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Agglomeration in the European automobile supplier industry

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Abstract

Motor vehicle and motor vehicle parts production plants tend to exhibit a strong degree of agglomeration. This paper estimates a spatial model utilizing detailed plant-level data that is pooled across seven countries in Europe. The paper makes several contributions. First, we assemble a set of nearly 1,800 European plant locations of the largest motor vehicle parts suppliers, as well as the location of all light vehicle assembly plants operational in 2010. Second, we obtain detailed spatial data – at a higher resolution than what is provided by the NUTS-3 regions – for five European countries (France, Spain, Italy, Poland, and the Czech Republic). For the U.K. (ward level) and Germany (community level) we acquired spatial data at an even more detailed level. These seven countries are home to over 70% of the plants in our data set. The ability to pool data from multiple countries allows us to estimate a location model for a large share of the vehicle parts industry, an industry that extends across all of Europe. The modeling results suggest that the main forces of agglomeration in the European auto supplier sector are (1) highway access (connecting supplier plants as well as suppliers and their downstream customers, the assembly plants), (2) the desire to locate near assembly plants, (3) as well as near other parts producing plants.

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Motivation

The geography of automobile production in Europe is characterized by agglomeration (see figure 1). Not only is the production of light vehicles (passenger cars and light trucks) concentrated in relatively few countries (such as the U.K, France, Spain, Germany, and the Czech Republic), but the industry also clusters within these countries. Note for example the rather sharp concentration of light vehicle production in northern France as well as northern Spain, two of the three largest vehicle producers in Europe in 2011 (see table 1).

Spatial agglomeration of industrial activity has received considerable attention in the economics literature (see for example Krugman 1991, Ellison and Glaeser 1997, Duranton and Overman 2005 and 2008). Most of the auto industry-specific literature relates to U.S. and North-American data (Klier and McMillen 2006 and 2008, Smith and Florida 1994, Woodward 1992), where, incidentally, the industry's location pattern very much resembles the degree of agglomeration observed in Europe. However, hardly any formal analysis exists regarding the geography of the auto industry from a Europe-wide perspective.

This paper focuses on the location of plants that produce motor vehicle parts. It contributes to the regional economics literature in several ways. First, it represents an effort to analyze the European auto industry at a regional (that is, multi-country) level. In order to do that, a unique data set needed to be constructed, combining spatial data from several countries. Second, the formal analysis focuses on the spatial pattern of the locations of motor vehicle parts plants in Europe, utilizing a unique set of plant-level data. A conditional logit model estimates the relative importance of industry-specific measures of agglomeration as well as the contribution of the presence of transportation infrastructure. One of the benefits of estimating such a model is the fact that its results can be compared to the existing literature that addresses data for North America.

The modeling results suggest that the main forces of agglomeration in the European auto supplier sector are (1) highway access (connecting supplier plants as well as suppliers and their downstream customers, the assembly plants), (2) the desire to locate near assembly plants, (3) as well as near other parts producing plants. These findings correspond very closely to evidence for the same industry from North America. They are consistent with the importance of tight linkages between assemblers and suppliers in the context of just-in-time production, requiring a number of logistics and supplier function to be performed in rather close proximity to the assembly location. The similarity of findings for Europe and North America suggest the use of the same production model in the auto industry in both regions. The role of the geographic center of the industry in Europe (Stuttgart), is found to be not nearly as important as in the U.S. (Detroit).

Auto industry in Europe

There is an extensive literature that describes and analyzes the evolution of the auto industry in Europe (see for example Domanski and Lung 2009, Domanski and Gwosdz 2009, Jürgens and Krzywdzinski 2010, and Lung 2003). Until the establishment of the European Economic Union, and its successor, the European Union, 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 producers headquartered in that country (so-called national champions). Fiat (Italy), Volkswagen (Germany), Renault and Peugeot (France), as well as Leyland and Rover (U.K.) fall into that category. While consumers were able to choose amongst products from virtually every producer in Europe, production facilities tended to be clustered in the country each vehicle producer was headquartered in. As economic integration gained momentum in Western Europe in the late 70s and during the 80s, Portugal and, especially, Spain attracted a number of new vehicle assembly plants due to the noticeably lower wage levels prevalent in both countries at the time.[1]

