Auto production footprints: Comparing Europe and North America

Thomas H. Klier and James M. Rubenstein

Introduction and summary

Today's footprints of motor vehicle production[1] in Europe and North America appear at first glance to be remarkably similar: In both regions, plants producing motor vehicles are highly agglomerated, which is typical of manufacturing activities. The auto industry is a global industry: A dozen or so mass producers compete with one another around the world. Because these automakers employ similar production models in their plants, one might expect similar forces to shape their production location decisions. This article evaluates whether the same general factors explain the broad patterns seen in the auto industry's footprints in Europe and North America. This question is of particular interest because to date, little comparative analysis of this kind has been performed, especially involving Europe as a whole. In general, most auto industry analysis of Europe has focused on its individual countries instead of the entirety of the region.

We begin the article with a description of the current distribution of motor vehicle production in both North America and Europe. Then we review the principles of agglomeration and industrial location theories and discuss their applicability to auto production siting decisions. Next, we examine whether these principles adequately explain changes in the geographical distribution of auto production in North America. We outline key events in Europe around 1990 that affected the spatial distribution of auto production there. And we evaluate to what extent the principles of agglomeration and industrial location theories are sufficient to explain the changing geography of auto production in Europe. In doing so, we also illustrate the growing importance of a northwest–southeast corridor in Europe, where the auto industry has become concentrated. Furthermore, we discuss trends in auto assembly plant openings and closings—both inside and outside this European corridor of production—since 1990. Finally, we highlight the features of auto production in Europe and North America that are not consistent with agglomeration theory.

The current geography of auto production in North America and Europe

Motor vehicle production involves two types of firms: vehicle assemblers and producers of parts (or parts suppliers). Today about a dozen carmakers put together light vehicles (see note 1) at approximately 80 assembly plants in Europe and approximately 70 assembly plants

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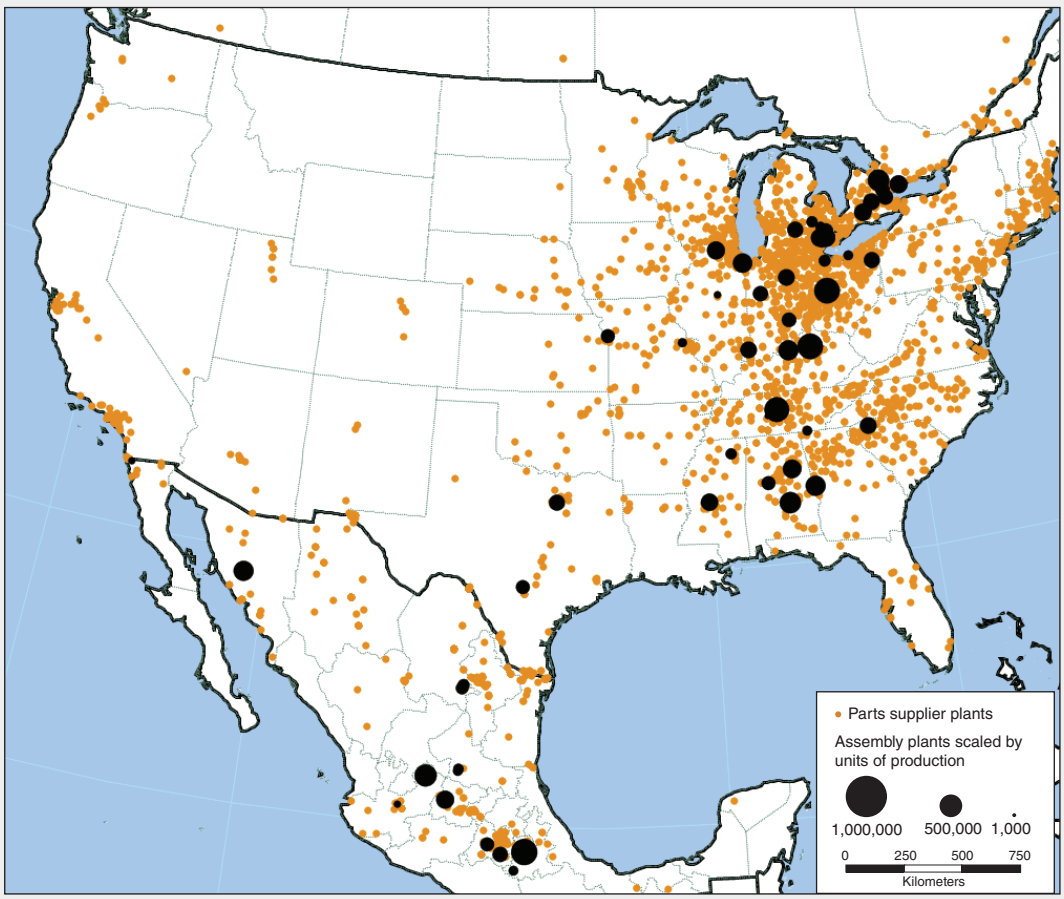
FIGURE 1

Auto assembly and parts supplier plants in North America, 2013



Sources: Authors' adaptation of data from Ward's AutoInfoBank, Elm Analytics, auto company websites, and Maptitude.

in North America. The roughly 15,000 parts that go into each vehicle are produced at several thousand parts supplier plants in both regions.[2]

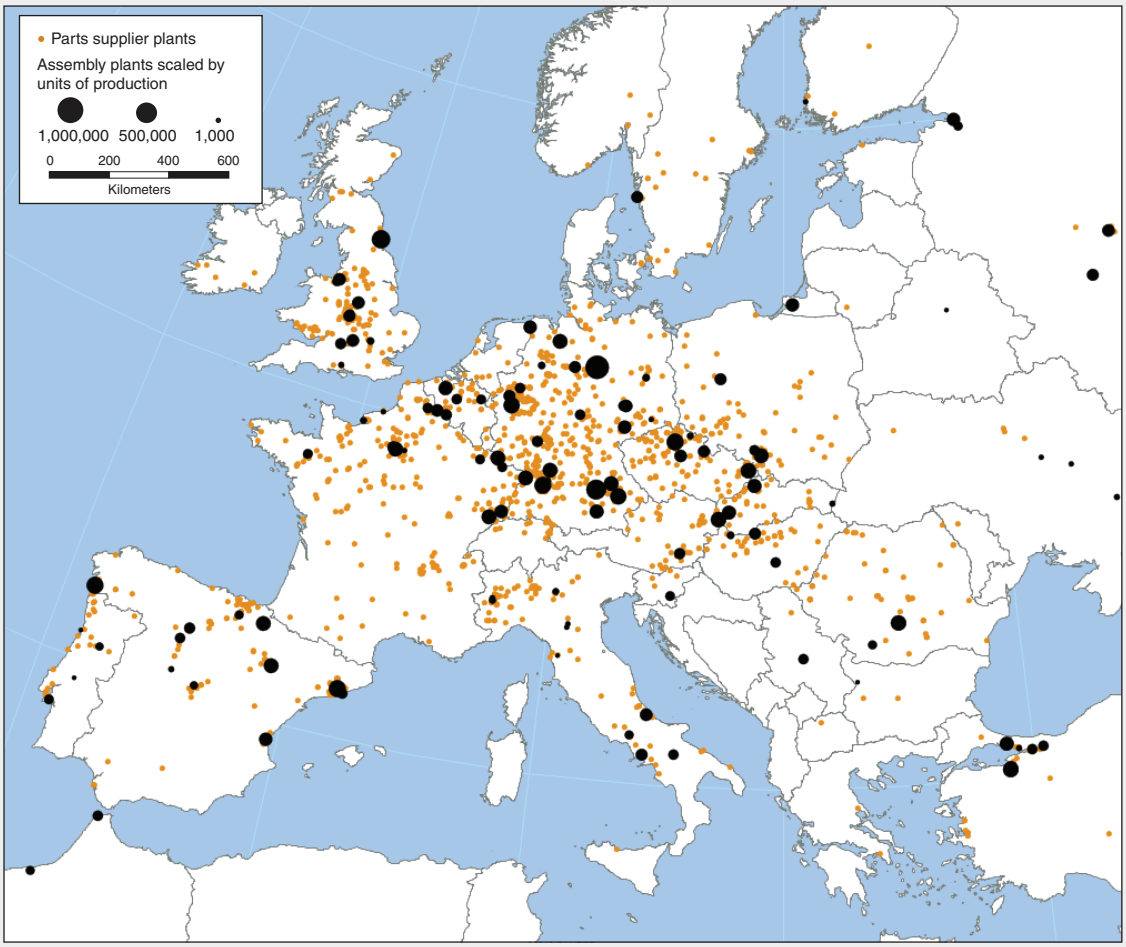
For the purposes of this article, Europe is defined as the 16 member countries of the European Union (EU)[3] that have produced at least 100,000 motor vehicles in any year between 1990 and 2013. The 16 countries are Austria, Belgium, Czechia,[4] France, Germany, Hungary, Italy, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom (UK). In 2013, auto production reached at least 100,000 units in 15 of these 16 countries; the exception was the Netherlands, where auto production last hit 100,000 units in 2005. In this article, Central Europe refers to Czechia, Hungary, Poland, Romania, Slovakia, and Slovenia, while Western Europe refers to the other ten auto-producing countries. Here, North America refers to Canada, Mexico, and the United States.

