Determinants of supplier plant location: Evidence from the auto industry

Thomas Klier

Introduction and summary

The auto industry in the United States directly employs over 1 million workers, and is so large that gross motor vehicle output alone represents more than 3 percent of the U.S. economy. In discussing its fortunes, however, we often focus on the assembly segment of the industry. Assembly-related activities represent only the most visible part of this industry, the tip of the iceberg, if you will. Below the waterline lies the entire supply structure that ultimately feeds into the assembly line, at the end of which rolls off a car or light truck. That part of the industry, which encompasses everything from inputs such as steel coils to the subassembly of entire vehicle interiors, is larger, both by count of plants and employment, than the assembly part of the industry.[1] Yet our understanding of the auto supplier industry is quite limited, mostly due to the noisiness of the publicly available data for that sector.[2]

From numerous trade and business press stories, we know that the way auto suppliers relate to their assembly customers has fundamentally changed over the last 20 years. The main driver was the arrival of lean manufacturing, a production system aimed at the elimination of waste in every area of production including product design, supplier networks, and factory management, in North America during the early 1980s. Since then, lean manufacturing production techniques have become standard practice for auto assembly as well as the largest supplier companies. Some auto assemblers even operate "supplier support organizations" in order to transfer technology and knowledge to improve the efficiency of operations at their suppliers. Furthermore, assemblers no longer interact directly with most of their suppliers. The number of independent supplier plants assembly companies work with *directly* has fallen greatly during the last ten years to 15 years. In turn, many suppliers now supply primarily other supplier plants. At the same time, the Big Three automakers, notably Ford and General Motors (GM), have increased the share of parts they procure from outside their company. For example, both Ford and GM spun off many of their own parts plants as independent companies several years ago. In addition, the remaining assembler-owned parts plants have experienced rather dramatic job reductions over the last few years (Klier, 2005). Finally, this industry, like most manufacturing industries, has become noticeably more international. As producers of cars and light trucks pursue a global manufacturing footprint, their main suppliers need to be able to meet the needs of the assemblers globally (Roland Berger, 2004).

In estimating models of supplier plant location, this article contributes to the current discussion of the changing geography in the U.S. auto industry. The ongoing loss of market share by the domestically headquartered producers to foreign-headquartered producers of vehicles, both through imports as well as production in the U.S., raises important questions about the location trends for the industry (Klier, 2005).[3] Between the first quarter of 2000 and the first quarter of 2005, the U.S. share of light-vehicle sales by Big Three nameplates has fallen from 67.9 percent to 57.8 percent. While some of that market share loss is attributable to a rise in imports, most of it is explained by increased U.S. production of foreign-headquartered assembly companies. This matters for the geography of this industry as most of these "new domestic" assembly plants in North America tend to be located farther south than the assembly plants of the traditional domestic

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producers. In fact, the assembly plants opened most recently, such as the Honda plant in Lincoln, Alabama, and the Nissan plant in Canton, Mississippi, have been situated in the most southern area of the auto region. As the geography of the auto sector continues to change, one wonders whether Detroit can continue to be the hub of this industry over the medium-term horizon.[4] The public policy issues of a changing location pattern in the auto sector are considerable as the traditional auto states are struggling with this southward shift of auto production and related economic activities.[5] For example, Michigan is currently suffering from its heavy exposure to the domestic auto and parts makers. In her 2005 State of the State address, Michigan Governor Jennifer Granholm proposed a sizable bond issue to attract and retain jobs in the state. The business press reported recently that Michigan is heavily recruiting Toyota to locate one of two currently proposed assembly facilities in the state (Hakim, 2005).

This article utilizes detailed plant-based data on the U.S. auto supplier industry. After describing the spatial properties of this data, I estimate two simple models of plant location.[6] I find the auto industry to be strongly spatially concentrated. The core of the auto region is densely packed with plants, reaching from Michigan up into Ontario, west to Chicago, and south to northern Alabama and into the Carolinas. The states within the auto region show variations along a number of dimensions. For example, the northern half of the auto region is more densely populated by domestic supplier plants[7] whereas foreign plants are more concentrated in the southern half. That pattern is not surprising as it replicates the regional distribution of assembly facilities. Union plants are concentrated in Michigan, Indiana, and Ontario. Larger plants, however, tend to be located farther away from Detroit. A plant-level model of employment shows that plants located farther from Detroit tend to have larger employment, as do tier 1 (discussed in detail later in the text) and foreign-owned plants. In addition, I find plant size to vary by type of part produced. Modeling plant location choices of recently opened supplier plants at the county level consistently finds the presence of an interstate highway to be significantly related to plants locating in such counties. In addition, the size of the market, as measured by the number of assembly plants within a day's drive (approximately 450 miles) from a county, is positively related to the number of recently opened plants in a county.