The second major event to shape the footprint of this industry in Europe was the fall of the iron curtain, starting in the late 80s. Subsequently automobile production expanded eastward in a major way.[2] The move into Eastern Europe was motivated by a desire to access the newly opened local markets as well as to draw on substantially lower labor costs. Between 1980 and 2010 the number of assembly plants in Eastern Europe rose from 6 to 21. Two thirds of the additional plants were located in just four countries: the Czech Republic, Poland, Slovakia, and Russia. Prior to that, the lower wage countries in Western Europe at the time, primarily Spain and Portugal, had been the main beneficiaries of new automotive investment, following the political liberalization of these two countries during the 70s and their subsequent integration into what was then the European Economic Union.

[1] Both Portugal and Spain had attracted initial assembly plant investment much before that, during the 50s, primarily as a way for producers to gain a foothold in those markets. However, the presence of assembly operations in southwestern Europe grew noticeably during the 1980s.

[2] Note that during the cold war many Eastern European countries, such as Poland, Czechoslovakia, Romania and East Germany, had their own automobile industries and companies. As Eastern Europe opened up to market-based competition and competitors, the old vehicle producers either went under or were absorbed by western European producers (for example, VW acquired the Czech producer Skoda, Renault acquired the Rumanian producer Dacia). In addition, many new assembly operations (so-called greenfield plants, such as Opel's plant in Eisenach, Germany) were established subsequently.

Europe’s auto industry is quite regionally integrated today. The mass producers all operate some plants located outside their home country. The industry footprint is spatially concentrated, displaying a strong east-west orientation, with the core automotive region extending south-east from England through northern France, Belgium, Germany, southern Poland, the Czech Republic and Slovakia (see Figure 1).

The auto producers’ supply chain extends throughout Europe as well. It consists of a large number of companies, ranging from large, global suppliers to small, family-run businesses. A key element linking the parts and assembly plants are requirements of the production system regarding delivery frequency and accuracy (in terms of being on time). Several papers address the evolving footprint of motor vehicle parts production in Europe (see Sadler (1999), Frigant and Layan (2009), and Frigant (2009)). Frigant (2009) suggests that “suppliers’ spatial reorganizations have occurred on a grand scale” (p. 433). He states that the pull of lower coast locations has been one of the dominant influences. However, he notes that “productive constraints limit the distance at which delocalization can occur” (p. 434). Jürgens and Krzywdzinski (2010) find evidence of relocation of production activities from western to Eastern Europe. The authors identify several phases of development for the parts sector: During the mid-90s production locations were established for labor intensive parts. Production of parts often served local markets. During that time qualified local suppliers were scarce. Going forward, more products as well as the capability to produce complex parts requiring skilled labor were added in plants in central and eastern Europe. At that time exports from there to western Europe, particularly to Germany, grew rapidly.

Data

Auto industry data

Data for assembly plant locations in Europe were obtained from the European Automobile Manufacturers Association (ACEA) as well as from company websites. Information on the location of plants producing motor vehicle parts was obtained via company websites for the year 2010. We started with a list of the largest supplier companies by revenue.[3] For each of those companies we compiled a current list of production facilities from the company websites. Our list focuses on production establishments and, when possible, only includes locations that produce output for automotive applications.

Figure 2 adds the footprint of the production facilities of the largest motor vehicle parts suppliers present in Europe to the footprint of vehicle assembly operations. The map shows 1,744 individual parts plants, representing 94 companies.

Population data

To measure the extent of the auto supplier industry's agglomeration we compare it to the distribution of population. Population data are easy to obtain at a relatively high level of resolution for a large number of countries as Eurostat offers it for the so-called NUTS-3 regions.[4] The NUTS-3 region data are available with the underlying shapefiles.

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[3] To compile the list of supplier companies for Europe we started with a list of the global 100 largest suppliers. We sorted by revenue in Europe (excluding the ones that don't do business in Europe) and cross-referenced with a list of the 30 largest motor vehicle parts suppliers in Europe. We end up with a list of 94 companies.

[4] The NUTS (Nomenclature des Unites Territoriales Statistiques) classification was established at Eurostat for all OECD member countries. It represents a geocode standard for identifying subdivisions of countries. The NUTS-3 level distinguishes 1,303 regions.

