The geographic evolution of the U.S. auto industry

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Introduction and summary

For months now, the U.S. auto industry has been making front page news. The Big Three automakers continue to restructure and cut production capacity amid ongoing market share losses. The debt of both Ford and General Motors (GM) has been downgraded substantially below investment grade status. Some analysts have even raised the possibility of bankruptcy for one of the large Detroit-based carmakers. Related to the market share losses by domestic producers and their supplier base is a profound regional redistribution of production activity.[1]

This article takes a long-term view regarding the changing geography of the U.S. auto industry over the past 25 years. Since 1979, Michigan alone has shed almost one-third of its auto industry employment.[2] During the same period, southern states, such as Kentucky, Tennessee, Alabama, and the Carolinas, more than tripled their employment in the auto industry. Detroit has historically been and continues to be the center of the U.S. motor vehicle industry. Michigan is by far the state with the greatest concentration of auto industry jobs in the country, with 35 percent of its manufacturing employment in the auto sector (here, defined as the sector that involves the assembly of light vehicles and the production of motor vehicle parts). Indeed, the motor vehicle industry continues to be concentrated in the Midwest: 47 percent of motor vehicle employment resides in the industry's three core states of Michigan, Indiana, and Ohio.

Yet, several separate developments continue to reshape the U.S. auto industry. In the late 1970s, domestic vehicle producers began shutting down their coastal vehicle assembly plants in response to the changing economics of transportation costs associated with serving the national market. In addition, there was the arrival of the so-called transplants—production facilities located in the U.S. but owned and operated by foreign-headquartered companies, such as Honda and Nissan. Since their arrival in the early 1980s, these plants have gained 23 percent of U.S. light vehicle sales. These foreign-owned plants, while located in the center of the country, tend to be sited away from where the Big Three have traditionally established their assembly plants. Finally, domestic producers also had to scale back operations as they lost 10 percentage points of market share during the past decade to brands and nameplates produced outside North America. The combination of these trends, plus related developments in the auto supplier sector, has noticeably changed the face of the U.S. auto industry over the past 25 years.

In this article, we trace the changes in the footprint of the auto industry. We start in 1980 and track the evolution of the auto industry's geography through 2003. The early 1980s represents a key period of interest as foreign-based auto assembly and supplier companies started opening up production operations within the U.S. The market share of transplants has been growing quite steadily over the past 20 years. By utilizing historical data on assembly plant locations, we are able to compare spatial developments in this industry during the 1980s and 1990s. In addition, we compare changes in the location patterns of assembly and supplier plants over each decade separately and across the entire span of the two decades combined.

Literature

For many years, economists and economic geographers have tried to understand why economic activity

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is clustered (for example, see Krugman, 1991; Ellison and Glaeser, 1997). A number of papers directly address the geography of the auto industry. Of primary interest is the relative location of assembly plants and supplier plants. Also important is the location of suppliers relative to the assembly operations, as well as the location of assembly plants relative to their customers.

In describing the location pattern of *assembly* plants, Rubenstein (1992) reveals the rise and subsequent disappearance of the system of branch assembly plants.[3] In essence, Rubenstein explains, this is a story of transportation cost economics, based on the distance from assembly plants to the vehicle buying public. A producer interested in serving the national market is faced with the question of where to locate its vehicle assembly plants to minimize the cost of production. Production costs include the procurement of parts and materials, as well as the distribution of the final products to the dealers. In the case of bulky consumer products, such as automobiles, the cost of distribution is not trivial. Rubenstein shows that the number of different models of cars and light trucks has been growing substantially faster than the overall market since the mid-1970s. This development resulted in smaller production runs of individual models. As a rule of thumb, today, an individual model supports at most one assembly plant.[4] To minimize the cost of distribution of its output, these assembly plants need to be located centrally relative to their market. Consequently, assembly plants reconcentrated in the Midwest and the South. However, the agglomeration among assembly plants became less tight as newly sited plants chose nontraditional locations.[5]