Motor vehicle production in North America is clustered in a north–south corridor, mostly in the United States, called "auto alley" (see figure 1). This corridor is roughly 800 miles long and 250 miles wide,[5] extending between Michigan and Alabama. The spine of auto alley is formed by the north–south interstate highways I-65 and I-75. Auto alley extends into Canada along Route 401 (Klier and Rubenstein, 2008; Klier and McMillen, 2006, 2008; and Rubenstein, 1992). Within the United States, auto alley accounted for nearly 90 percent of light vehicle production in 2013.

In Europe, motor vehicle production is clustered in a corridor along a northwest–southeast axis between the Danube River and the North Sea, with an extension across the English Channel into the United Kingdom (see figure 2).[6] This corridor is roughly 800 miles long and 250 miles wide; it encompasses nearly the same amount of area and has almost the same shape as North America's auto alley. In Europe, the corridor

FIGURE 2

Auto assembly and parts supplier plants in Europe, 2013



Sources: Authors' adaptation of data from ACEA, IHS Global Insight, auto company websites, and Maptitude.

of motor vehicle production encompasses the assembly plants of the United Kingdom, northeastern France, Belgium, the Netherlands, Germany, Austria, southern Poland, Czechia, Slovakia, and Hungary. The corridor lies roughly along the major east–west highways E30 and E50. Its eastern and western ends are approximately equivalent to the maximum distance that truck drivers can reach in one day from southwestern Germany—Europe's economic and population center.[7]

It is remarkable that the motor vehicle production corridors in North America and Europe do not just appear rather similar but also represent comparable shares of their respective regions' total auto plants. Approximately 73 percent of North America's auto assembly plants and 62 percent of its parts supplier plants are located in auto alley, including the Canadian extension. And approximately 73 percent of Europe's vehicle assembly plants and 74 percent of its parts supplier plants are located in the auto production corridor, including the UK extension.[8]

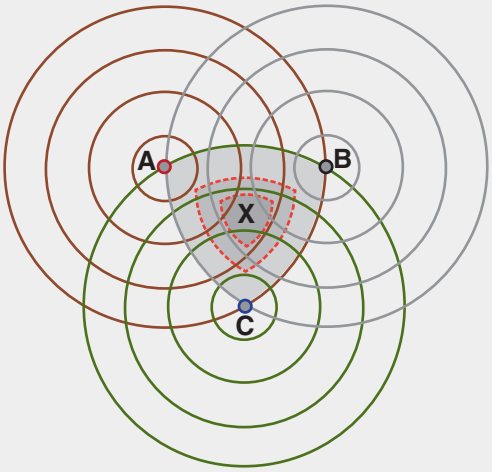
Most of North America's motor vehicle production outside auto alley takes place in Mexico, which is home to 19 percent of the region's assembly plants and 20 percent of its parts supplier plants. In Europe, Spain is the leading area of auto assembly outside the corridor, and Romania and Italy are the leading areas of auto parts production outside the corridor (Frigant and Miollan, 2014).

Agglomeration and industrial location theories

Agglomeration is the association of productive activities in proximity to one another (Gregory et al., 2009, p. 14). As shown in figure 3, three competitors may independently compute each of their optimal plant

FIGURE 3

Agglomeration theory



Note: See the text for further details.

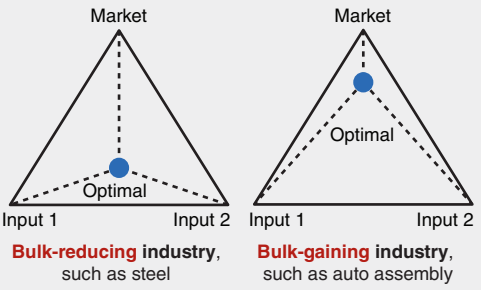
sites as locations A, B, and C. But if all three locate at location X, they benefit from agglomeration economies. According to Marshall (1920), agglomeration can reduce the cost of obtaining inputs and shipping final goods, the cost of moving workers across employers,[9] and the cost of disseminating new ideas (thereby encouraging "knowledge spillovers" and faster rates of innovation). According to Ellison, Glaeser, and Kerr (2010, p. 1195), "the benefits of agglomeration ultimately reflect gains that occur when proximity reduces transport costs," which include not only shipping costs but also the costs of moving employees and ideas.

As noted before, manufacturing activity tends to be agglomerated (see, for example, Krugman, 1991; Ellison and Glaeser, 1997; Head and Mayer, 2004; and Duranton and Overman, 2005, 2008). Among manufacturing industries, the auto industry is consistently ranked as one of the most agglomerated (Ellison and Glaeser, 1997; Duranton and Overman, 2005; and Goldman, Klier, and Walstrum, 2015). Indeed, there tends to be a high degree of co-location of auto assembly plants and parts supplier plants. Competing carmakers have, in many cases, placed their assembly plants fairly close to one another geographically. Moreover, these assembly plants often share a network of parts suppliers that are within a reasonable distance from their locations. The proximity of auto assembly plants to parts suppliers can result in lower prices for inputs for carmakers; meanwhile, suppliers benefit from being able to do business with multiple auto assembly customers.

Industrial location theory helps researchers within the field of economic geography better understand and explain plant location decisions. The theory comes

FIGURE 4

Weber's theory for least-cost industrial location



Bulk-reducing industry, such as steel

Bulk-gaining industry, such as auto assembly

Note: See the text for further details.
Source: Weber (1929).

from the work of Alfred Weber (1929). Weber argued that the optimal location for a factory is the point that minimizes the aggregate costs of bringing in inputs from suppliers and shipping out final products to consumers. So, according to Weber, the least-cost location can be computed from a geometric model. As shown in figure 4, the optimal location for a factory with one market and two sources of inputs is a point that minimizes the aggregate cost of shipping the two inputs to the factory and shipping the finished product to the market.

In his theory of industrial location, Weber (1929) distinguishes between two types of industries—namely, *bulk-reducing* industries and *bulk-gaining* industries. In a bulk-reducing industry—one with inputs that are heavier or occupy a greater volume than the final product—production facilities tend to locate near the sources of inputs in order to minimize the shipping costs (see the schematic on the left in figure 4). Conversely, in a bulk-gaining industry—one whose fabricated product is heavier or occupies a greater volume than the inputs—production facilities have a tendency to be near the markets for the final good in order to minimize the shipping costs (see the schematic on the right in figure 4).

Copper and steel provide examples of bulk-reducing industries. For example, in the United States, most copper concentration mills, smelters, and refineries are located near copper mines in Arizona (Ó hUallacháin and Matthews, 1994; and Rubenstein, 2014). In addition, in the United States, integrated steel mills are clustered in the southern Great Lakes region to minimize the aggregate shipping costs of the two principal inputs—coal from Appalachia and iron ore from northern Minnesota. As the U.S. steel industry has been increasingly relying on foreign sources of iron ore, the transportation cost advantage of a southern Great Lakes location has been reduced (Hogan, 1987; and Rubenstein, 2014).

Motor vehicle assembly is an example of a bulk-gaining industry. An assembled motor vehicle occupies a much greater volume and is more expensive to ship than the sum of its individual parts. Consequently, carmakers have selected assembly plant sites that minimize their costs of shipping finished vehicles to dealerships. It should be noted, however, that other factors, such as economies of scale in production and the ability to acquire and assemble pieces for a large enough tract of land at an affordable price, also affect carmakers' plant location decisions (Rubenstein, 1992).

The literature on production agglomeration and industrial location includes numerous papers that estimate the role of specific factors in explaining the distribution of manufacturing in general, as well as that of individual industries (for a detailed tabulation, see Arauzo-Carod, Liviano-Solis, and Manjón-Antolín, 2010). As one of the largest manufacturing industries, the auto industry has been the focus of much attention in this literature. Nearly all of the empirical analysis relies on U.S. and North American data. For instance, Woodward (1992) examines foreign direct investment in the U.S. manufacturing sector, and finds evidence that access to interstate highways plays a crucial role in where foreign carmakers decide to establish plants outside metropolitan areas. Smith and Florida (1994) estimate a model for Japanese-affiliated automotive-related plants within the United States, and find proximity to assembly plants to be an important factor in the location decisions of components supplier plants. Klier and McMillen (2008) estimate the location pattern of motor vehicle parts plants by way of a conditional logit model, and find the observed location choices are well explained by factors linked to agglomeration. Two of these factors—namely, good highway access and shorter distance to assembly plants—suggest that cost considerations of transporting goods play a significant role in supplier plant siting decisions. A third factor—shorter distance to Detroit—suggests such decisions may be partly based on wanting to have ready access to the news and innovations (knowledge spillovers) emanating from the center of the auto industry in the United States. Incidentally, that article illustrates the reorientation of supplier plant locations along the north–south auto alley (from a concentrated area surrounding Detroit, with southern Michigan, Indiana, and Ohio as its hub). It establishes that the degree of agglomeration for old and new plants is quite similar, despite this reorientation. More generally, Klier and Rubenstein (2008, 2013a) provide an extensive account of how the footprint of the auto industry in North America has evolved over the past several decades.

