses the extent to which vehicle production and powertrain sourcing in North America and Europe is integrated within each of the regions, and how that has changed between 2000 and 2016.

As the expanded geography of the trade areas in North America and the EU have been in place for some time now, producers have been able to take advantage of easier movement across national borders to allocate final assembly and powertrain production operations among multiple countries within the two regions. Therefore, we would expect to find an increasing number of vehicles sold in North America to be produced at engine, transmission, and final assembly facilities located in more than one North American country. Similarly, many vehicles sold in Europe would be produced at engine, transmission, and final assembly facilities located in more than one European country.

We measure the extent of the integration of vehicle production within North America and within Europe in two ways:

1 Reliance on a production region: The share of assembly operations and powertrain sourcing taking place within the region, rather than being imported from elsewhere in the world.

2 Reliance on multiple countries within a production region: The share of assembly operations and powertrain sourcing dispersed among more than one country in the region rather than concentrated in only one of the region's countries.

4.1 Share of vehicles and powertrains imported from the same region

The share of light vehicles sold in each region that were also produced in the same region is consistently high, fluctuating between 76% and 82%. That measure strongly suggests a high degree of regional integration of vehicle assembly. Over the observation period, the share of imports of finished vehicles from outside each region has risen slightly from 2000 to 2016: from 17.8% to 23.7% in North America, and from 20.0% to 20.7% in Europe Table 2. Those increases may be related to the easing of trade for each of these two regions with countries elsewhere. New economic trade theory suggests that consumer preferences for variety drive trade in differentiated versions of the same good (Mostashari, 2010). Accordingly, trade in like goods increases as the variety of the good increases.

Table 2 Change in vehicles and powertrains imported from other regions [%]

% imported from other regions	*Vehicles*		*Engines*		*Transmissions*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*
North America	17.8	23.7	11.6	14.1	25.1	23.3
European Union	~20	20.7	3.5	5.6	7.7	14.8

Source: Automotive News Data Centre, Mexico Automotive Industry Association, and European Automobile Manufacturers Association (vehicles) and IHS (powertrains)

What do we know about the origin of powertrains (engines and transmissions) for vehicles assembled in North America and Europe, respectively? Here too the level of reliance on the immediate production region is high: regional sourcing of engines fluctuates between 86% and 94%. For transmissions the percentage varies a bit more, ranging from 75% to 92%. As in the case of finished vehicles, the reliance of powertrain sourcing on the immediate production region declines somewhat during the observation period, for engines from 88.4% to 85.9% in North America, and from 96.5% to 94.4% in Europe. In the case of transmissions, the share declines from 92.3% to 85.2% in Europe, but rises from 74.9% to 76.7% in North America.

North American assembly plants increased their imports of engines from other regions from 12% in 2000 to 14% in 2016. Assembly plants in Europe imported very few engines from other regions in 2000 or in 2016, though the share did increase from 4% in 2000 to 6% in 2016.

The share of transmissions imported into Europe's assembly plants increased more substantially, from 8% in 2000 to 15% in 2016. The sole exception to the pattern of increased imports is a slight decrease in the share of transmissions imported into North American assembly plants, from 25% in 2000 to 23% in 2016. The decrease is the result of a significant expansion of transmission production in Mexico during that time period. Of the eight transmission plants operating in Mexico in 2016, six were added after 2000. All of the six are part of the supply chain of three vehicle producers that have been producing vehicles in North America for quite some time: GM, Honda, and Nissan.

4.2 Share of powertrains made in the same country as final assembly

Our second measure of regional integration looks at the reliance of sourcing on multiple countries from within the same region. How has that changed between 2000 and 2016? It

turns out that sourcing from within a region has become more integrated in the sense that it relies on balance to a larger extent on more than one country. We observe that trend consistently across both regions and for both powertrain components.