Several other papers investigate the location decisions of auto *supplier* plants. Woodward (1992) and Smith and Florida (1994) model the locations of foreign-owned auto supplier plants. They establish the importance of highway transportation in choosing a supplier plant location. Several papers utilize a detailed plant-level data set on the auto supplier industry. All of these papers focus on post-1990 supplier plant location decisions. Klier, Ma, and McMillen (2004) directly compare the location decisions of domestically owned and foreign-owned supplier plants. Klier and McMillen (2005) estimate the clustering of auto supplier plants, using a spatial probit estimator. In estimating location choices of auto supplier plants since 1994, Klier (2005) confirms the importance of highway transportation as well as the proximity to assembly plants. These last two papers cover only the past decade of supplier plant location decisions. In addition, they do not draw on the detailed historical data detailing the evolving footprint of auto production since 1980.

Data and methodology

Underlying the analysis presented in this article are two very detailed data sets. We compiled a historical data set on the operation of light vehicle *assembly* plants.[6] This data set covers the years 1980–2003. The unit of observation is an assembly line. An assembly line refers to the configuration of machinery that produces a finished vehicle from numerous parts and components. While there are several ways to influence actual output at a given assembly line, such as changing the number of shifts or the line speed, the minimum efficient scale of a modern vehicle assembly line operating with two shifts is around 200,000 units a year.

An assembly plant location can encompass multiple assembly lines. Thus, we are able to distinguish different sizes of assembly plants. For example, when Toyota opened its first assembly plant in the U.S. in Georgetown, Kentucky, the plant had only one assembly line. Within a few years of opening that plant, Toyota decided to expand it by adding a second assembly line. This expansion required the construction of additional facilities at the site. Adding a second assembly line essentially doubled the size of the assembly plant. Thus, from the point of view of the suppliers, a second assembly line represents approximately twice as much business as before. Using assembly lines instead of assembly plants as units of observation allows us to recognize differences in scale across assembly plants. Our data set accounts for the addition or deletion of assembly lines on an annual frequency starting in 1980.

We base our analysis of *supplier* plant density on data acquired from ELM International, a Michigan-based vendor. Though not designed with research applications in mind, the ELM database is intended to cover the entire North American auto industry. Data are available at the plant and company levels. However, plants producing primarily for the aftermarket are not part of the database, nor are plants that produce machine tools or raw materials such as steel and paint.[7]

We use the ELM database from year-end 2003, which provides 3,542 plant-level records. The database includes information on a plant's address, products, employment, parts produced, customer(s), union status, and square footage. We performed a number of operations to clean up the data. First, we cross-checked records with state manufacturing directories to obtain information on the plant's age.[8] We obtained information on captive plants from Harbour Consulting (2003). We also appended information on the nationality of the company to the record of each plant from the ELM company-level data. For the 150 largest supplier companies, we cross-checked the accuracy and completeness of ELM International's plant listings—both the number of plants and their locations—with the individual company's website whenever possible.[9] The cross-checking resulted in a net addition of 335 records. Finally, we checked the accuracy of the employment for the largest plants (those with more than 2,000 employees) by reviewing company websites or making phone calls to the company. After these steps, the data set comprises 4,478 observations of auto supplier plants located in North America, of which 3,416 are located in the U.S., 461 in Canada, and 601 in Mexico. To our knowledge, this data set contains the most accurate description of the North American auto supplier industry currently available. Our formal analysis draws only on the U.S. data.

One of our objectives in the empirical analysis is to determine whether supplier plant location decisions differ across the two most recent decades. The data on supplier plants, however, represent only one cross section—all supplier plants that were active at a particular point in time (in the year 2003). And yet, we have data on the ages of these plants, and so, we can draw inferences on the geographic distribution of supplier plants in earlier years. Admittedly, these findings are affected by survivor bias. For example, suppose that some of the supplier plants that were active in the 1970s in the Northeast shut down as the industry migrated south, but supplier plants that were active in the South in the 1970s did not need to shut down. In this case, using data on plants that were active in 2003 would make it seem as if there were relatively more plants down South in the 1970s than there really were.[10]

These data allow us to present detailed information on the changing face of the U.S. auto industry. First, we present a set of maps (figures 1 through 9) to illustrate our findings.[11] Then we discuss a formal modeling effort of the location decision of auto supplier plants.