The evolution of North America's auto production footprint

While motor vehicle production in North America tends to be concentrated today, as it has in the past, the industry's footprint has changed over time (this section draws heavily on Rubenstein, 1992). In North America, motor vehicle production experienced two periods of intense agglomeration. The first period began during the first decade of the twentieth century, and the second started during the 1980s. In the intervening years, the industry's assembly footprint broadened with the establishment of the system of branch assembly plants.

When commercial production of motor vehicles began in the United States during the 1890s, more than half of the firms were located in the Northeast. The distribution of producers changed twice in the early twentieth century. First, most production shifted from the Northeast to southeastern Michigan. Motor vehicle production clustered in southeastern Michigan in the first years of the twentieth century primarily because of existing agglomerations of producers of critical components. In 1900, southeastern Michigan was the center of production of gasoline engines, which at the time were used primarily to power boats and farm machinery. The area was also the center of production of horse-drawn carriages, which were later developed into car bodies. In 1913, southeastern Michigan accounted for 80 percent of total motor vehicle production in the United States.

While most parts continued to be made in and near southeastern Michigan after that date, most assembly plants were relocated to major urban areas around the country, such as New York, Los Angeles, and Chicago, beginning in the second decade of the twentieth century. After clustering their operations in southeastern Michigan in the first decade of the twentieth century, Ford and General Motors (GM) opened branch assembly plants around the country. Ford started doing this during the 1910s, and GM followed suit during the 1920s. Instead of shipping finished vehicles from southeastern Michigan to consumers around the country, the leading carmakers determined that it was cheaper to ship parts around the country and put together vehicles at branch assembly plants situated near population centers, where vehicle buyers were clustered, essentially following Weber's (1929) principles for siting factories for a bulk-gaining industry.[10] Production of parts remained in the Midwest, as rail cars—the principal mode of shipping freight in the early decades of the twentieth century—could accommodate stacked-up parts, intended for assembling vehicles at branch assembly plants, far more easily than fully assembled vehicles.

Carmakers began to abandon the branch assembly plant system during the 1960s. As a result, the assembly footprint began to tighten again. The impetus for this change was the introduction of a variety of models of different sizes that could not be built on the same assembly line. Instead, each assembly plant was devoted to producing models of a single size. Consistent with the principles of industrial location theory based on Weber (1929), carmakers calculated that if a single-sized model was to be assembled at a single plant, its location needed to minimize the aggregate cost of shipping to consumers throughout North America. That region became known as auto alley (see figure 1 on p. 102).[11] In calculating the optimal location for their assembly plants, carmakers determined the key factor was the percentage of the nation's dealerships that could be reached within a one-day drive by truckers. (From the 1960s onward, trucks were the primary mode for delivering assembled vehicles.) A location in auto alley makes possible one-day delivery to population centers between New York and Texas. Note that auto alley is several hundred miles east of the U.S. center of population, located in Missouri—which is too far west to permit one-day delivery to the East Coast markets and not far enough west to reach California markets in one day.

Later on, in the 1980s, Japanese-owned carmakers began to assemble vehicles in the United States. They too determined that in order to minimize the costs of shipping their final products throughout North America, the optimal locations for their assembly plants were in auto alley (Woodward, 1992).

The history of Europe's fragmented auto production footprint

In this section, we discuss the historical distribution of motor vehicle production in Europe. In the following section, we highlight factors that precipitated changes in this distribution late in the twentieth century.

For most of the twentieth century, motor vehicle production in Europe was fragmented among the region's individual countries. Europe's automobile industry represented a collection of national industries, with each of the major vehicle-producing countries dominated by one or a small number of vehicle producers headquartered in that country—the so-called national champions (Lagendijk, 1997). Fiat of Italy, Volkswagen (VW) of Germany, Renault and Peugeot of France, and Leyland and Rover of the United Kingdom were examples of national champions during the twentieth century.[12]

While consumers were able to choose among products from virtually every auto producer in Europe, each vehicle assembler's production facilities were clustered in the country where it was headquartered (see figure 5, which illustrates this pattern for 1990). Accordingly, most motor vehicles sold in France were produced in France by French companies, and most motor vehicles sold in Italy were produced in Italy by Italian companies—and this pattern also held in the United Kingdom, Spain, and less populous countries, such as Sweden and Czechoslovakia. While the U.S. auto industry clustered in the early twentieth century around the single geographical node of southeastern Michigan, Europe featured multiple nodes, including Paris, France; Wolfsburg, Germany; Turin, Italy; and Coventry, UK (Bentley, Bailey, and MacNeill, 2013; and Lung, 2004).

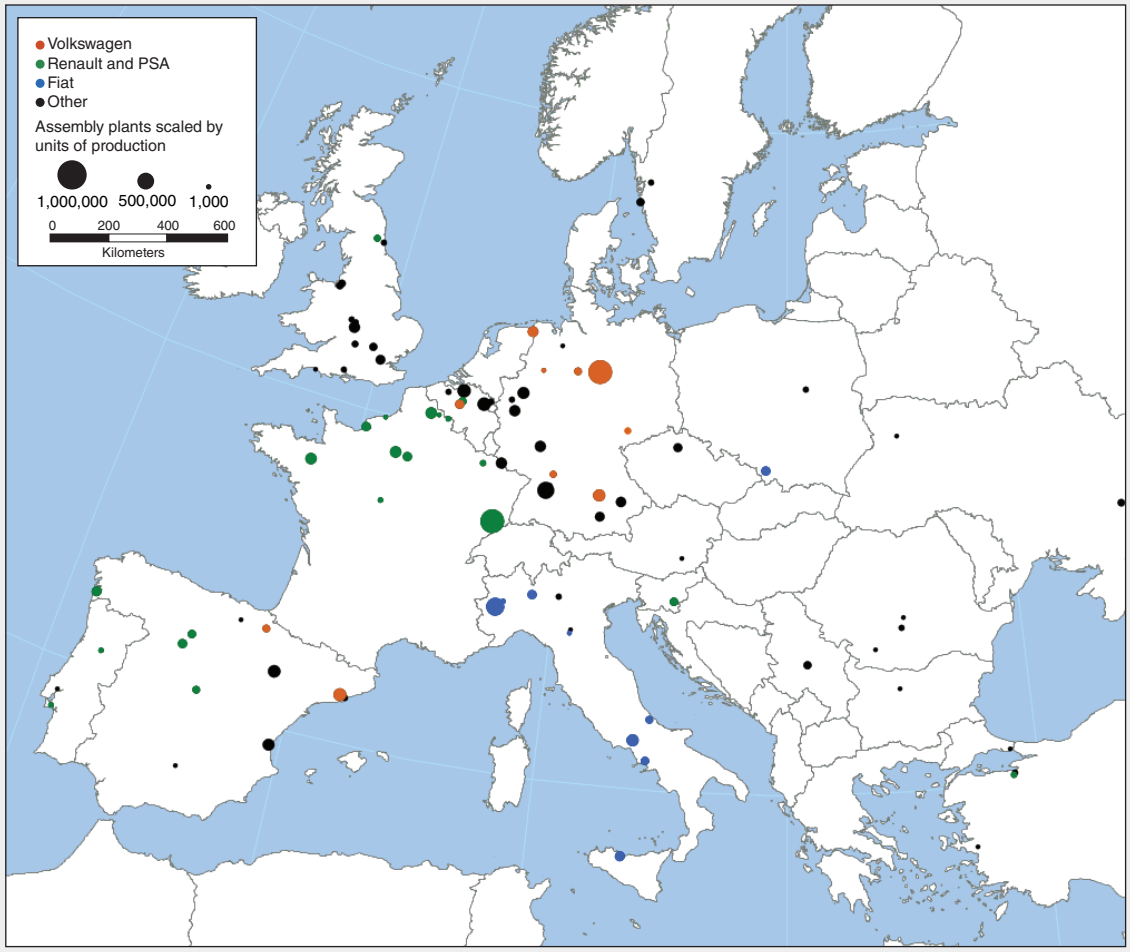
Despite the polycentric nature of Europe's motor vehicle industry, which persisted for most of the twentieth century, the region's pioneering carmakers were collaborating across national boundaries as early as the late nineteenth century. For example, engines from Germany's Benz (a predecessor of today's Daimler) were used in vehicles made throughout Europe, and France's Panhard et Levassor (a predecessor of today's PSA Peugeot Citroën[13]) created the assembly platform structure with the engine in front that became the auto industry's standard (Flink, 1988, pp. 15–22).

But during World Wars I and II and the interwar period, protectionist policies effectively precluded region-wide agglomeration of Europe's motor vehicle industry (Flink, 1988, p. 253). That is, each of the more populous countries in Europe protected its own motor vehicle industry from producers of other countries through high tariffs—which deterred region-wide auto production agglomeration. In 1915, for example, the United Kingdom imposed a 25 percent tariff on the import of assembled vehicles, as well as a 10 percent tariff on imported parts (Womack, Jones, and Roos, 1990, p. 228). In 1931, the average tariff on the import of manufactured goods was 30 percent in France, 21 percent in Germany, 46 percent in Italy, and 63 percent in Spain (Bairoch, 1993, p. 40). As a result of tariffs, as well as patriotic loyalty to domestic brands, the distribution of motor vehicle production across Europe remained polycentric. The British auto industry agglomerated around Coventry in the United Kingdom, the Italian auto industry around Turin in Italy, and so on across Europe's individual countries.