Literature review

Economic interest in agglomeration issues goes back to at least Alfred Marshall (1920); for more recent research, see Krugman (1991) and Ellison and Glaeser (1997).

Regarding the question of what drives the geography of the auto industry, a number of studies address the reconcentration of *assembly* plants in the Midwest, a development which started in the mid-1970s. Rubenstein (1992) attributes this to the demise of the branch plant system, which was based on producing identical models in plants located close to population centers. The subsequent reconcentration of assembly plants in the heart of the country was driven by an increase in the choice of models available to the consumer that far outpaced the growth of the market, resulting in much reduced production runs per model. As a result, individual models tend to support only a single assembly plant. That plant is then best located in the heart of the country, as the final product has to be shipped all over the country from that one production location.

Geographic trends in the *supplier* industry have followed a different pattern. While this part of the auto industry has remained remarkably concentrated in the Midwest since the industry's beginning over 100 years ago, it has experienced a migration of mostly labor-intensive parts to the southern U.S. and Mexico for some time. For example, in 2002, 73 percent of all wiring harnesses—gatherings of electrical wires terminating in a central plug that distribute electricity in a car to operate the turn signals, brake lights, etc.—"consumed" in the U.S. were imported, 82.7 percent of which were produced in Mexico.

There is evidence that, within the auto region, assembly and supplier plants want to locate in proximity to one another (see Smith and Florida, 1994, for a model for Japanese-affiliated manufacturing establishments in auto-related industries). State of the art supply chain management requires most supplier plants to be located within a day's drive from the assembly plant customer (see Klier, 1999, and 2005). And so, supplier networks of individual assembly plants are of a regional nature, as the existing transportation infrastructure allows for reliable on-time delivery of products (see Woodward, 1992, and Smith and Florida, 1994, for the importance of highway transportation).

Yet, as the auto industry continues to be very highly concentrated across space, the geographic extension of its core region has changed. No longer reaching eastward from Detroit to Pennsylvania and New York, it now is defined in a marked north–south direction, extending from Detroit to Kentucky and Tennessee and beyond with fingers reaching north into Canada and south into Mexico. In other words, the core auto region has pivoted around Detroit over

several decades. During the last few years this development has gained greater attention as the old-line auto states have been losing production and employment to the southern end of the auto corridor. The changing fortunes of domestic and foreign assembly plant customers appear to be profoundly reshaping the regional distribution of supplier employment (Klier, 2005).

How to measure the auto supplier industry?

Overview of the supplier industry

For the purpose of this article, auto suppliers are companies that supply light-vehicle assembly companies.[8] Among them, one can distinguish the following categories: suppliers that deal directly with the assembly company and those that deal primarily with other suppliers. The first category is commonly referred to as tier 1 suppliers, while the other category is referred to as tier 2 suppliers. The number of tier 1 suppliers has been shrinking over the last decade, as assemblers have been reducing the number of companies they do business with directly. At the same time, that segment of the supplier industry has been subject to a series of mergers and acquisitions. Finally, there are a number of tier 1 parts operations that are owned and operated by the assemblers themselves, such as engine and stamping facilities. These are generally referred to as *captive suppliers*. A number of years ago the two largest U.S. assemblers decided to spin off the majority of their captive parts operations. In 1999, GM spun off most of its captive plants as Delphi, which instantly became the largest independent tier 1 auto parts supplier. One year later, Ford Motor Company divested a large number of its captive plants as a separate company called Visteon. It then became the second largest independent parts supplier in North America.[9] Table 1 lists the 15 largest auto supplier companies as ranked by the industry weekly *Automotive News* in 2003 based on sales in North America. The 50 largest suppliers on that list each have global sales exceeding $1 billion, amounting to a total of about $285 billion. If one classifies these companies based on the location of their headquarters, the following pattern emerges: 53 percent of the 150 largest suppliers represent companies based in one of the NAFTA (North American Free Trade Agreement) countries, 20 percent are from Japan, and the remaining 27 percent are from Europe. This illustrates the degree of global competition present in this industry.