The share of engines and the share of transmissions sourced from a different country than where the vehicle was assembled in the same region increased between 2000 and 2016 in both North America and Europe, although modestly in all cases. In North America, the share of engines sourced from another country in the same region increased from 30.7% to 30.9%, and the share of transmissions sourced from another country increased from 26% to 28%. In Europe, the share of powertrains sourced from another country in Europe increased a bit more, from 47% to 54% for engines and from 41% to 46% for transmissions. For Europe, the level of powertrain imports from other countries within the same region is likely higher than in North America simply due to the smaller footprint of individual countries within Europe.

On the other hand, the share of both engines and transmissions sourced in the same country as the final assembly operations declined in both North America and Europe between 2000 and 2016. The declines were modest in North America (US), from 58% to 55% for engines and from 49.4% to 48.8% for transmissions. The declines were more substantial in Europe, from 49% to 41% for engines and from 51% to 40% for transmissions Table 3.

Table 3 Change in powertrain sourcing compared with final assembly operations [%]

Powertrain sourcing compared with final assembly operations	*North America*				*Europe*			
	Engine		*Transmission*		*Engine*		*Transmission*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*	*2000*	*2016*
Same country as final assembly	57.7	54.9	49.4	48.8	49.1	40.7	51.1	39.6
Same region, different country	30.7	30.9	25.5	27.8	47.4	53.8	41.2	45.6
Different region	11.6	14.1	25.1	23.3	3.5	5.6	7.7	14.8

Source: Authors' calculations based on data from IHS Markit as of October 2017

A more restrictive measure provides the same geographic breakdown for sourcing both engine and transmission from the same country. The share of both powertrain components produced in the same country as final assembly is lower than that of sourcing only the engine or only the transmission. In 2016, only 31% of final assembly operations in North America sourced both engine and transmission from the same country as the final assembly plant, and only 22% in Europe. While most engines and transmissions are produced in the same region where the final assembly plants are located, relatively few vehicles are put together with engine, transmission, and final assembly operations all in the same country.

Combining the two measures of integration, reliance on one region and reliance on multiple countries within a region, we find that sourcing within both regions has become more integrated. That reflects the trade creation effect ascribed to regional trade agreements. Not surprisingly, the reliance on only one country within a production region

declined. On net, however, the share of powertrains sourced from outside the region has increased somewhat.

We suggest the varying economies of scale among final assembly, engine, and transmission production play a role here. For example, a company may need to open two assembly plants and ramp up production to one-quarter million vehicles annually before justifying the construction of a new transmission plant which would operate most efficiently with an annual output of one-half million. A carmaker that has entered either Europe or North America for the first time since 2000 or with only one vehicle assembly plant (for example Mazda and Audi in Mexico), most likely relies on imports of powertrain components from outside the region until its assembly output is large enough to justify a powertrain plant in the same region.

The exception to that pattern represents transmission sourcing in North America: the share of transmissions imported from elsewhere for vehicle assembly in North America declined slightly between 2000 and 2016. However, at 23%, it represents the highest level of imports of either component in either region even in 2016.

5 Extent of integration among subareas within regions

This section examines changes in the sourcing geography within each of the two regions. We utilise the concepts of core, semi-periphery, and integrated periphery.

5.1 Distribution of final assembly and powertrain sourcing in 2016

In 2016, 39 of North America's 62 assembly plants producing at least 50,000 vehicles were in the core subarea, defined as the US, along with 22 of 37 engine plants and 19 of 27 transmission plants Table 4. The core subarea for Europe's powertrain production is home to a remarkably similar number of final assembly, engine, and transmission plants as in North America: 36 of the region's total of 75assembly plants, 19 of 40 total engine plants, and 21 of 35 total transmission plants.