Spatial fragmentation of Europe's auto production persisted after World War II. The Iron Curtain[14] divided Germany in two and isolated Central European countries from most consumer goods produced in Western Europe. The agreements and organizations promoting economic unity in Western Europe, beginning with the

FIGURE 5

National champions' auto assembly plants in Europe, 1990



Notes: Although the data are for 1990, the national borders reflect those as of 2013. See the text for further details on the national champions.
Sources: Authors' adaptation of data from ACEA, IHS Global Insight, auto company websites, and Maptitude.

1951 Treaty of Paris and 1957 Treaty of Rome, removed some of the barriers to trade within the six original members of the European Economic Community, or EEC (Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany).[15] However, some restrictions on the trade of motor vehicles across borders remained in place (Flink, 1988, pp. 298–299).

Incidentally, agglomeration of motor vehicle production was also discouraged by EEC policies promoting investment in areas within the six member states—which were suffering from high levels of poverty and unemployment, as well as significant losses in manufacturing. As part of these policies, the manufacturing sector received incentives to disperse new production facilities to areas not traditionally associated with industrial production, such as Belgium, southern Italy, and western France (Lung, 2004).

The economic slowdown in the 1970s, triggered by the two oil shocks of the decade, brought some restructuring to motor vehicle production in Europe. In response to the slowdown, some countries protected their national champions of automotive production and some did not. France and Italy were examples of the former: They maintained policies protecting their domestic carmakers, thereby limiting the entry of foreign competitors, especially those based in Asia. Additionally, domestic carmakers based in France and Italy consolidated around this time: In Italy, Fiat took over Lancia (in 1969) and Alfa Romeo (in 1986); and in France, Peugeot merged with Citroën (in 1976) (Flink, 1988).

Meanwhile, major changes in motor vehicle production were occurring in the United Kingdom and Spain. In the UK, after the consolidation of the domestic

auto industry in the 1960s, the last British-owned carmaker, British Leyland (later renamed Rover), still struggled in the 1970s and 1980s (despite receiving government aid). Eventually, its assets, including its UK plants, were sold to foreign producers (Gibbs, 2013; and Northedge, 2009). In Spain, foreign carmakers built a number of assembly plants, in particular during the 1970s and 1980s.[16] At the time, Spain was considered an attractive location for the combination of its proximity to European consumers and its relatively low labor costs within Western Europe (Pallares-Barbera, 1998).

Figure 5 (on p. 107) shows the distribution of auto assembly plants in Europe in 1990. The proximity of assembly plants to each other should *not* be mistaken for agglomeration influenced by economic factors. The locations of the three largest auto assembly plants in Europe circa 1990—Wolfsburg, Germany; Sochaux, France; and Mirafiori, Italy—illustrate the lack of importance of economic geography factors in site selection (as discussed earlier in the section on agglomeration and industrial location theories). Wolfsburg, a city constructed from scratch by the Nazis during the 1930s in order to build "the people's car," is located in Lower Saxony, a state of Germany not traditionally associated with manufacturing, some distance away from the Ruhr Valley, historically the center of production (and population) in Germany (Flink, 1988). Sochaux—in far eastern France, fairly remote from Paris, the country's principal market—was the home of the Peugeot family (Flink, 1988). In Italy, the Mirafiori factory was built in a suburb of Turin—hometown of Fiat's owners, the Agnelli family, but quite far north of Rome, the country's largest market (Clark, 2012).

Toward auto production agglomeration across Europe

A sizable literature describes and analyzes the evolution of the auto industry in Europe (see, for example, Bentley, Bailey, and MacNeill, 2013, for an extensive discussion, as well as Domański and Lung, 2009; Domański and Gwosdz, 2009; Jürgens and Krzywdzinski, 2009; and Lung, 2004). During the early 1990s, two key economic and political events had a profound impact on Europe's motor vehicle industry: the ratification of the Treaty on European Union (the Maastricht Treaty) and the dismantling of the Iron Curtain. These two events enlarged the market of Europe and ultimately enabled a more agglomerated distribution of motor vehicle production across the entire continent.

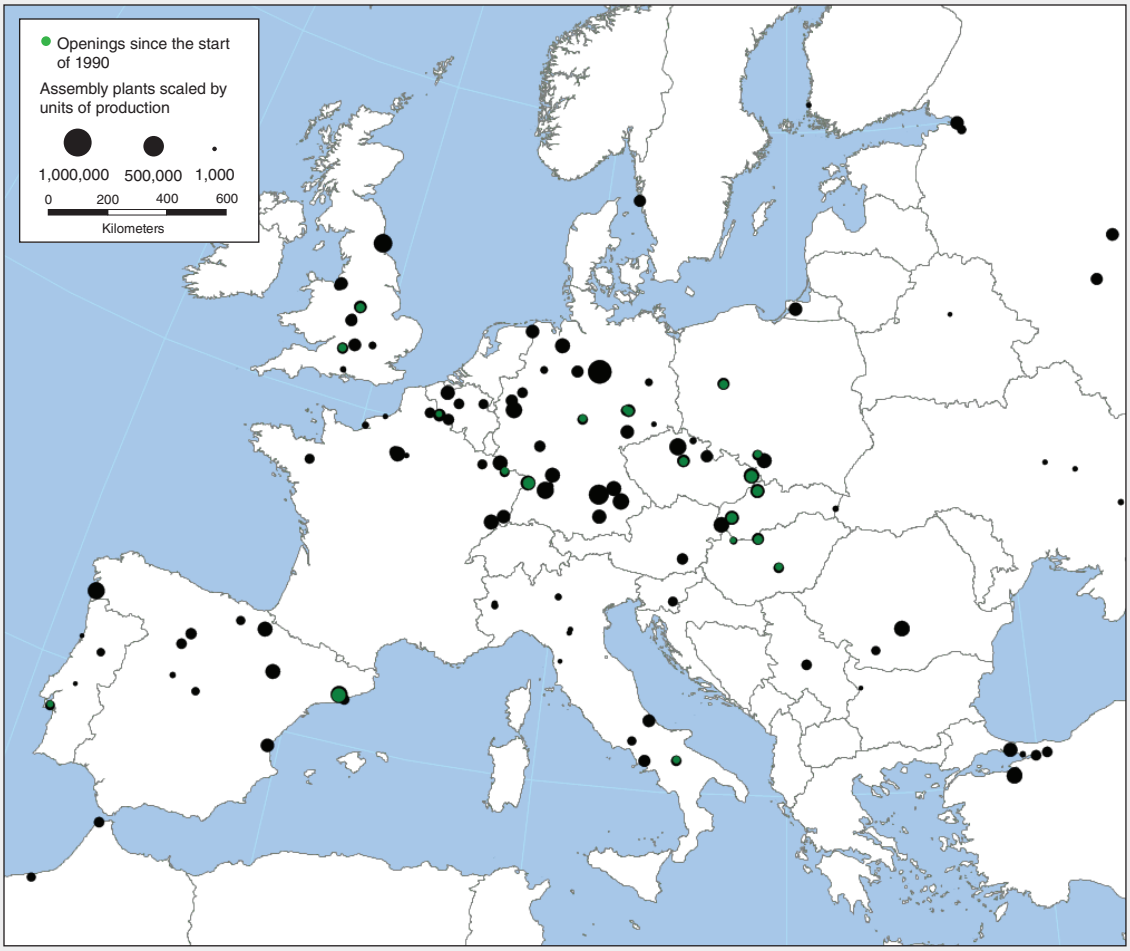
The Treaty on European Union—the single most important step in European unification—was drafted in 1991, signed by the 12 member countries in 1992, and implemented beginning in 1993. It established common foreign and security policies; assigned stronger decision-making authority to the European Parliament and other supranational institutions; and set the groundwork for the economic and monetary union, including the introduction of the euro as a common currency across the region.[17] For the auto industry, European unification ushered in a uniform region-wide regulatory framework for energy efficiency and pollution-control technologies, as well as other vehicular technologies. Tariffs were removed, and national differences in the pricing of motor vehicles were reduced (Lung, 2004).

The dismantling of the Iron Curtain unified the western and eastern parts of Europe, and rather quickly led to a considerable enlargement of the market for motor vehicles and other goods. The fall of communism in Europe that occurred between 1989 and 1991 brought about democratically elected governments in several countries that are now referred to as Central Europe (see p. 102 for the countries we consider to be part of this region for the purposes of this article). Negotiations between certain Central European countries and the European Union removed trade barriers during the 1990s, and culminated in the accession into the European Union of Czechia, Hungary, Poland, Slovakia, and Slovenia in 2004 and of Bulgaria and Romania in 2007. EU membership required the adoption of EU regulations—a source of stability for the conduct of business in Central Europe. As a result, making a substantial investment in Central Europe became not only a feasible option but an attractive one for carmakers to consider (Domański, Klier, and Rubenstein, 2014; and Domański and Lung, 2009).