At first glance our plant data line up rather well with the distribution of population (see figure 3). The attractiveness of utilizing the NUTS-3 regions is that that data is available for essentially all EU member countries. Unfortunately, there are two disadvantages to the NUTS-3 data. First, the underlying geographic areas are not uniformly sized. Note that for several countries (Germany, Belgium, and the Netherlands) the NUTS-3 regions are noticeably smaller. Second, the NUTS regions are likely too large for our project as a number of regions are home to many parts plants. E.g., 27 individual NUTS-3 regions include 10 or more supplier plant locations; the highest occupancy is 44.

To obtain more detailed population data we inquired with the respective statistical agencies for a set of seven European countries that are home to a large number of motor vehicle parts plants, representing 71% of the observations in our data (and 68% of European light vehicle production in 2011). The countries with the largest number of plants are Germany, France, Spain, Italy, U.K., Poland, and the Czech Republic (table 2). We obtained population data from the statistical agencies for France, Spain, Italy, Poland, and the Czech Republic. The population data for Germany and the U.K was included with the detailed spatial data we acquired for those two countries (see below). We end up with population data that is more detailed than NUTS-3 for seven European countries. The level of detail, however, varies by country (see Table 3).

Spatial data

Both plant and population data are defined as points. In order to model location choices we need to place them in area-based spatial units. The idea is to have a grid, an area-based measure that covers a country's space. Ideally we would want to have a grid of high enough resolution to avoid occupancy of a single cell by many parts plants.[5]

There are two ways to go about this task: One can use existing spatial units, such as the NUTS-3 regional grid. Note that for the purposes of this paper NUTS-3 regions are too aggregate. That leaves us with country-specific spatial units. While more detailed than NUTS-3, they also tend to differ in important features. For example, the U.K wards data and the German "community" data, files we acquired for this study, treat population density differently. U.K. wards are designed to capture a similar amount of population; the footprint of a ward gets smaller in size as its population goes up. In Germany, on the other hand, large cities are defined as one area, representing a single observation of population.

The alternative to working with existing, country-specific spatial data is to create a consistently defined grid that extends across all relevant countries. This can be done fairly easily from within any GIS software program. In applying that methodology to the seven countries of interest we chose to make the elements of the grid small enough to reduce as much as possible the multiple incidence of plants in a spatial cell. The grid we chose consists of identical cells of 0.1 degree length (that corresponds to an area of about 30 square miles).[6] In comparing these cells to the size of wards (the shapefiles we utilize for the UK), our grid cells correspond to the larger of the UK wards (see A. Briant et al, 2010, on the importance of size but not shape of the areas when constructing a grid).

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[5] Our grid includes only two cells with 10 or more parts plants (one with ten, another one with 17). Only 13 of the 27,698 cells include more than 5 plants.

[6] The grid is anchored in a way that is replicable if we were to generate grids with alternate cell size.

A unit of observation will be a plant location defined at the level of a spatial area. Aggregation-based variables will be calculated in reference to the centroid of each of these areas. To assure consistency in the aggregation of the underlying data we geocoded our plant observations at the same spatial level. For example, we coded plant locations at the grid-cell level rather than the more detailed street address.

Finally, in the process of defining spatial variables for our location model, there are a number of border issues to consider. First, our self-made grid does not necessarily follow a country's border. As several of the countries include a number of small islands, such as Mallorca (Spain), we deleted all islands as well as all grid cells that are entirely over water.[7] That leaves some cells that partially cover land as well as water, as well as cells that cover land areas from more than one country. Cells, which are truncated in terms of the land area they cover received a dummy variable to acknowledge the truncation of possible locations. Cells extending into countries that are not in our data set, such as Portugal and Austria, receive the same treatment as they are truncated as well. Cells that extend into an adjacent country that is included in our data set, for example a cell at the border between France and Spain can include land from both countries. These cells receive a dummy variable for each of the two countries they are part of. They are, however, not included in the "border cell" category.

How does our grid treat the presence of economic activity in neighboring countries that are not part of the grid? Our model includes several variables that measure the agglomeration of auto industry activity relative to the centroid of a grid cell. Since we have data on the location of auto parts plants as well as auto assembly plants for essentially all of Europe, we can

[7] Small countries, such as Andorra, are treated like islands and are excluded from the grid.

account for the presence of such plants in a country that borders our grid. However, we cannot include the presence of population in neighboring countries outside the grid, as we do not have detailed population data for those countries.