Table 4 Number of powertrain and assembly plants by location, 2016

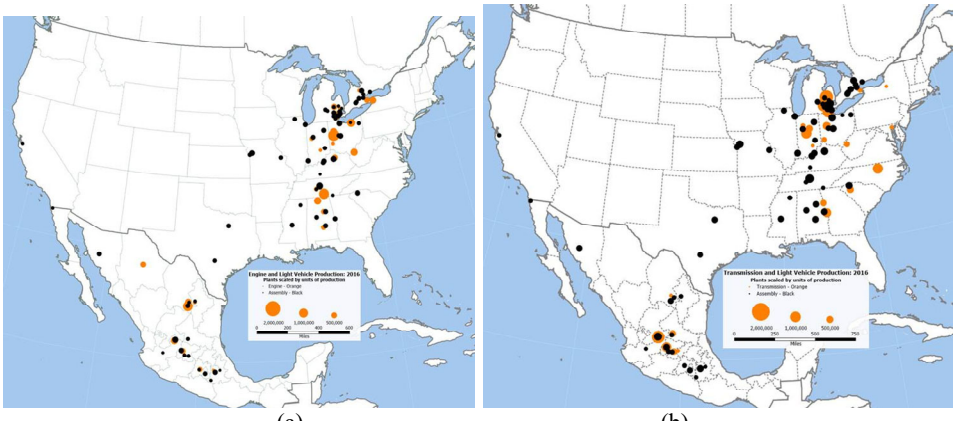
Sourcing share	*Final assembly*		*Engine*		*Transmission*	
Location	*N. Am.*	*Europe*	*N. Am.*	*Europe*	*N. Am.*	*Europe*
Core	39	36	22	19	19	21
Auto alley	35	32	22	15	16	15
Other	4	4	0	4	3	6
Semi-periphery	8	23	4	12	1	5
Integrated periphery	15	16	11	9	7	9
Total	62	75	37	40	27	35

Notes: The table excludes assembly plants that produced less than 50,000 units in 2016, as well as assembly plants performing contract work for carmakers. For Europe, auto alley is defined as France and Germany, Italy represents the other core country.

Source: Authors' calculations based on data from IHS Markit as of October 2017

The 22 engine plants in the North American core in 2016 were all in auto alley, including seven in Michigan and four in Ohio Figure 3. The 19 transmission plants in the US included 16 in auto alley, with three each in Indiana, Michigan, and Ohio. In Europe, the 19 engine plants in the core included 12 in Germany, three in France, and four in Italy Figure 4. The 21 transmission plants in the core included nine in Germany and six each in France and Italy.

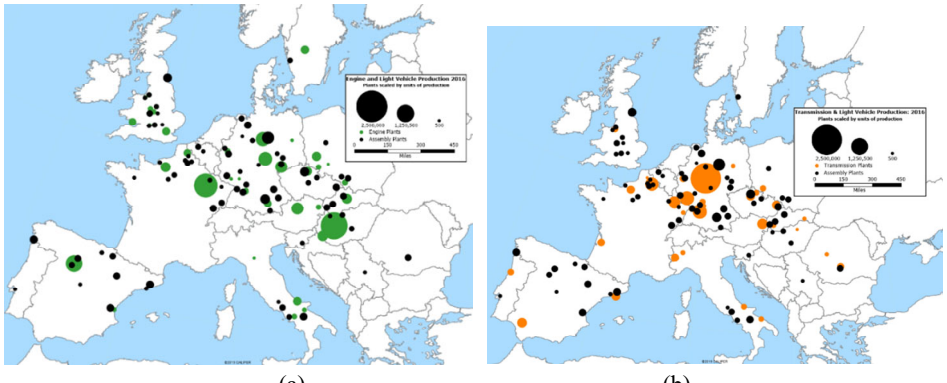
Figure 3 North America final assembly plants, 2016, (a) engine plants (b) transmission plants (see online version for colours)



(a) (b)

Source: Authors' calculations based on data from IHS Markit as of October 2017

Figure 4 Europe final assembly plants, 2016, (a) engine plants (b) transmission plants (see online version for colours)



(a) (b)

Source: Authors' calculations based on data from IHS Markit as of October 2017

The two regions' integrated peripheries have nearly identical numbers of final assembly and powertrain plants. North America's integrated periphery (Mexico) has 15 assembly

plants, 11 engine plants, and 7 transmission plants, whereas Europe's integrated periphery has 16 assembly plants, 9 engine plants, and 9 transmission plants.

In all cases, the number of final assembly plants is around twice as high as the number of transmission plants, with the number of engine plants falling in between. This reflects underlying differences in the economies of scale of the three types of vehicle production operations.