More than any other factor, the accession of Central European countries into the European Union promoted region-wide integration of the region's motor vehicle industry. Central Europe was home to an auto industry under communism. Yet under communist rule, factories there produced small cars and trucks that were quite different from those in Western Europe and that had little appeal to consumers in other countries. Trade barriers to the West had resulted in the import (export) of very few new vehicles into (out of) Central Europe. By contrast, in a unified Europe, motor vehicles no longer varied widely among the region's individual countries. Automobile production subsequently expanded eastward in a major way.[18] This expansion of the auto industry's footprint led to a significant increase in its production capacity. As Central Europe increased its share of Europe's light vehicle production from just over 5 percent in 1990 to 20 percent within two decades (Domański, Klier, and Rubenstein, 2014), more than ten new assembly

FIGURE 6

Auto assembly plant openings in Europe between 1990 and 2013



Note: The national borders reflect those as of 2013.
Sources: Authors' adaptation of data from ACEA, IHS Global Insight, auto company websites, and Maptitude.

plants were opened in that region (see figure 6). The auto assemblers' move into Central European countries was motivated by a desire to gain access to the newly opened local markets, as well as by the cost advantages (especially for labor) these nations offered (Domański and Lung, 2009).[19] Between 1990 and 2013 the number of large assembly plants (capable of producing at least 100,000 vehicles per year) in Central Europe rose from eight to 18.[20] The majority of these additional plants were located in just three countries: Czechia, Poland, and Slovakia. Prior to that time, Spain and Portugal had been the main beneficiaries of new automotive investment in Europe.[21]

Around 1990, European carmakers also faced two key challenges that threatened their long-term competitive positions in their respective home markets. One principal challenge concerned quality and productivity issues. The 1990 book *The Machine That Changed the World*—produced by researchers with the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology (MIT)[22]—was highly critical of European motor vehicle industry practices, suggesting that European producers lagged their international competitors in terms of productivity and quality. The other principal challenge to European carmakers at the time was increased competition from Japanese carmakers. In 1990 Japanese carmakers had a more modest presence in Western Europe as a whole than in North America (where they had opened seven assembly plants during the 1980s). Japanese auto companies held 24 percent of light vehicle sales in the United States in 1990; in contrast, Japanese auto assembly firms had only 11.6 percent of comparable sales in Western Europe in 1990.[23] The only two Japanese-owned assembly

TABLE 1

Number of large auto assembly plants and their share of auto production, by location within Europe, 1990 and 2013

Assembly operations	Inside corridor	Outside corridor
Number of assembly plants		
Total in 1990	52	22
Opened between 1990 and 2013	17	3
Closed between 1990 and 2013	11	3
Total in 2013	58	22
Percentage of production		
1990	68	32
2013	78	22

Notes: The corridor refers to the auto production corridor in Europe. See table 2 for a list of the ten countries inside the corridor and the six countries outside it. The sample for this table is limited to large auto assembly plants, which are defined as plants capable of producing at least 100,000 units per year.
Sources: Authors' calculations based on data from ACEA, IHS Global Insight, and auto company websites.

plants in Europe in 1990 were operated by Nissan in Sunderland, UK, and in Barcelona, Spain; and neither had yet reached annual production levels of at least 100,000 units.[24] Conventional wisdom in 1990 was that Japanese carmakers would soon attain in Europe as a whole the levels of sales and production found in North America and in smaller European countries (Dicken, 1992; and Lagendijk, 1997). European carmakers responded to both challenges by adopting Japanese-inspired production methods that closed the gaps in quality and productivity with their foreign competitors.[25] More to the point of this article, European carmakers also altered the spatial distribution of auto production within Europe, favoring locations consistent with Weber's (1929) principles of factory site selection for an industry producing bulk-gaining goods. This was yet another way for European auto assemblers to improve their productivity in response to competition from North America and Asia.

Features of agglomerated auto production in Europe

As we explained in detail in the previous section, the changes in the underlying economic geography of Europe encouraged agglomeration of the region's motor vehicle production. Following the collapse of communism in Central Europe, the footprint of Europe's motor vehicle production changed from a multinational polycentric distribution (with production generally self-contained within individual countries) to a region-wide agglomeration in a corridor with a northwest–southeast axis (figure 6 on p. 109).[26] The new distribution of auto production across Europe more closely resembles the clustering of auto production observed in North America. Auto producers in Europe today are optimizing their operations over a much larger area than before 1990, choosing plant locations that minimize the costs of reaching a large market. In this section, we elaborate on two distinctive trends of Europe's increasingly agglomerated distribution of motor vehicle production: namely, 1) that most new auto production facilities have been situated inside an agglomerated corridor and 2) that new automotive investment within the corridor has been occurring primarily in the eastern portion.

Changing distribution of auto production facilities across the whole of Europe

In 1990, carmakers operated 74 large assembly plants in Europe (with each plant capable of producing at least 100,000 vehicles per year). Between 1990 and 2013, 20 large auto assembly plants were opened in Europe and 14 were closed. As a result of these changes, in 2013 Europe had a total of 80 large auto assembly plants (see table 1).

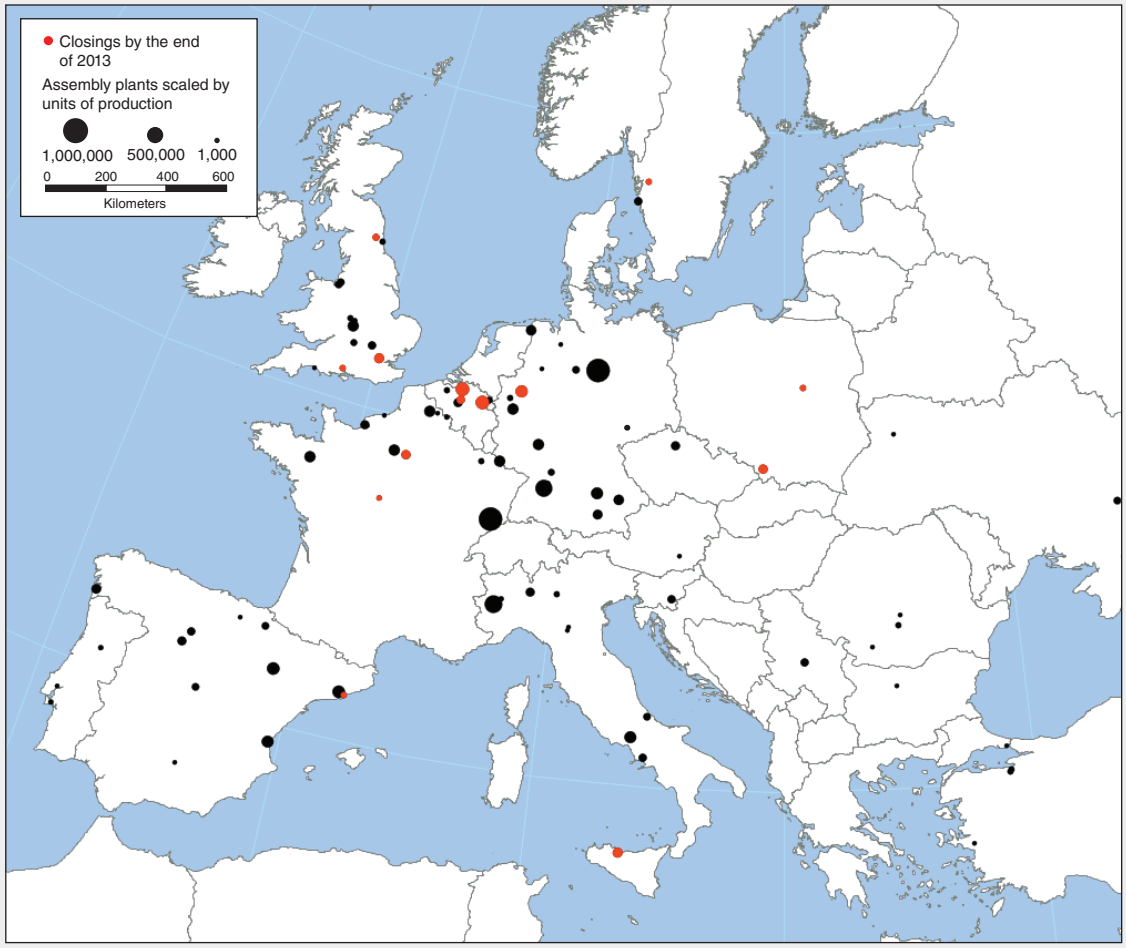
Europe's large auto assembly plant count had risen since 1990 mostly because of the clustering of investment in the region's auto corridor. The number of large plants inside the corridor increased from 52 in 1990 to 58 in 2013, while the number outside the corridor remained at 22. Forty-one of the 52 large plants inside the corridor in 1990 were still open in 2013, while 11 were closed and 17 new ones were opened (see figure 7 and table 1). Meanwhile, 19 of the 22 large plants outside the corridor in 1990 were still open in 2013, while three were closed and three new ones replaced them (see figure 7 and table 1).