Finally, there is the question of spatial resolution within a country. A cell in the grid we constructed covers approximately 30 square miles. If the underlying population data are not very detailed, even our detailed grid can lead to a possibly discontinuous measure of population. For example, in the case of Poland there is generally only one population observation per grid cell.

Table 4 presents descriptive statistics for the variables used in our analysis. Data are presented for each of the seven countries individually as well as jointly. In addition, we present descriptive statistics for samples of randomly chosen alternative locations. These alternative locations represent the rejected alternatives for our conditional logit models. To identify these alternatives, we match each plant with five randomly chosen grid cells that are different from the plant's actual location as well as different from each other. Candidate alternatives are represented by any location within a country, as well as within any of the seven countries in the pooled model. The alternative for one plant may include a grid cell that already has another plant.

The presence of a two-way divided highway in a grid cell increases the likelihood of a auto parts plant being located there. We include population (the level of population as well as, alternatively, a gravity-based measure of population density). We also include country dummies (in the pooled model), a measure of the distance to Stuttgart (serving as a proxy for the spatial center of the European auto industry), as well as several other measures of the industry geography. Parts plants are more likely to be located near assembly plants as well as near other parts plants.

A conditional logit model of plant locations

We estimate conditional logit models to explain the probability that an auto supplier is located in a grid cell. This analysis follows Klier and McMillen (2008), who estimated the location decision of plants at a similar level of geographic detail. The 2008 paper utilized data for the U.S. and estimated location decision over 28,000 possible zip codes. This paper estimates a similar model for European data, utilizing a location grid that consists of 27,698 cells (encompassing seven countries).[8] For each plant, we know the characteristics of the rejected locations as well as the characteristics of the chosen location. In combining that information, a conditional logit model produces an efficient set of coefficient estimates. Implicitly, at the pooled level, each plant faces 27,698 potential location choices.[9] However, we follow Ben-Akiva and Lerman (1985) and randomly choose five rejected alternatives when estimating the model. Since the rejected alternatives are chosen randomly, the resulting coefficient estimates are consistent and more efficient than a multinomial logit model estimated at a higher level of aggregation.

[8] Several other papers estimate location decisions of auto suppliers; see for example Woodward (1992) and Smith and Florida (1994). However, the models are estimated at a higher level of spatial aggregation by utilizing county-level data.

[9] When we estimate the conditional logit model for each country separately, the choice set is smaller: France (6,717 choices), Italy (3,143 choices), Spain (5,533 choices), Czech Republic (1,107 choices), Poland (4,332 choices), Germany (4,945 choices), and the U.K. (Wales and England in our case, 2,317 choices). Alternatively, in the case of Germany and the U.K. we also estimate the model at based on shapefile data. Then the choice sets are as follows: Germany (12,302), U.K (8,499).

The resulting dataset has 6n observations. The dependent variable, measuring a plant's location, equals 1 for the first observation for each plant and zero for the next five observations. The explanatory variables include the characteristics of the chosen plant location as well as the characteristics of the randomly chosen rejected locations. Standard errors are adjusted for the clustering that is implicit in having six observations for each plant.

The main results are shown in Table 5; column 8 presents the pooled regression, columns 1 through 7 are estimated at the country level. The results are very similar across the seven countries as well as for the combined data set. A grid cell is more likely to be chosen as a plant location if a highway runs through it, the more parts supplier plants are located within a 100 km radius, if the location is close to the nearest vehicle assembly plant and as the level of population increases (that effect is very small in size). The pseudo-R-squared of the pooled model is 0.43, suggesting a good fit by the standards of discrete choice models.[10]

The results reported are robust to different specifications. Table 6 presents the estimates obtained from applying the same model to the shapefiles for the U.K. (England and Wales) and Germany. The shapefiles are defined differently for both countries (the represent "wards" in the U.K. and "communities", the least aggregate level available, in Germany). Table 7 presents another alternate estimation. It is based on the NUTS-3 level regions. Despite the

[10] Note that the model defines the distance to control for spatial production linkages as 100km, a distance a bit shorter than what has been used in work utilizing data for North America. Our results are robust with respect to the choice of distance.

larger size of the underlying spatial areas, the results hold up well, both for the seven countries (column 1) as well as for the entire set of NUTS-3 countries (column 2).