All the maps on changes in the assembly and supplier industry geography are based on a density measure derived from the raw data. We explain the density measure in more detail in box 1.

Evolution of the industry's geography

Assembly lines

This section demonstrates the changing density of assembly lines in the U.S. auto industry. The maps focus on the eastern half of the United States, where the vast majority of assembly lines are located. Each map shows the distribution of the density measure previously described as measured at a specific point in time. The density is measured at the county level with a radius of 50 miles from the county centroid.

Figure 1 shows the density of light vehicle assembly lines in 1980. It shows the geography of 55 assembly

BOX 1

Density measure

There are many ways to illustrate the concentration of plants. The obvious choice seems to be to measure the number of plants located within a county. Yet, while county size does not vary greatly for the eastern United States, this approach would be compromised by the arbitrariness of county boundaries. Instead, we start at the centroid of a county and draw a circumference with a 50-mile radius. That way we can compare identical geographic areas. Finally, because our primary interest is to represent local effects of agglomeration, we introduce a cubic function to give more weight to plants near the center of a county.[1]

The specific measure we use is the tri-cube kernel density measure. It is a standard kernel estimator. We chose it because of the following properties: It measures the density of plants near each county i as a function of the distance between each plant j and the county (note that plant locations are measured at the ZIP Code level and county locations are measured by the county centroid). For example, if there are 25 supplier plants in a county and they are all located in the ZIP Code that includes the county centroid, the term inside the summation sign for that county turns out to be 1. In that case the density D_i represents the share of all plants (J) in that county. That interpretation of the density measure represents an upper bound. As plants are located farther from the county centroid, their weight in the density calculation is reduced. Plants that are located farther away than the radial distance (which in our case is set to 50 miles) do not affect the density measure.

The density measure for each county is divided by all observations of the same plants at that point in time in the area of study (the eastern United States), and the share is then multiplied by 100.

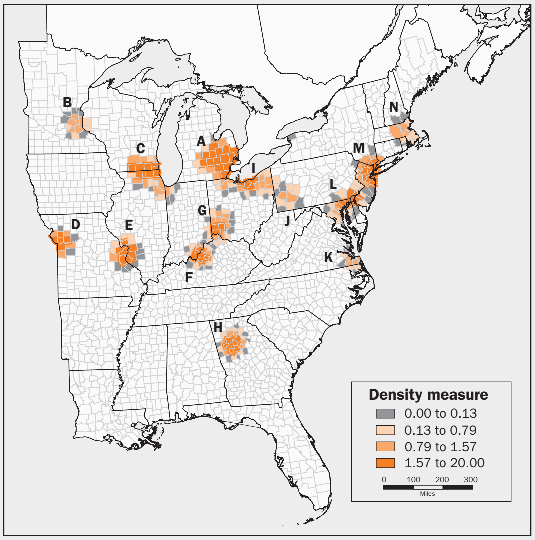
j = 1, …, J plants,
D_i = density of plants around county i,
d_{ij} = distance between county i and plant j, and
h = radius.

$$D_i = 100\left(\frac{1}{J}\sum_{j=1}^{J}\left(1-\left(\frac{d_{ij}}{h}\right)^3\right)^3 I\left(d_{ij}<h\right)\right).$$

[1]The density measure of assembly operations is calculated based on the presence of assembly lines instead of assembly plants. We think of these measures as essentially interchangeable. The advantage of utilizing assembly lines as units of observation is that it allows us rather easily to distinguish differences in the scale of assembly plant locations.