The semi-periphery, on the other hand, displays different patterns in the two regions. North America's semi-periphery (Canada) has only 8 final assembly plants, 4 engine plants, and 1 transmission plant, whereas Europe's semi-periphery has 23 final assembly plants, 12 engine plants, and 5 transmission plants. Compared with the core and integrated periphery, the two semi-periphery subareas have few powertrain plants relative to final assembly plants. Assembly plants in Canada source most of their powertrain from the US

5.2 Changes in intraregional sourcing

Both regions' final assembly operations grew in the integrated periphery sub-area and declined in both the core and semi-periphery. Vehicle assembly increased between 2000 and 2016 in the integrated periphery of both regions, from 1.9 million vehicles to 3.5 million in North America and from 1.4 million to 4.0 million in Europe. As a result, the share of final assembly output in the integrated periphery increased between 2000 and 2016 from 11% to 20% in North America and from 8% to 22% in Europe Table 5.

Table 5 Change in distribution of final assembly operations within regions [%]

Share of region's final assembly operations	*North America*		*Europe*	
	2000	*2016*	*2000*	*2016*
Core	72.2	66.8	55.8	48.9
Semi-periphery	17.0	13.5	36.4	29.0
Integrated periphery	10.8	19.7	7.8	22.2
N [million vehicles]	17.1	17.6	17.5	18.0

Source: Authors' calculations based on data from IHS Markit as of October 2017

Meanwhile, production declined between 2000 and 2016 in the other two subareas of both regions. Production in the core declined from 12.4 million to 11.8 million in North America and from 9.7 million to 8.8 million in Europe. Final assembly output declined in the semi-periphery from 2.9 million to 2.4 million in North America and from 6.4 million to 5.2 million in Europe.

Changes in the distribution of powertrain sourcing mirror the patterns for assembly plants. The integrated periphery gained in both North America and Europe, whereas the other two subareas declined Table 6. The core areas provided the majority of powertrains in both North America and Europe Yet, in both regions the share of engines and transmissions sourced from factories in the core declined between 2000 and 2016, as did the share of powertrains sourced in the semi-periphery. In Europe the core region's sourcing share declined most steeply for both powertrain components, whereas in North America the largest decline in engine sourcing occurred in the semi-periphery (Canada).

Table 6 Intraregional differences in powertrain sourcing [%]

	North America				*Europe*			
	Engine		*Transmission*		*Engine*		*Transmission*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*	*2000*	*2016*
Core	66.2	57.8	67.9	56.4	58.2	42.0	64.8	56.7
Semi-periphery	12.4	5.1	5.4	1.1	25.8	24.5	20.4	14.3
Integrated periphery	9.8	23.0	1.6	19.0	12.5	27.9	7.1	14.2
Other regions	11.6	14.1	25.1	23.5	3.5	5.6	7.7	14.8

Source: Authors' calculations based on data from IHS Markit as of October 2017

Table 7 Distribution of powertrain sourcing by core assembly plants [%]

	From the same subarea		*From the semi-periphery*		*From integrated periphery plants*		*From other world regions*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*	*2000*	*2016*
Engine								
North America	68.9	64.9	11.6	5.3	6.7	16.7	12.8	13.1
Europe	70.6	53.4	15.9	19.6	12.5	23.1	1.1	3.9
Transmission								
North America	67.3	62.6	7.1	0.1	1.0	17.2	24.6	20.1
Europe	82.3	75.8	10.8	8.4	5.4	5.9	1.5	9.9

Source: Authors' calculations based on data from IHS Markit as of October 2017

The integrated periphery supplied an increasing share of engines and transmissions to final assembly plants in both regions. Mexico's share of North American assembly plant sourcing increased from 10% in 2000 to 23% in 2016 for engines and from 2% to 19% for transmissions. Europe's integrated periphery increased its share of supplying Europe's assembly plants with engines from 13% in 2000 to 28% in 2016. For transmissions, the share rose from 7% in 2000 to 14% in 2016.