The models suggest that the main forces of agglomeration in the auto supplier sector are (1) highway access (connecting supplier plants as well as suppliers and their downstream customers, the assembly plants), (2) the desire to locate near assembly plants, (3) as well as near other parts producing plants. Unlike in the U.S. (Detroit), the role of the geographic center of the industry in Europe (Stuttgart) is not nearly as important.[11]

We also estimate the models with an alternate measure of population. The main issue is that the underlying population data are measured at different levels of resolution across the seven countries. In Poland, then measure of population is presented in rather aggregate fashion (see Table 3). In the U.K. the wards shrink in size as population increases. In Germany, large cities are represented by one shapefile with a corresponding observation for population (that is, there is no population gradient within a city). When we overlay our self-made grid, it results in several cells empty of population per large city. We feel a potentially better way to address this is by defining a gravity-based measure of population density. The measure is calculated over a certain radius extending out from each centroid of the grid cells, smoothing out population density in the process. We chose a radius of 10 miles, as well as a decaying function of population along that distance. Our results are robust with respect to the choice of the population measure.

[11] Part of this difference is possibly due to fundamental differences between the two regions, such as the fact that Europe represents a collection of sovereign states, as well as the different footprint of the underlying geography. The question of how to compare the relative degree of agglomeration across two regions is a subject of ongoing research by the authors of this paper.

Conclusion

This paper sets out to apply a standard location model to a new set of data on plant locations of motor vehicle parts producers in Europe. The contributions of this paper are concentrated in the collection and preparation of the data. To our knowledge it represents the first attempt to estimate a location model for this industry across a multi-country region in Europe. Other than collecting the plant location data itself, challenges arose from combining population data that are measured differently across countries as well as finding a common spatial framework upon which to base our formal analysis. The main results presented rely on a very detailed, uniform grid for seven European countries. It consists of over 27,000 individual cells and allows for consistent and efficient estimation of parameters.

The modeling results suggest that the main forces of agglomeration in the European auto supplier sector are (1) highway access (connecting supplier plants as well as suppliers and their downstream customers, the assembly plants), (2) the desire to locate near assembly plants, (3) as well as near other parts producing plants. These findings correspond very closely to evidence for the same industry for North America. The importance of reasonably close spatial proximity in the European auto industry suggests the prevalence of just-in-time production methods. Unlike in the U.S., the role of the geographic center of the industry (Stuttgart in Europe, Detroit in the U.S.) is found to be not nearly as important.