As a result of these plant openings and closures, the percentage of Europe's large auto assembly plant production located in the corridor increased noticeably between 1990 and 2013: In 1990, 68 percent of the region's 14.4 million vehicles were assembled in the corridor; however, in 2013, 78 percent of the region's 15.4 million vehicles were assembled in the corridor (see table 1). By comparison, approximately 73 percent of North American production took place in auto alley in 2013.[27]

As a bulk-gaining industry, the motor vehicle industry tends to have its assembly plants agglomerate in order to minimize the costs of shipping the final products to the consumers. Consistent with this principle of industrial location theory based on Weber (1929), Europe's auto production corridor is situated within the continent's area of highest population concentration. Figure 8 shows each NUTS-3[28] region's level of population within a 450-kilometer radius from its centroid

FIGURE 7

Auto assembly plant closings in Europe between 1990 and 2013



Note: The national borders reflect those as of 2013.
Sources: Authors' adaptation of data from ACEA, IHS Global Insight, auto company websites, and Maptitude.

as of 2013. The highest values appear for NUTS-3 regions within Germany, northeastern France, and western Czechia. This area represents the heart of Europe's auto production corridor.

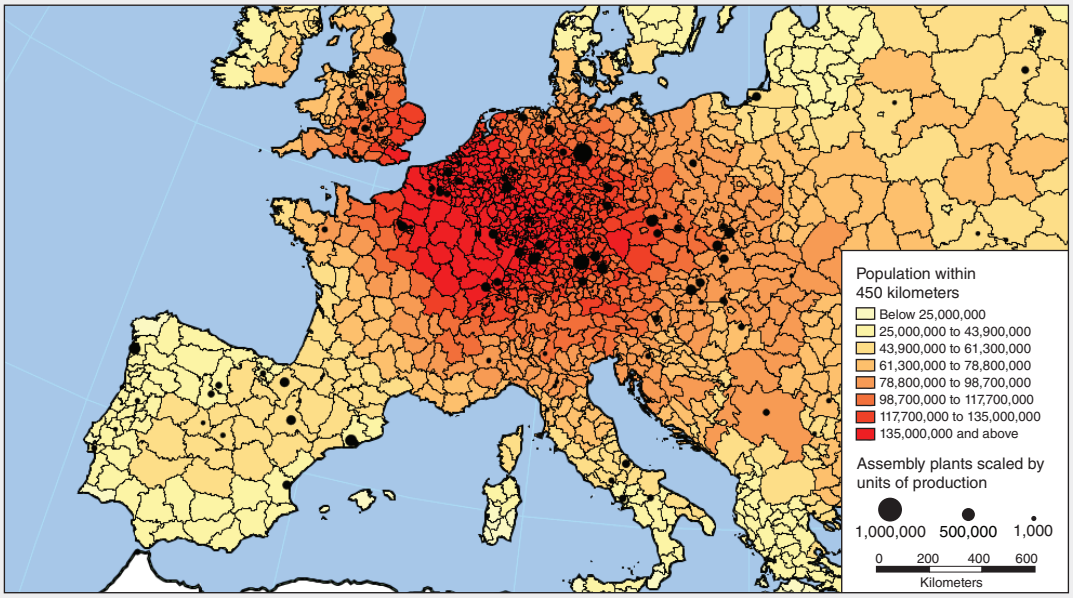
Within a one-day drive of Europe's auto production corridor (roughly 600 kilometers) are clustered approximately 80 percent of the region's population, about 85 percent of the region's total gross national income (and therefore buying power for new vehicles), and around 70 percent of the region's new vehicle sales in 2014.[29]

As the region's largest auto producer, Volkswagen has been the carmaker with the most location decisions affecting (and affected by) the agglomeration of assembly plant production in Europe. VW built six of the 20 new plants in Europe between 1990 and 2013 and owned only one of the 14 that were closed (a plant in Barcelona, Spain, that was replaced with a new facility nearby). In addition, VW took over five plants in Central Europe—specifically, three in Czechia and one each in Slovakia and Poland—along with one plant each in the former East Germany, Portugal, and Spain. Asian carmakers opened seven new plants across Europe—specifically, two each in Czechia and the UK and one each in France, Hungary, and Slovakia (two of the plants were joint ventures between Toyota and PSA).[30]

Most auto parts suppliers' plants are also located in the auto production corridor, although the percentage is lower than that for large auto assembly plants. The 100 largest parts suppliers (by revenues) together had 1,825 plants in Europe in 2011, and 74 percent of these were located in the auto production corridor.[31] Moreover, of the nearly 1 million employees working

FIGURE 8

Auto assembly plants and the level of population, by NUTS-3 region, in Europe, 2013



Notes: NUTS stands for Nomenclature of units for territorial statistics (or, in French, *Nomenclature des Unités territoriales statistiques*). For details on the European Union standard for regions at the NUTS-3 level, see note 28 and http://ec.europa.eu/eurostat/web/nuts/overview. For each NUTS-3 region, the population level within a 450-kilometer radius of its centroid is given.

Sources: Authors' adaptation of data from Eurostat, ACEA, IHS Global Insight, auto company websites, and Maptitude.

for parts suppliers in 2010, about 688,000, or around 70 percent, of them had their auto parts jobs in the corridor (see table 2).

Assembly plant distribution within the auto production corridor

Europe's auto production corridor is subdivided into a western portion and an eastern portion. The dividing line follows the old Iron Curtain. The eastern portion encompasses the auto assembly plants in the Central European countries of Czechia, Hungary, Poland, and Slovakia, as well as the former East Germany. The western portion encompasses the auto assembly plants in Austria, Belgium, France, the Netherlands, the United Kingdom, and the former West Germany. The western portion of the corridor accounted for 56 percent of all large auto assembly plant production in Europe in 2013 (down somewhat from 64 percent in 1990), while the eastern portion accounted for 22 percent of it (up substantially from 4 percent in 1990) (see table 3).

Most of the new assembly plants were sited in the eastern portion of the auto production corridor, while most of the closed plants were situated in the western portion (see figure 6 on p. 109 and figure 7 on p. 111). In 1990, the western portion had 44 of the corridor's

TABLE 2

Auto parts supplier employment in Europe, 2010

Location	Number of jobs
Western portion of corridor	**390,299**
Germany	244,382
France	61,759
United Kingdom (estimated)	56,600
Belgium	10,947
Austria	11,956
Netherlands	4,655
Eastern portion of corridor	**297,054**
Poland	105,762
Czechia	102,425
Hungary	51,617
Slovakia	37,250
Outside corridor	**295,911**
Romania	97,072
Italy	86,022
Spain	66,421
Portugal	21,433
Sweden	16,454
Slovenia	8,509
Total	**983,264**

Source: Authors' calculations based on data from Frigant and Miollan (2014).

52 large auto assembly plants (capable of producing 100,000 vehicles per year) and the eastern portion had eight. Twelve of the 17 large assembly plants that opened in the corridor between 1990 and 2013 were in the eastern portion. In contrast, nine of the 11 large auto assembly plant closures in the corridor over this period were in the western portion. As a result, the number of large assembly plants in the eastern portion increased from eight in 1990 to 18 in 2013 (specifically, from three to five in Czechia, from zero to three in Hungary, from one to three in Slovakia, and from one to four in the former East Germany). Meanwhile, the number of large assembly plants in the western portion of the corridor declined from 44 to 40; three of the four net closures occurred in Belgium, while very few changes in the number of large plants occurred in the three primary car-producing countries in the western portion (that is, the number of assembly plants remained at 15 in the former West Germany and at 11 in France, but decreased from 11 to ten in the UK) (see table 3). The corresponding increase of the auto corridor's production share (up from 68 percent in 1990 to 78 percent in 2013) was even more tilted in favor its eastern portion: The light vehicle production share of the western part of the corridor dropped by 8 percentage points—from 64 percent to 56 percent—whereas the eastern part's share more than quintupled—from 4 percent to 22 percent (see table 3).

As indicated earlier, the carmakers' push into Central Europe after the dismantling of communism and removal of trade barriers was initially motivated by the lower costs of labor in the countries there.[32] The hourly compensation cost for auto workers in 2007, for example, was (at a purchasing power parity, or PPP, exchange rate[33]) $11.30 in Poland, $12.30 in Hungary, and $16.64 in Czechia, compared with $44.47 in Germany, $26.34 in France, $28.02 in Spain, $27.66 in the UK, and $24.64 in Italy (Stanford, 2010, p. 392).