Plant-level data

The analysis of auto supplier plants presented in this article is based on data acquired from ELM International, a Michigan-based vendor. While not designed with research applications in mind, the ELM database is intended to cover auto supplier companies and their plants in North America.[10] The database provides 3,542 plant-level records. Included is information on a plant's

TABLE 1

Largest auto supplier companies, 2003

			OEM automotive parts sales ($ bn.)	
Rank	Company name	HQ in	North America	Worldwide
1	Delphi Corp.	U.S.	19.5	25.5
2	Visteon Corp.	U.S.	11.1	16.9
3	Lear Corp.	U.S.	9.4	14.4
4	Magna International	CDN	9.1	12.4
5	Johnson Controls Inc.	U.S.	8.0	13.7
6	Dana Corp.	U.S.	5.5	7.3
7	Robert Bosch Corp.	GER	5.0	19.1
8	TRW Automotive Inc.	U.S.	4.6	9.9
9	Denso International America Inc.	J	3.9	15.3
10	ThyssenKrupp Automotive AG	GER	3.7	6.2
11	American Axle	U.S.	3.5	3.5
12	Collins & Aikman	U.S.	2.9	3.9
13	DuPont Automotive	U.S.	2.8	5.4
14	Continental AG	GER	2.3	5.6
15	Yazaki North America	J	2.2	5.8
			93.5	164.9

Note: OEM is original equipment manufacturer; CDN is Canada; GER is Germany; and J is Japan.
Source: *Automotive News*, available at www.autonews.com/datacenter.cms?dataCenterId=129, by subscription.

address, employment, parts produced, customer(s), union status, as well as square footage. In order to clean up the data for research purposes, several operations were performed. First, records were cross-checked with state manufacturing directories to obtain information on the plant's age.[11] We also appended information on the nationality of the company to the record of each plant from the ELM company-level data.[12] Plants of supplier companies listed in the 2003 *Automotive News* "top 150 automotive suppliers list" were coded with the companies' ranks in that listing. Information on captive parts plants was also checked with Harbour (2003). For all the *Automotive News* top 150 companies, the accuracy and completeness of ELM's plant listings—that is, the number of plants as well as their location—was crosschecked with the companies' websites when possible.[13] Overall, that resulted in a net addition of 335 records. Finally, the accuracy of the employment for the largest plants (employment greater 2,000) was also checked with company websites or phone calls. After this preparation the data consists of 3,877 observations of auto supplier plants located in the U.S. and Canada (see table 2).[14] To my knowledge, this may well be the most accurate plant-level description of the North American auto supplier industry currently available.

Table 2 summarizes the supplier plant data for the U.S. and Canada along several dimensions. Of the 3,877 plants more than half are characterized as lower tier suppliers. That is, they primarily do business with other supplier companies. These plants tend to be smaller (their average employment is 241) than tier 1 suppliers (average employment of 388), which make up 42 percent of all plants. Captive suppliers, while small in numbers, represent by far the largest plants. Their average employment is above 1,000. Of the three groups, captive plants tend to be located closest to Detroit. The union variable covers only 83 percent of all plants; 25 percent are unionized, while 58 percent are not. Unionized plants have larger employment and are located closer to Detroit than nonunion plants. As for ownership, just under 80 percent of supplier plants are part of a company that has its headquarters in the U.S., Canada, or Mexico. "Foreign" plants are larger and are located farther away from Detroit than "domestic" plants. Finally, a quarter of the plants appears to be single-establishment firms.[15] These plants show the lowest average employment of all groups listed in table 2.

Spatial characteristics of the auto supplier industry

This plant-level data allows a fairly detailed description of the spatial properties of the auto supplier industry. Figure 1 shows the distribution of auto supplier plants. It represents all 3,877 U.S. and Canadian plants in the data set, aggregated to the zip code level of detail. The symbols representing supplier plants are scaled to convey the spatial density of plant locations.