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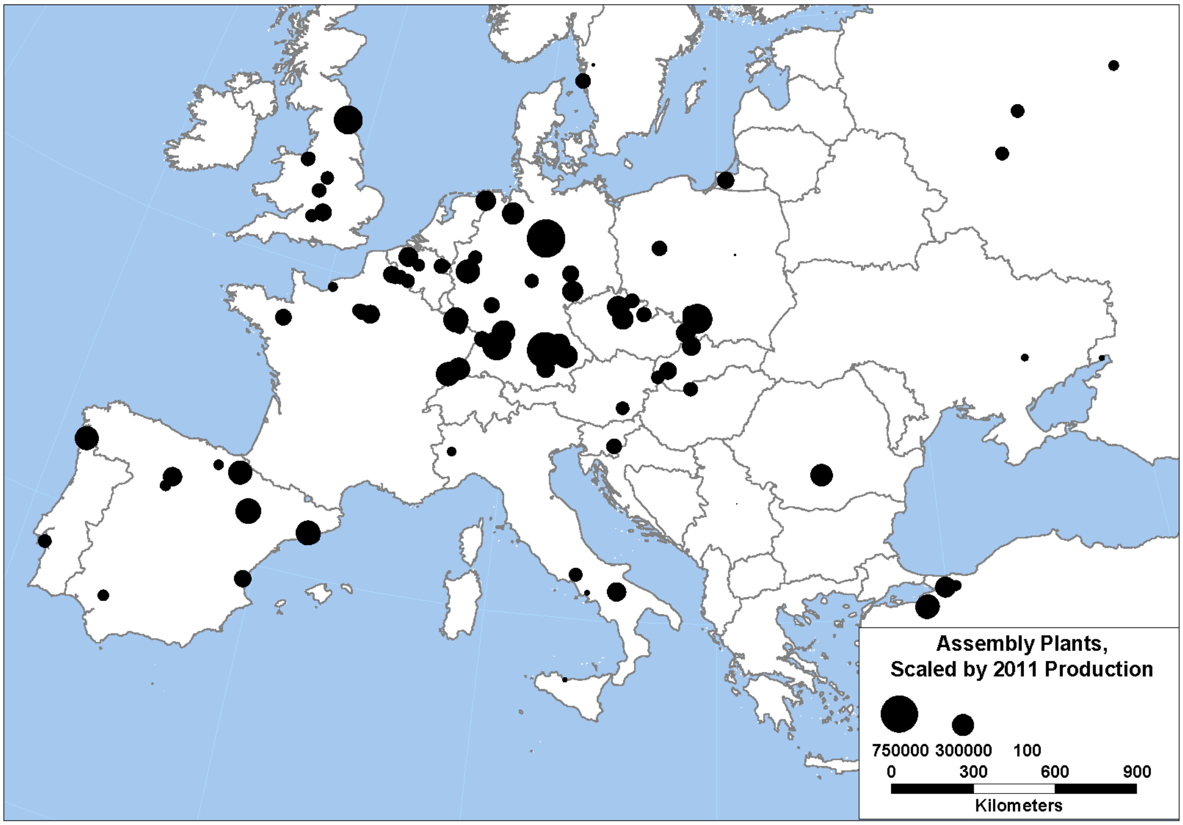
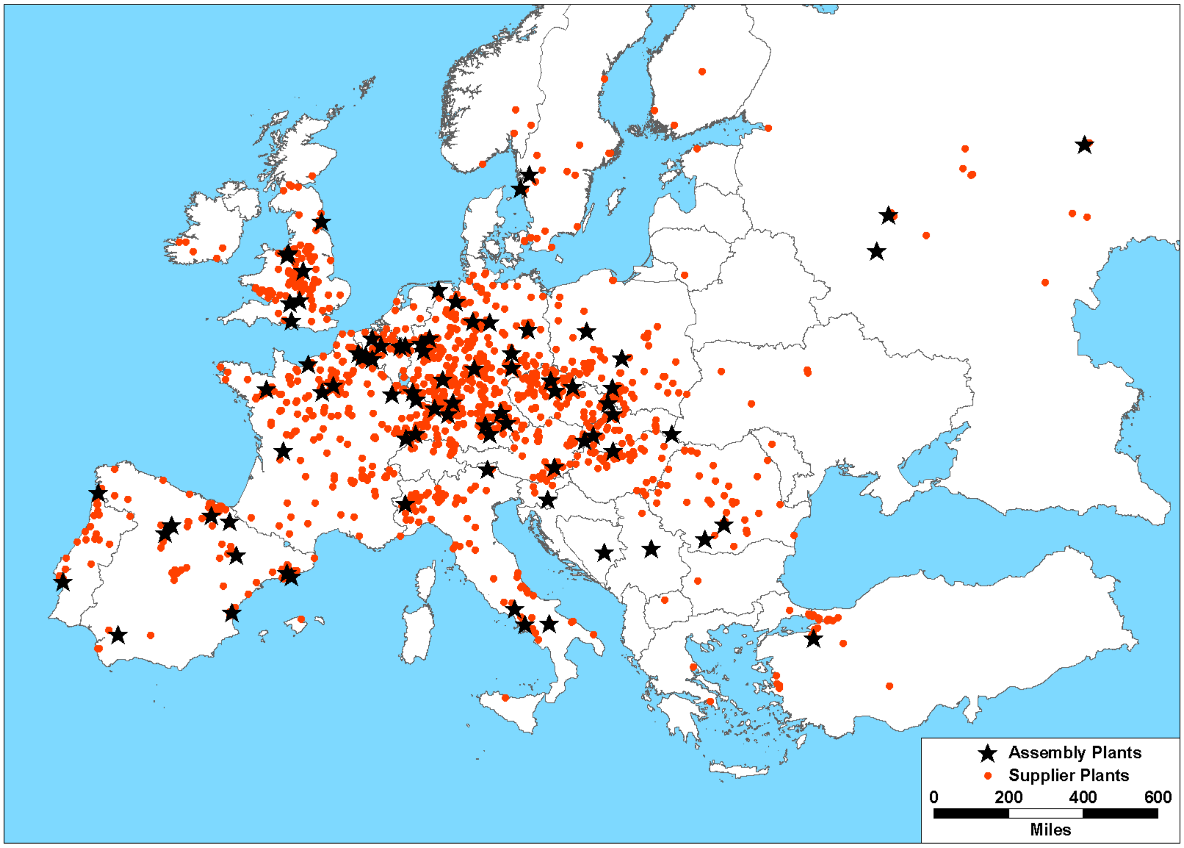
Figure 1: Geography of light vehicle production in Europe, 2011