Several indicators suggest that auto production has become integrated across a much wider area of Europe than it was in 1990. First, the tight linkage between motor vehicle production by the national champions (VW, Fiat, PSA, and Renault–Nissan[34]) and their respective home countries has been noticeably eroded (see figure 9 and table 4).[35] Today all four of these major European auto producers have a substantial production presence in Central Europe. Their new investments in production facilities sited in Central European countries lowered the share of auto production in their respective home countries (to just around 50 percent of total European auto production in 2013 from well above the 50 percent mark in 1990; see table 4).[36] For further evidence of motor vehicle production having become integrated across a wider expanse of Europe than in 1990, we point to two low-cost automotive brands that are produced in Central Europe for sale in all of Europe. Renault–Nissan produces Dacia vehicles primarily at its Piteşti plant in Romania. VW produces Škoda vehicles primarily at two plants in Czechia (Mladá Boleslav and Kvasiny). For both brands, most of their European sales now take place in Western Europe. For Dacia, the Western European sales share grew from 0 percent to 83 percent between 2000 and 2013; for Škoda, it increased from 55 percent to 74 percent over the same period.[37]

TABLE 3

Number and share of large auto assembly plants and their share of auto production, by location within Europe, 1990 and 2013

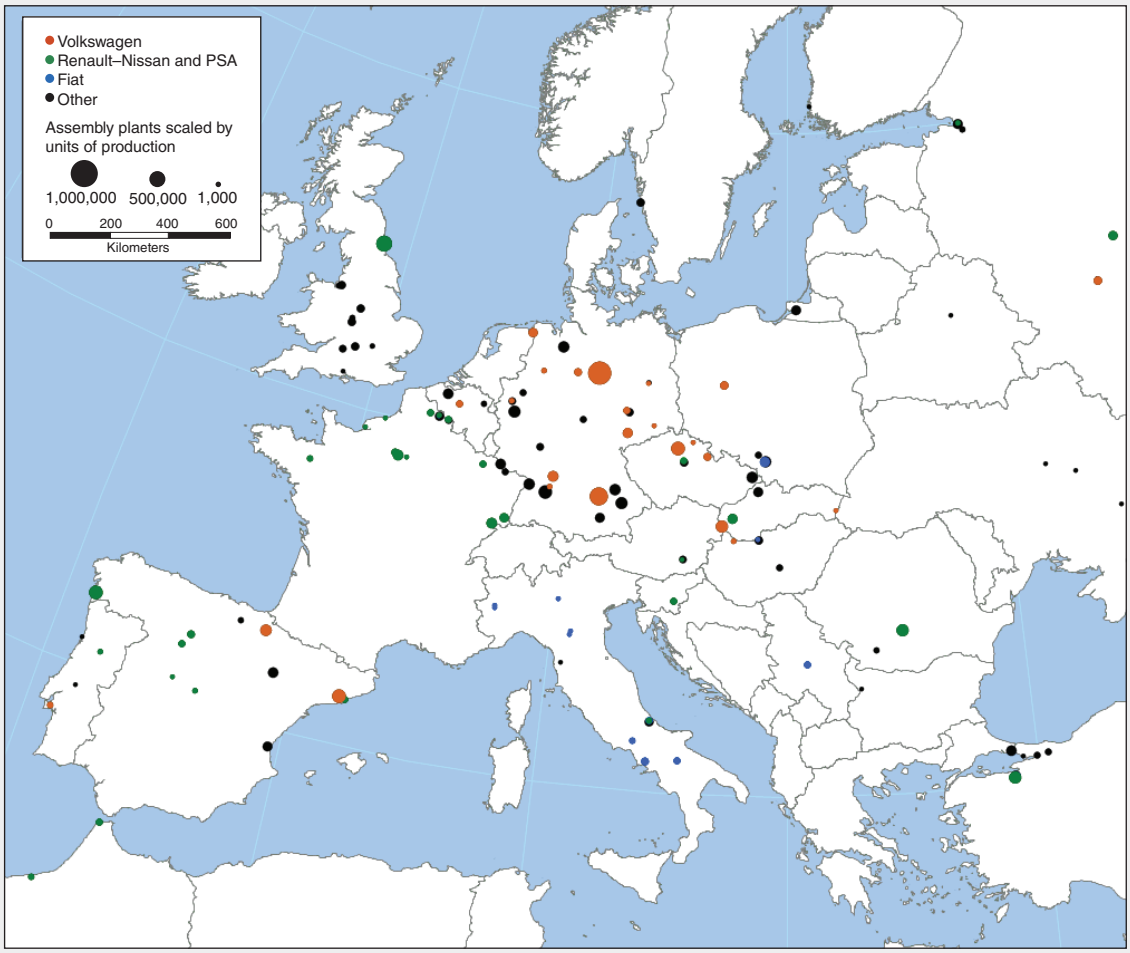
	1990				2013			
	Western portion of corridor	Eastern portion of corridor	Outside corridor	All	Western portion of corridor	Eastern portion of corridor	Outside corridor	All
Number of large assembly plants	44	8	22	74	40	18	22	80
Percentage of large assembly plants	59	11	30	100	50	23	28	100
Percentage of production	64	4	32	100	56	22	22	100

Notes: The corridor refers to the auto production corridor in Europe. See table 2 for a list of the countries in each of the three geographical categories. In this table, Germany is accounted for somewhat differently than it is in tables 1 and 2: Plants located in the former West Germany are included in the western portion of the auto corridor, while plants located in the former East Germany are included in the eastern portion of the auto corridor, as noted in the text. This is done to allow for a more detailed discussion of the geography within the auto corridor. The sample for this table is limited to large auto assembly plants, which are defined as plants capable of producing at least 100,000 units per year. Certain percentage rows may not total because of rounding.

Sources: Authors' calculations based on data from ACEA, IHS Global Insight, and auto company websites.

FIGURE 9

National champions' auto assembly plants in Europe, 2013



Notes: See the text for further details on the national champions. Renault began its strategic alliance with Japanese automaker Nissan in 1999 (see note 34 for further details).
Sources: Authors' adaptation of data from ACEA, IHS Global Insight, auto company websites, and Maptitude.

Outliers of auto production agglomeration in Europe and North America

From our previous discussion and map figures, it should be clear that motor vehicle production in Europe and North America does not take place exclusively inside their respective auto industry corridors today. Some investment continues to flow toward production facilities located outside these corridors. In this section, we briefly touch on the principal exceptions to the patterns of agglomeration of motor vehicle production in Europe and North America.[38]

In Europe, 19 of the 22 large plants in operation outside the corridor in 1990 remained open in 2013, while three were closed and three new ones were opened (see table 1 on p. 110). In both 1990 and 2013, Spain had ten of the 22 assembly plants and Italy had seven. The three closed plants were in Italy, Spain, and Sweden, and the three new ones were in Italy, Portugal, and Spain. In Spain, the new plant in the Barcelona area was built to replace the one that had been shuttered there. Yet, simply reporting the counts of auto assembly plants in 1990 versus 2013 can be a bit misleading because production volumes within assembly plants can be adjusted noticeably. The percentage breakdown of European auto output by location shows a larger change in the production footprint in Europe: For plants outside the auto corridor, the share of production declined noticeably from 32 percent in 1990 to 22 percent in 2013 (see table 1 on p. 110).

In Spain, large-scale investment in motor vehicle production began in the early 1950s. A Spanish-owned carmaker SEAT (Sociedad Española de Automóviles

TABLE 4

Home country share of auto production and sales in Europe, 1990 and 2013

	Home country percentage of production		Home country percentage of sales	
Automaker (home country)	1990	2013	1990	2013
Fiat (Italy)	91	56	71	48
Volkswagen (Germany)	72	55	46	41
Renault–Nissan (France)	55	27	54	37
PSA (France)	73	48	48	42

Notes: The 1990 and 2013 production values and the 2013 sales values apply to the 16 European countries of interest in the article (see p. 102). However, the 1990 sales values apply to only the following ten countries: Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. The six Central European countries for that year were excluded because trade barriers prevented imports of new vehicles into these countries. Renault began its strategic alliance with Japanese automaker Nissan in 1999 (see note 34 for further details).
Sources: Authors' calculations based on data from ACEA, IHS Global Insight, Crain Communications Inc. (1992), and auto company websites.

de Turismo) was established in 1950 by a state-owned industrial holding company, and it became a subsidiary of VW in 1990. In addition to SEAT's Barcelona plant, four other assembly plants were opened in Spain in the 1950s, and these four are still in use; they were built by Daimler, Renault, Chrysler, and Citroën (the plants built by the last two are now owned by PSA). A second wave of investment in the late 1970s and early 1980s resulted in the openings of five more of Spain's current inventory of ten assembly plants. Carmakers are expected to maintain the current roster of assembly plants in Spain, but new assembly plants have been situated by Renault–Nissan and PSA on the other side of the Strait of Gibraltar, in Morocco (to take advantage of relatively lower labor costs there). New vehicle production in Spain stood at around 2 million units in both 1990 and 2013.

Since 1990, auto production in Europe has been increasing in an extension of the corridor toward the east. Romania, which we did *not* include in the definition of the corridor, is a major production center for Renault–Nissan. Several carmakers have important production facilities in Turkey that export vehicles to Europe. After the breakup of the Soviet Union, production in Russia also appeared likely to become integrated into the European market, but events in recent years have pushed that likelihood into a future beyond the planning horizon for carmakers' investment decisions (see, for example, Adomanis, 2015).