5.3 Changing sourcing patterns within subareas

In this section we compare powertrain sourcing patterns of vehicle assembly plants at a more disaggregate level, based on the subarea in which they are located in: core, semi-periphery, or integrated periphery. A key indicator of the degree of regional integration is the extent to which components are sourced from different countries within a region rather than procured from only one country. With increasing integration, a final assembly plant in one country might source more of its engines and transmissions from plants in other countries of the region (see Section 4.2). Here we ask the question if the same pattern holds at the subarea level.

In both North America and Europe, the share of powertrains produced in the same subarea as final assembly operations is considerably higher in the core than in either the semi-periphery or the integrated periphery. This represents a legacy of the historic clustering of vehicle production in the core areas of both regions, as well as the continuing concentration of national champions in these countries.

In terms of changes during the observation period, we find that across the board sourcing from the integrated periphery increases between 2000 and 2016. In other words, sourcing has increased from the countries added to the existing trade agreements in both North America and Europe.

Assembly plants in North America's and Europe's core areas display similar changes in sourcing patterns between 2000 and 2016. In both regions, for assembly plants located in the core the shares of engines and of transmissions sourced from plants in the core declined, while sourcing from plants in the integrated periphery rose Table 7.

In both North America and Europe, assembly plants in the semi-periphery also increased their sourcing of powertrains from plants in the integrated periphery, in most cases by substantial levels. Changes in powertrain sourcing from plants in the core and semi-periphery were not consistent between North America and Europe. Assembly plants in North America's semi-periphery (Canada) sourced more engines from the core (US) and fewer from Canada, whereas the opposite was the case for transmission sourcing. Europe's semi-periphery assembly plants sourced smaller shares of engines and transmissions from the core and a smaller share of transmissions from the semi-periphery, but more engines from the semi-periphery.

Within North America, the semi-periphery (Canada) had by far the lowest share of powertrains sourced in the same country as final assembly operations. At the same time, Canada's final assembly plants had by far the highest share of powertrains sourced from other countries in the same region – essentially the US – and the lowest share of powertrains imported from other regions (Table 8). Canada's situation reflects the long-standing integration of its vehicle production with that of the US.

Table 8 Distribution of powertrain sourcing by semi-periphery assembly plants [%]

	From the same subarea		*From core plants*		*From integrated periphery plants*		*From other world regions*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*	*2000*	*2016*
Engine								
North America	18.2	6.7	75.2	82.5	1.0	9.2	5.6	1.6
Europe	43.6	48.2	41.4	33.8	9.6	12.8	5.5	5.1
Transmission								
North America	0.0	7.5	90.2	58.2	0.4	11.9	9.4	21.6
Europe	36.5	14.3	44.4	34.9	3.0	38.2	16.1	25.1

Source: Authors' calculations based on data from IHS Markit as of October 2017

Table 9 Distribution of powertrain sourcing by integrated periphery assembly plants [%]

	From the same subarea		*From core plants*		*From the semi-periphery*		*From other world regions*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*	*2000*	*2016*
Engine								
North America	44.8	54.0	33.9	16.5	8.6	3.2	12.8	26.2
Europe	38.2	58.2	48.2	27.8	14.0	4.3	11.9	9.8
Transmission								
North America	7.3	30.1	37.0	34.3	2.3	0.0	53.4	35.6
Europe	38.2	38.3	34.9	40.1	14.3	9.6	12.6	11.9

Source: Authors' calculations based on data from IHS Markit as of October 2017

Table 10 Distribution of powertrain sourcing by individual core countries [%]

	From the same country		*From other core plants*		*From other subareas*		*From other world regions*	
	2000	*2016*	*2000*	*2016*	*2000*	*2016*	*2000*	*2016*
Engine								
France	85.3	66.7	5.7	0.0	8.9	23.5	0.1	9.8
Germany	47.2	46.1	0.0	0.5	50.8	53.4	2.0	0.0
Italy	95.2	60.3	4.8	11.5	0.0	13.2	0.0	15.1
USA	68.9	64.9	n/a	n/a	18.3	22.0	12.8	13.1
Transmission								
France	78.3	61.8	3.9	5.1	17.7	15.9	0.2	17.2
Germany	63.8	68.2	12.8	9.2	21.3	15.9	2.2	6.6
Italy	86.4	59.3	11.7	22.9	0.0	3.5	1.9	14.3
USA	67.3	62.6	n/a	n/a	8.1	17.3	24.6	20.1