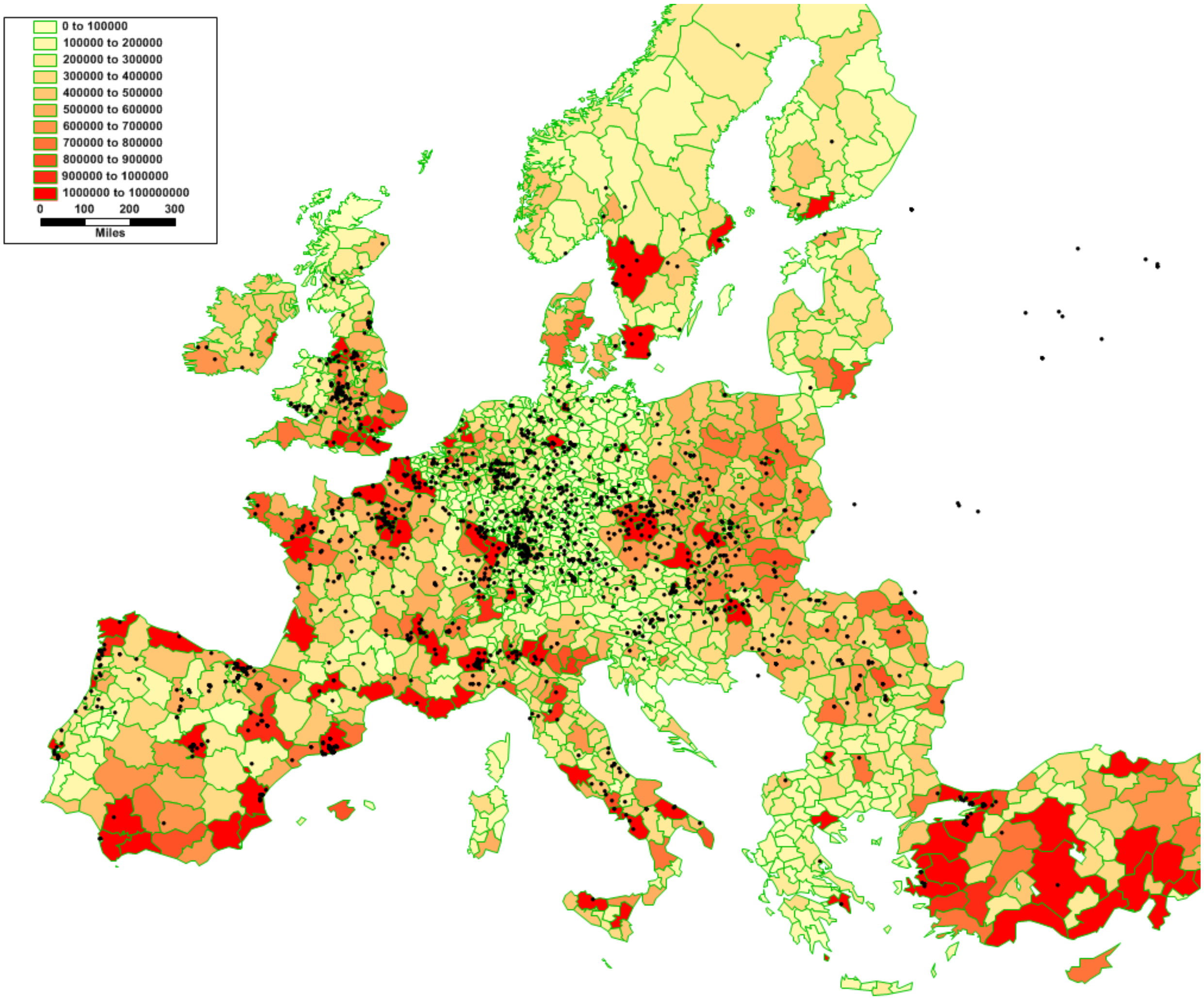
Source: ACEA

Figure 2: Geography of motor vehicle parts production in Europe, 2011



Source: ACAE, company website, authors' data

Figure 3: NUTS-3 regions, population density, and location of motor vehicle parts plants