The most interesting feature of the map is the high degree of clustering exhibited by this industry. It is self-evident that southern Michigan represents the hub of the North American auto sector.[16] The core region of this industry extends from that area west to Chicago, northeast to Toronto, and south to Tennessee and arguably into northern Mississippi, Alabama, Georgia, and the Carolinas.[17] Pennsylvania represents the link between the heart of the industry in the Midwest and a cluster on the East Coast. West of the Mississippi the country is mostly empty of auto supplier activity except for a thinly populated band that extends from eastern Texas and northern Louisiana

TABLE 2

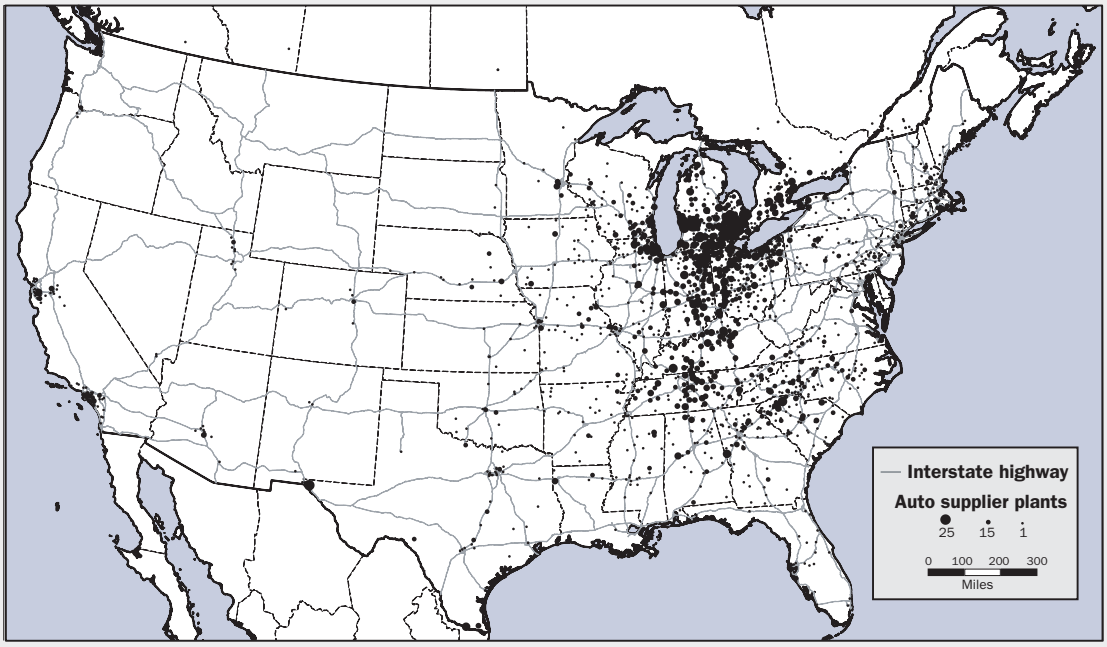
Supplier data summary, U.S. and Canada, 2003

	% of plants	% of employment	Average employment	Median distance to Detroit (miles)
Tier 1 suppliers	41.7	49.5	388	253
Captive suppliers	2.7	9.5	1,153	136
Lower tier suppliers	55.6	40.9	241	218
Union	25.3	38.0	491	180
Nonunion	58.1	52.0	293	256
Domestic	79.2	77.3	319	210
Foreign	20.8	22.7	357	309
Single plant	24.0	17.0	236	198
Multiplant	76.0	83.0	400	247
All	100	100	327	237

Note: Based upon 3,877 observations at auto supplier plants.

FIGURE 1

Distribution of auto supplier plants



north to Nebraska and Iowa and into Minnesota. Other than that, one can observe two clusters in California, one in the Bay area and the other in the L.A. basin. Finally, Utah, Colorado, Arizona, and New Mexico are home to small localized clusters, and the border between Texas and Mexico shows centers of activity around El Paso and Laredo/Brownsville. These are related to border crossings that link the Mexico-based maquiladora plants to the U.S.-based suppliers.[18]

Table 3 provides further detail on the *distribution of plants and employment* in the auto supplier industry. The information is first summarized by the four Census regions plus Canada (see panel A). The bottom panel of the table provides an alterantive breakdown of the data, focusing on the two halves of the auto corridor. Column 2 shows that 90.1 percent of all 3,877 plants are located in the Midwest, South, or Canada. Michigan alone is home to 22.5 percent of all auto supplier *plants*, followed by Ohio (11.6 percent) and Ontario (10.7 percent). The auto corridor as a group represents just under 79 percent of all auto supplier plants in the U.S. and Canada. Columns 3–8 of table 3 provide three different breakdowns of the location of auto supplier plants.