FIGURE 1

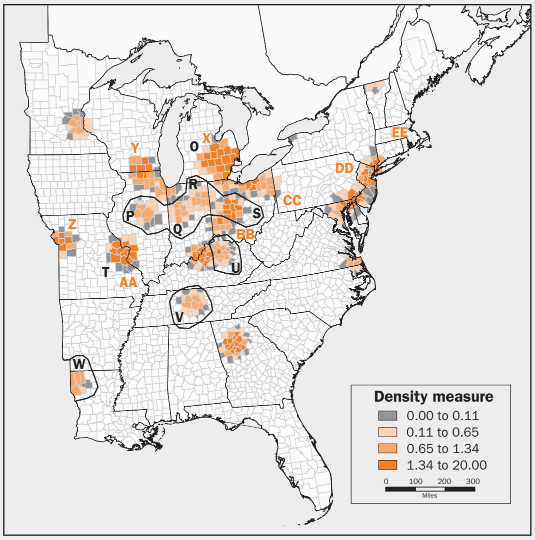
Assembly line density in 1980



Note: For further details, see the text and the appendix, table A1.
Sources: ELM International and assembly company websites.

FIGURE 2

Assembly line density in 1990



Note: For further details, see the text and the appendix, table A1.
Sources: ELM International and assembly company websites.

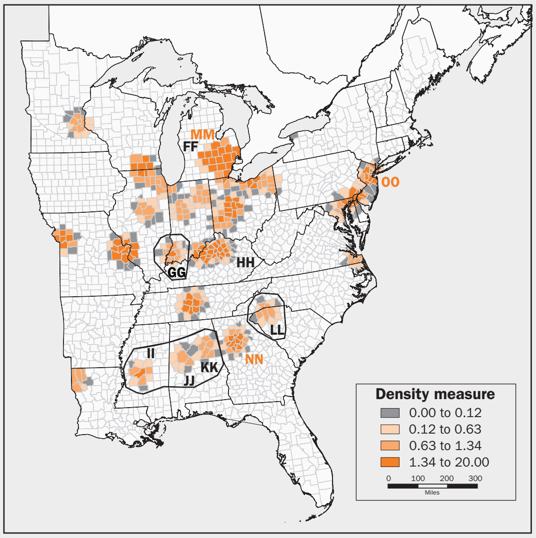
lines operational in that year. With the exception of cluster H, which represents one Ford and two GM assembly lines located in the Atlanta region, all assembly lines are located in a fairly compact region that extends north–south from the Twin Cities in Minnesota to Kansas City, and from there all the way to the East Coast.

By far the highest density of assembly operations is found in southeastern Michigan: Wayne, Oakland, and Macomb counties are the only counties with a density value in double digits (incidentally, this is true at all three points in time that are analyzed). Secondary clusters, encompassing at least three assembly lines, are located in southern Wisconsin and Chicago (C), Kansas City (D), northern Ohio (I), Maryland (L), and New York (M).[12]

During the 1980s, the number of assembly lines on net increased by only one. Underlying this summary statistic, however, are much larger gross flows: 13 assembly lines opened and 12 assembly lines closed in the region shown. Figure 2 depicts the density of assembly lines in the year 1990. It specifically labels the changes, that is, the assembly line openings (black letters) and closures (orange letters) experienced during the decade. New assembly locations at previously unoccupied sites—so-called greenfield locations—are outlined in black. Comparing figures 1 and 2, the well-defined east–west auto region visible in 1980 begins to change in two major ways. The relative importance of the East Coast as an assembly location is being reduced by the closures of three assembly lines,