Source: Authors' calculations based on data from IHS Markit as of October 2017

Assembly plants in the integrated peripheries of North America and Europe display some key similarities and some key differences. The key similarity is the relatively large share of powertrains sourced from plants also in the integrated periphery: 54% of engines and 30% of transmissions in North America's integrated periphery and 58% of engines and 38% of transmissions in Europe's integrated periphery.

The share of powertrains sourced from plants in the integrated periphery increased substantially between 2000 and 2016 for assembly plants in both North America and in Europe, with the exception of that for transmissions in Europe, which was unchanged from an already significant level in 2000.

In 2016, final assembly plants in North America's integrated periphery (Mexico) source a relatively high share of engines from plants also located in Mexico (54%), while utilising a relatively low share of transmissions from elsewhere in the region (34%), essentially the US s Table 9. However, Mexico also imports a relatively high share of engines and transmissions from other regions of the world, essentially Europe and East Asia. This reflects Mexico's status as a growing location for vehicle production.[5]

5.4 Sourcing patterns among countries within Europe's subareas

At the subregional scale, North America has only one country identified with each of the three subareas, whereas Europe has multiple countries allocated to each. This section looks briefly at subregional differences among individual countries within Europe's three subareas.

Europe's core countries of France, Germany, and Italy have experienced especially disparate fortunes. In 2000, the auto industries of France and Italy were largely self-contained. French assembly plants produced 3.3 million vehicles in 2000 and sourced 85% of their engines and 78% of their transmissions from plants in France. Domestic sourcing was even higher for the 2.0 million vehicles assembled in Italy in 2000: 95% of engines and 86% of transmissions were sourced from Italian powertrain plants Table 10.

Between 2000 and 2016, final assembly output declined in France from 3.3 million to 2.0 million and in Italy from 1.6 million to 0.9 million. Domestic sourcing of powertrains declined even more, as the surviving assembly plants procured more of their powertrains from elsewhere in Europe or other regions. French assembly plants sourced 1.4 million engines and 1.3 million transmissions from French powertrain plants in 2016, compared with 2.8 million engines and 2.5 million transmissions in 2000. The decline was even greater in Italy, where assembly plants sourced 600,000 engines and 600,000 transmissions from Italian powertrain plants in 2016, compared with 1.5 million engines and 1.4 million transmissions in 2000.

Meanwhile, final assembly output in Europe's other core country Germany increased from 4.9 million vehicles in 2000 to 5.8 million in 2016. Shares of sourcing from German powertrain plants remained about the same, but with the increase in output, assembly plants increased their sourcing from domestic powertrain plants from 2.3 million engines in 2000 to 2.7 million in 2016 and from 3.1 million transmissions in 2000 to 4.0 million in 2016.

Spain and the UK account for nearly 90% of Europe's semi-periphery assembly plant output. Final assembly output did not change much in those countries between 2000 and 2016. The remaining countries in the semi-periphery displayed sharp declines more comparable with Canada, from 1.8 million assembled in 2000 to 644,000 in 2016.

Changes in powertrain sourcing in Europe's semi-periphery were mixed. The UK assembly plants sourced 57% of their engines from domestic plants, consistent with core countries, whereas Spain's assembly plants sourced only 20% of their engines from domestic plants. On the other hand, domestic sourcing of transmissions declined in the U.K. from 26% in 2000 to virtually nil in 2016 and in Spain from 32% to 19%.