In North America, the principal center of motor vehicle production outside auto alley is in central Mexico. Sixteen assembly plants were in operation in 2013, with three more under construction at that time. Production in Mexico increased from 820,558 vehicles in 1990 to 3,038,196 in 2013, so not surprisingly, its share of North American auto production rose from 6 percent in 1990 to 19 percent in 2013. The primary factors driving increased auto production in Mexico have been relatively low production costs and strong export opportunities (Klier and Rubenstein, 2013b). Approximately 60 percent of Mexico's auto production is for export to the United States and Canada, about 20 percent is for export to other regions, and around 20 percent is for domestic consumption.[39]

Conclusion

The footprints of motor vehicle assembly (and parts) production in North America and Europe are concentrated today. In this article, we laid out in broad strokes the process by which the geography of Europe's light vehicle industry has changed since 1990. It turns out that the auto industry in Europe restructured its footprint according to the principles of agglomeration and industrial location theories (including the key principle of locating assembly plants closer to customers for bulk-gaining industries). Those principles also help explain the current footprint of motor vehicle assembly observed in North America. Today both North America and Europe display agglomerated distributions of motor vehicle production that are strikingly similar. While the two regions have reached their respective patterns of auto production agglomeration based on different histories, similar forces have shaped the spatial convergence of auto production now observed in both regions.

North America's spatial pattern of auto production has been formed through decisions made by international carmakers to site their plants in auto alley and decisions by Ford, General Motors, and Chrysler to replace coastal branch assembly plants with new plants in auto alley. Europe's auto production corridor has developed primarily through decisions by the region's long-standing national champions—VW, Fiat, PSA, and Renault–Nissan—to replace country-specific production strategies designed to serve country-specific markets with region-wide production strategies designed to serve the economic space of an enlarged Europe following the fall of the Iron Curtain.

NOTES

[1]Specifically, we are interested in light vehicle production—that is, the production of passenger cars and light trucks (referred to as light commercial vehicles in Europe). Excluded from our analysis are heavy-duty trucks (such as those used in the construction industry) and buses.

[2]In this section, unless indicated otherwise, references to assembly and parts plant counts and light vehicle production (and their percentages by various geographical divisions) in Europe are from authors' calculations based on data from the ACEA (Association des Constructeurs Européens d'Automobiles, or, in English, the European Automobile Manufacturers' Association; see http://www.acea.be), IHS Global Insight, and auto (assembly and parts) company websites. Also, unless indicated otherwise, references to assembly and parts plant counts and light vehicle production (and their percentages by various geographical divisions) in North America are from authors' calculations based on data from Ward's AutoInfoBank (database by subscription), Elm Analytics, and auto company websites.

[3]For a description of the EU and further details on its history and policies, see http://europa.eu/index_en.htm.

[4]The Czech Republic is the English translation of the country's constitutional name, but Czechia is the official English short form of the name according to the United Nations. The use of Czechia instead of the Czech Republic is equivalent to the use of the United Kingdom instead of the United Kingdom of Great Britain and Northern Ireland. See http://www.czechia-initiative.com.

[5]As shown in figure 1 (p. 102), auto alley is approximately 1,300 kilometers long and 400 kilometers wide.

[6]In figures 2 and 5–9, we refrain from labeling individual countries (or states) because the plant data would be obscured. For a detailed map of Europe with all the countries identified, use the map function at http://europa.eu/about-eu/countries/index_en.htm. Moreover, the set of auto assembly plants shown in these map figures is slightly less restrictive than the one used in tables 1 and 3, where we limit ourselves to just large plants. Large plants are defined as plants capable of producing at least 100,000 units per year.

[7]According to Google Maps, from Stuttgart, Germany, it is 11 hours by truck to Coventry, United Kingdom; nine hours to Budapest, Hungary; 12 hours to Barcelona, Spain; and 13 hours to Naples, Italy. We include the United Kingdom in the European auto production corridor based on road travel times.

[8]Analysis of European auto parts suppliers is based on data obtained by authors from the websites of the 100 largest parts suppliers (by revenues) in Europe. The data referenced here apply to 2011. (For an earlier version of these data [for 2010], see Klier and McMillen, 2013.)

[9]In theory, industry clustering leads to labor market pooling, facilitating economies of scale. As firms fail, workers can quickly move to other employers, thereby maximizing their productivity and lowering the variance in worker wages. Moreover, clustering facilitates better worker–firm matches.

[10]In the past, each assembly plant produced a much smaller number of vehicles than the 200,000 per year that are typically made today. For example, in 1925 Ford assembled 1.5 million vehicles at 32 assembly plants, for an annual average of fewer than 50,000 vehicles per plant (Rubenstein, 1992).

[11]The location of parts-producing plants has shifted southward (from the area centered on southeastern Michigan) as well. However, as noted before, Klier and McMillen (2008) find that the degree of agglomeration among parts supplier plants has remained essentially unchanged.

[12]Not all of these auto assemblers survived. For example, neither Leyland nor Rover continues to exist as an independent British company. Some have changed their corporate structure. For example, Fiat merged with Chrysler in 2014 and is now known as FCA (Fiat Chrysler Automobiles), Renault formed a partnership with Nissan in 1999, and Peugeot merged with Citroën in 1976.

[13]The official company name is PSA Peugeot Citroën, but it is commonly referred to as PSA.

[14]Over the period 1946–90, the term Iron Curtain referred to the border between the democratic countries of Western Europe and the communist countries of Central and Eastern Europe (the Eastern Bloc). For more details, see http://www.britannica.com/event/Iron-Curtain.

[15]The European Economic Community was informally known as the Common Market. The European Union replaced the EEC in 1993. For more details, see http://www.britannica.com/topic/European-Community-European-economic-association.

[16]Spain and, to some extent, Portugal had managed to attract initial auto assembly plant investment long before then, during the 1950s, because foreign auto producers wanted to gain footholds in those two markets. The presence of auto assembly operations in southwestern Europe grew noticeably during the second half of the 1970s and the early 1980s, before both countries joined the European Union in 1986.

[17]See http://www.europeanlawmonitor.org/eu-information/treaties/.

[18]Note that during the Cold War (1947–91) many Central European countries, such as Poland, Czechoslovakia, Romania, and East Germany, had their own automobile industries and motor-vehicle-producing companies. As Central (and Eastern) Europe opened up to market-based competition and outside competitors, those motor vehicle producers either went under or were absorbed by Western European producers (for example, Volkswagen acquired the Czech producer Škoda, and Renault acquired the Romanian producer Dacia). In addition, many new auto assembly operations (so-called greenfield plants, such as Opel's plant in Eisenach, which is within the former East Germany) were established (information from IHS Global Insight and auto company websites).

[19]Domański and Lung (2009, p. 5) state that "on the whole, the relatively high productivity of the CEE [Central and Eastern Europe] labour force based on its skills and motivation together with the new technology and organization of production and combined with lower wages led to the attraction of a great amount of foreign direct investment in the auto industry during the last 15 years."

[20]An additional plant was announced in 2014. It is to be built in Września, Poland. Production at the plant is scheduled to start in 2016. See http://www.volkswagen-poznan.pl/en/new-plant.

[21]Authors' calculations based on data from ACEA, IHS Global Insight, and auto company websites.

[22]Womack, Jones, and Roos (1990).

[23]Authors' calculations based on data from Ward's AutoInfoBank and Crain Communications Inc. (1992).

[24]IHS Global Insight.

[25]For an example of how consumers have responded to improvements in European automotive quality, see J.D. Power (2014).

[26]Note the differences in the footprint of auto production in 2013 (figure 6 on p. 109) versus 1990 (see figure 5 and its description on pp. 106–108).

[27]Authors' calculations based on data from Ward's AutoInfoBank.

[28]NUTS stands for Nomenclature of units for territorial statistics (or, in French, *Nomenclature des Unités territoriales statistiques*). The NUTS classification is a standard developed and maintained by the European Union for dividing up its members' territories in order to produce regional statistics. The NUTS system favors existing administrative units. For more details, see http://ec.europa.eu/eurostat/web/nuts/overview.

[29]Authors' calculations based on data from Eurostat.

[30]This information is from IHS Global Insight and auto company websites.

[31]Authors' calculations based on data obtained from company websites of the 100 largest auto parts suppliers (by revenues).

[32]Within Europe there was a widespread expectation that these new locations of auto production in Central Europe would evolve into sizable centers of new auto demand. See, for example, Jullien and Pardi (2015).

[33]Purchasing power parity exchange rate refers to the rate at which one country's currency would have to be converted into another's to buy the same amount of goods and services in each country.

[34]As mentioned earlier, Renault began its strategic alliance with Nissan in 1999. For further details, see http://blog.alliance-renault-nissan.com/node/239.

[35]Brincks, Klier, and Rubenstein (forthcoming) specifically address differences among the national champions, especially in regard to changes in their respective production footprints across Europe.

[36]The share of national champions' light vehicle sales in their home countries also fell over the period 1990–2013 (see table 4 on p. 115).

[37]Authors' calculations based on data from IHS Global Insight.

[38]In this section, unless indicated otherwise, references to assembly plant counts and light vehicle production (and their percentages by various geographical divisions) in Europe are from authors' calculations based on data from the ACEA, IHS Global Insight, and auto company websites. Also, unless indicated otherwise, references to assembly plant counts and light vehicle production (and their percentages by various geographical divisions) in North America are from authors' calculations based on data from Ward's AutoInfoBank and auto company websites.

[39]Authors' calculations based on data from IHS Global Insight.

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