Grouping supplier plants by *nationality of company*, one can see that the auto corridor consists of two halves: The northern end shows a higher concentration of domestic plants (64.7 percent) and lower concentration of foreign-owned plants (46.7 percent) than overall. Likewise, the southern end shows a much higher concentration of foreign-owned supplier plants (33.7 percent) and a smaller share of domestics (13.8 percent). In addition, 21.5 percent of domestic automotive supplier plants in the U.S. and Canada (and 19.6 percent of foreign ones) are located outside the auto corridor. The share of foreign supplier plants located at the southern end of the auto corridor is 2.4 times as large as the share of domestic plants. This pattern suggests an influence of the location of the primary customer on the supplier plant location (Klier, 1999, and Smith and Florida, 1994). The median distance of foreign-owned supplier plants to Detroit is 309 miles, noticeably larger than the 210 miles for domestic supplier plants (see table 2).[19] One can argue that in setting up operations in North America, foreign suppliers choose locations close to foreign-owned assembly plants, which presumably were their prime customers at that time.

The *tier status* of a supplier plant is measured by its inclusion in *Automotive News*' top 150 supplier companies list. That is a somewhat arbitrary yet plausible way to define which plants are tier 1 plants. In essence, it assumes that all of the large supplier companies' plants deal directly with assembly plants. Since captive

TABLE 3

Distribution of plants and employment by region, 2003

A. By Census region

	Plant count							Employment count						
	All	Domestic	Foreign	Tier 1 and captives	Others	Union	Nonunion	All	Domestic	Foreign	Tier 1 and captives	Others	Union	Nonunion
Observations	3,877	3,072	805	1,811	2,066	980	2,259	1,268,135	980,381	287,754	848,378	419,757	484,708	659,817
Region	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Midwest	54.3	57	44.2	53	55.5	61.2	54.2	52.7	56.2	40.7	58.2	41.5	66.1	45.9
Northeast	6.7	7	5.3	4.8	8.2	9	5.6	8	8.9	5.1	5.9	12.3	9	7.1
South	24.3	20.2	39.9	27.7	21.3	13.3	27.7	24.3	19	42.5	22.3	28.2	14.1	32.3
West	3.2	2.9	4.2	2.3	4	1.3	3.9	4.6	4.5	4.8	2.6	8.6	1	7.4
Canada	11.5	12.9	6.3	12.1	10.9	15.2	8.6	10.4	11.4	6.9	10.9	9.3	9.9	7.4
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

B. By auto corridor location

Region	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Auto corridor NORTH	60.9	64.7	46.7	59.4	62.3	72	58.2	58	62.5	43	64.6	44.9	72.2	48.1
Auto corridor SOUTH	17.9	13.8	33.7	21.1	14.9	7.8	21.4	18.6	13.4	36.2	17.8	20.1	9.1	25.9
rest of US/CDN	21.2	21.5	19.6	19.5	22.8	20.2	20.4	23.4	24.1	20.8	17.6	35	18.7	26
Sum	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Notes: Seventeen percent of plants have no information on their union status. Therefore, this comparison (columns 6, 7, 13, and 14) only applies to 83 percent of the records.
States not listed do not have automotive supplier plants located in them.
Midwest: IA, IL, IN, KS, MI, MN, MO, NE, OH, SD, WI
Northeast: CT, MA, ME, NH, NJ, NY, PA, RI, VT
South: AL, AR, DE, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV
West: AZ, CA, CO, NM, NV, OR, UT, WA
Auto corridor North: IL, IN, MI, OH, Ontario, WI
Auto corridor South: AL, GA, KY, MS, NC, SC, TN
Source: *Automotive News*, available at www.autonews.com/datacenter.cms?dataCenterId=129, by subscription.

suppliers tend to interact directly with assembly plants, they are grouped with tier 1 plants in table 3. While generally very similar in their regional distribution, tier 1/captive plants are more prevalent in the South and less so in the Northeast.

Table 3 also shows a disproportionate concentration of unionized supplier plants in the Midwest and Ontario.[20] Nonunionized plants, on the other hand, are concentrated in the South where many states have right to work laws. Within the auto corridor, this split shows very strongly. Seventy-two percent of all union plants are found in the northern end of the auto corridor. Correspondingly, they are quite rare in the southern end (7.8 percent of all unionized plants versus 21.4 percent of all nonunionized plants).