In Europe's integrated periphery, assembly output tripled between 2000 and 2016. Principal gains were in Czechia, Hungary, Romania, and Slovakia, but every country in the subarea had an increase. The share of powertrains sourced domestically increased at roughly the same level in the subarea as a whole, but variations existed among countries. Assembly plants in Czechia, Hungary, Poland, and Slovakia increased domestic sourcing of engines, those in Romania decreased domestic sourcing, and those in Serbia and Slovenia had no domestic engine sourcing in 2000 or 2016. Assembly plants in Czechia and Romania increased domestic sourcing of transmissions, whereas those in Poland, Slovakia, and Slovenia decreased, and those in Hungary and Serbia had none in 2000 or 2016.

Thus, while at an aggregated scale, the core and integrated periphery subareas of North America and Europe display similar trends with regard to vehicle production and powertrain sourcing, important variations can be observed among the countries grouped together within Europe's core and within its integrated periphery. For example, as Table 10 shows, the 2016 figures for the US and France are remarkably similar, whereas changes between 2000 and 2016 are quite different between these two countries, yet quite similar between the US and Germany.

6 Discussion

In the wake of new trade agreements that expanded the economic geographies in both Europe and North America,, regional integration encouraged the location of production facilities among multiple countries, taking advantage of subregional variations in factors of production among subareas within individual countries, with easier movement across borders. For example, Europe's largest engine plant, operated by VW in the integrated periphery location of Gyor, Hungary, is within a one-day driving distance of a dozen VW assembly plants in Czechia, Germany, and Slovakia. In North America, plants in Central Mexico are better connected with those in the US thanks to major improvements in the rail system. As regional trade agreements expanded in geographic scope in North America and Europe, one can observe trade creation, that is, increased sourcing across countries from the same region. We find that the newly admitted countries in both North America and Europe (the so-called integrated periphery) are the major beneficiary of this trade creation.

At the same time the share of imported vehicles and powertrains has not declined since the enlargement of the North American and European trade areas. We suggest a large part of the continued imports is explained by economies of scale: an international vehicle producer likely will import its products until sales volume in a region supports production there (about 200,000 units that can be built on the same line). The same argument applies to powertrain sourcing, except it typically takes at least two assembly plants to generate enough demand to site one engine plant or one transmission plant in the same region.

Despite the expanding economic geographies in both regions, the distribution of vehicle production has followed similar patterns in both North America and in Europe: Most vehicles are assembled in the region in which they are sold, with powertrains primarily sourced from within the same region. Economic geography principles continue to inform the industry's location decisions.

What does this mean for the changes to NAFTA that resulted in the ratification of USMCA in 2020? The USMCA trade agreement did not change the geographic scope of the previous regional trade agreement, but it did introduce some changes in the ease with which producers can utilise the entire North American geography. USMCA for the first time introduced wage provisions to North American auto industry trade. Once fully implemented, 40% of North American content must be produced with wages averaging at least $16 an hour. Final assembly, engine, and transmission plants in the US and Canada constitute a substantial percentage of plants that currently pay this wage level, whereas those in Mexico do not. The USMCA wage requirement, as well as the ability to utilise a new rapid response mechanism to address workers' rights may well impact decisions on the location of production within North America (see Ngo, 2021).

In addition, all of North America will face new rules of origin for vehicle and parts production, including higher requirements for regional content (Congressional Research Service, 2019). USMCA requires that at least 75% of parts defined as 'core' (essentially engine and transmission) originate in North America (Dziczek et al., (2018), p.4; US – Mexico-Canada Agreement, 2018). This requirement may result in more sourcing of powertrains, especially transmissions, from plants located in North America, thereby further strengthening regional integration.

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Notes

1 There are of course impacts of trade on industry structure. See for example Lagendijk (1995).

2 Lampón et al. (2016, p.596) use the term first periphery instead of semi-periphery, and second periphery instead of integrated periphery.

3 For Europe, we define auto alley as France and Germany.

4 Electric vehicles, small plant production as well as that at contract manufacturers together accounts for 3.8% of light vehicle production in Europe and 1.4% in North America in 2016.

5 Note the large decline in transmissions imported into Mexico from outside North America (the share fell from 53.4% to 35.6% between 2000 and 2016). That decline is the main driver of the overall reduction in transmission sourcing from outside the region for North America.