Note: Supplier plant locations are indicated by black dots. Population density by NUTS-3 region according to shading; the darker colors indicate higher density.

Source: Eurostat, authors' data

Table 1: Light vehicle production in Europe, 2011, by country

Production Country	**Units**	**percent**
GERMANY	5,567,598	30.1
SPAIN	2,298,979	12.4
FRANCE	2,108,553	11.4
UNITED KINGDOM	1,300,017	7.0
RUSSIA	1,193,237	6.5
CZECH REPUBLIC	1,153,959	6.2
TURKEY	1,046,552	5.7
POLAND	842,494	4.6
SLOVAKIA	569,472	3.1
BELGIUM	522,441	2.8
ITALY	499,182	2.7
ROMANIA	312,211	1.7
UZBEKISTAN	215,754	1.2
SWEDEN	175,793	1.0
SLOVENIA	165,510	0.9
HUNGARY	145,639	0.8
PORTUGAL	129,813	0.7
AUSTRIA	129,543	0.7
UKRAINE	47,779	0.3
NETHERLANDS	40,692	0.2
SERBIA	2,268	0.0
	18,467,486	100

Source: ACEA

Table 2: Distribution of parts plants by country

Country	Freq.	Perc.	Cum.
Austria	44	2.52	2.52
Belgium	37	2.12	4.64
Bulgaria	2	0.11	4.76
Czech	**102**	**5.85**	**10.61**
Czech Republic	2	0.11	10.72
Denmark	2	0.11	10.84
Estonia	1	0.06	10.89
Finland	3	0.17	11.07
France	**234**	**13.42**	**24.48**
Germany	**483**	**27.69**	**52.18**
Germay	1	0.06	52.24
Greece	2	0.11	52.35
Hungary	39	2.24	54.59
Ireland	5	0.29	54.87
Italy	**97**	**5.56**	**60.44**
Lithuania	1	0.06	60.49
Luxembourg	2	0.11	60.61
Macedonia	1	0.06	60.67
Moldova	1	0.06	60.72
Monaco	1	0.06	60.78
Netherlands	10	0.57	61.35
Norway	3	0.17	61.53
Poland	**84**	**4.82**	**66.34**
Portugal	36	2.06	68.41
Romania	65	3.73	72.13
Russia	28	1.61	73.74
Serbia	1	0.06	73.8
Slovakia	43	2.47	76.26
Slovenia	5	0.29	76.55
Spain	**184**	**10.55**	**87.1**
Sweden	24	1.38	88.47
Switzerland	10	0.57	89.05
Turkey	41	2.35	91.4
UK	**144**	**8.26**	**99.66**
Ukraine	6	0.34	100
Total	**1,744**	**100**	

Note: The number of observations in Table 2 don’t exactly match the ones reported in the regression tables. That is mostly due to the fact that border cells can include plants located in the adjacent country (e.g. along the French-German border). The differences are minor and do not affect our results.

Table 3: Population detail by country

Country	Number of observations	Minimum population size	year
France	36,210	0	2007
Spain	7,955	6	2008
Czech Republic	6,250	3	2010
Poland[12]	2,478	1,371	2008
Germany	12,302	0	2010
UK (England and Wales)	8,499	22	2009
Italy	7,325	34	2010

Source: country statistical agencies

[12] The data for Poland are reported at a more aggregate level. In addition, there are a number of mid-size cities that have surrounding counties with identical names. The city county reports only one population number, representing the aggregate of several smaller towns. As both data points are reported with the same name, we had no choice but to combine them in one location. That leads to the almost complete absence of a distribution of population within cells of our grid in the case of Poland. In other words, very few grid cells in Poland have more than one population observation.

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