FIGURE 3

Assembly line density in 2003



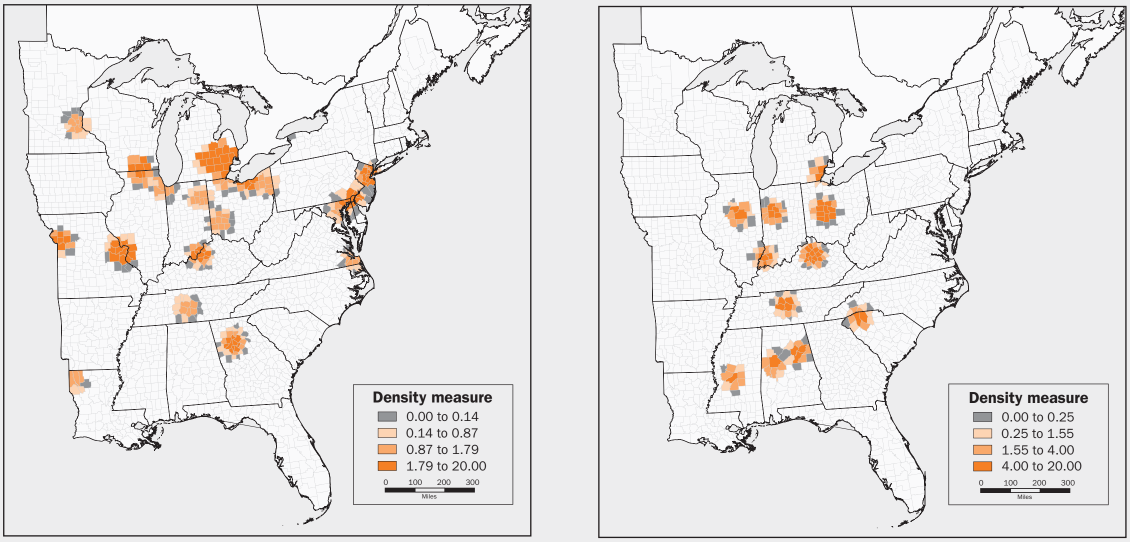
Note: For further details, see the text and the appendix, table A1.
Sources: ELM International and assembly company websites.

one each in Pennsylvania, New York, and Massachusetts. At the same time, the newly opened assembly lines extend the area of auto assembly southward. The majority of assembly lines opened during the decade represent a filling in of previously unoccupied areas in northern Illinois, Indiana, and Ohio. In addition, the

FIGURE 4

Assembly line density in 2003, by ownership

A. Domestically owned **B. Foreign-owned**



Sources: ELM International and assembly company websites.

auto region is pulled farther south by the Saturn and Nissan assembly operations opening in Tennessee (V), as well as GM's new assembly facility in Shreveport, Louisiana (W). (See table A1 in the appendix for details on assembly line openings and closings.)

The emerging north–south extension of the assembly region is reinforced during the 1990s and into the present decade (see figure 3). The number of assembly lines depicted in the map goes up from 56 to 58. The net changes mask a reduction of five assembly lines and an addition of seven. It is remarkable how much farther south the new assembly line openings are located during this decade compared with the previous decade. One new assembly line opened in the heart of the industry, in Lansing, Michigan. Other than this line, the northernmost assembly line addition was built in southern Indiana (GG), which represents the southern edge of the traditional east–west auto belt (see figure 1). By the same token, a second band of assembly lines was established at the far southern end of the auto corridor, reaching from central Mississippi to South Carolina. These assembly lines were built exclusively in greenfield locations—that is, in places where no major auto production or any other manufacturing facility had existed at the time.[13]

Finally, figure 4 displays the noticeably different densities of domestically owned and foreign-owned assembly line locations in the eastern half of the U.S. at the beginning of the twenty-first century. Figure 4, panel A shows the assembly lines of domestic producers in 2003. The distribution of the density measure very closely resembles the one from figure 1—that is, the traditional assembly region that is oriented east–west, with Detroit at its center. In contrast, assembly lines of foreign-headquartered assembly companies in figure 4, panel B are neatly arrayed in a region that has a clear north–south extension to it, with Detroit being just one of many locations.

Parts suppliers

Figures 5 and 6 show the distribution of supplier plant density at the beginning and at the end of the period we study. Very similar to the case of assembly lines, the most densely covered region of supplier plants can be seen as pulling back from the East Coast and extending farther south. The supplier industry, however, is characterized by many more plants covering the vast majority of counties in the eastern half of the U.S. Figure 7 demonstrates the differences in the density measures of domestically owned and foreign-owned supplier plants in 2003. Since there are fewer foreign-owned supplier plants than domestically owned ones, figure 7, panel B naturally has a larger share of counties without a supplier plant within 50 miles, compared with figure 7, panel A. Very similar to the ownership breakdown for assembly lines (see figure 4), figure 7 documents the fact that the density of foreign-owned supplier plants differs from that of domestically