The location of *employment*, shown in columns 9–15, resembles the location of plants, column 2, very closely in the aggregate. The auto corridor is home to 76.6 percent of the industry's employment and 78.8 percent of its plants. At a more disaggregate level, table 3 reveals a regional difference in the geography of plants and employment, indicating that plants located in the northern end of the auto corridor tend to have, on average, fewer employees. For example, employment at foreign-owned plants is noticeably more concentrated in the southern half of the auto corridor than employment at domestic plants. The foreign-owned plants located in the south also tend to be disproportionately large, as measured by employment. They represent 33.7 percent of all plants, yet 36.2 percent of all employment in the sector. In contrast, both domestic and foreign-owned plants located in the northern half are disproportionately smaller; that is, they represent a smaller share of industry employment than of plants. However, that pattern does not apply to unionized plants. For example, Michigan is home to 26.9 percent of unionized plants and 29.1 percent of employment at unionized plants.

Formal analysis of employment and plant distribution

This section reports on two formal models to estimate the location of employment as well as plant distribution. The idea is to formally test what underlies the observed agglomeration in the auto supplier industry. The models utilize data on U.S. plant locations only. Table 4 lists the summary statistics for both the plant-level as well as the county-level models reported.

First, we regress *plant*-level employment on a number of plant-level characteristics that the detailed database allows us to draw on. The model also uses a number of variables that are measured at the county level, such as the presence of an interstate highway. The model incorporates that information only for counties in which plants are actually located. That explains why the mean of the interstate highway variable is 0.78 in the plant-level model: 78 percent of plants are located in counties that are reached by an interstate highway.

The geography of plants is measured by two different variables. *DISTANCE* measures the straight-line distance between the centroid of the zip code in which the supplier plant is located and the centroid of the zip code for downtown Detroit.[21] Detroit seems an obvious spatial reference point as it is clearly the hub of this industry. *VDISTANCE* measures distance to Detroit only in the north–south direction. In addition, the following set of plant characteristics is included in the model. A set of dummy variables indicating if the plant is part of a single plant company; if it is part of one of the largest 150 supplier companies;[22] if it is an assembler-owned supplier plant (*CAPTIVE*); if it is unionized;[23] and if its headquarter operations are located outside North America. In addition, a group of dummy variables controls for what subsystem of the car the plant's output feeds into (table 5, p. 10).[24] Finally, the model includes a control variable for counties in right-to-work states as well as a couple interactive terms of the plant control variables.

Table 6 (p. 11) reports the results of three different specifications and the variables used in constructing each of them. A simple model (specification 1) can explain about 20 percent of the variation in the dependent variable. In addition, the model identifies a statistically significant relationship between the plant-level employment and tier status as well as nationality of headquarters: Plants of tier 1 supplier companies as well as plants of foreign-headquartered companies are found to have larger employment. The presence of unions in a supplier plant is only related to larger plant employment if the plant is either captive or part of a tier 1 supplier company. That is to say, unionized plants are larger than others only if they are either tier 1 or captive plants. Specification 2 controls for what the supplier plants are producing by distinguishing 8 major subsystems of a car. Employment at plants producing parts for chassis (such as tires), body, engine electrical (which includes the electronics components suppliers), and engine attached (often referred to as air and fuel handling) is consistently found to be larger than that of the control group, plants that produce generic parts. Finally, specification 3 controls for a number of county-level characteristics that might influence plant location decisions, such as the degree of local work force education, transportation infrastructure, as well as the presence of other

TABLE 4

Descriptive statistics

		County-level model		
	Plant-level model	All new plants	All new domestic	All new foreign
Employment	359.922 (473.248)			
Share of young supplier plants		0.042 0.162		
Share of domestic young suppliers			0.0229 0.114	
Share of foreign young suppliers				0.019 0.111
Log employment	5.35 (1.052)			
Distance to Detroit (miles)	361.933 (388.950)	456.174 205.216	456.174 205.216	456.174 205.216
Vertical distance to Detroit (miles)	203.768 (220.904)			
Single plant company	0.257			
Plant part of top 150 supplier	0.363			
Plant is captive	0.024			
Plant is unionized	0.262			
Company headquarters outside North America	0.206			
Right-to-work state	0.237	0.467	0.467	0.467
Interaction top 150 and unionized	0.106			
Interaction captive and unionized	0.019			
Parts for body (%)	0.142 (0.297)			
Parts for chassis (%)	0.199 (0.329)			
Parts for drivetrain (%)	0.039 (0.144)			
Parts for engine attached (%)	0.103 (0.249)			
Parts for engine electrical (%)	0.071 (0.225)			
Parts for engine (%)	0.093 (0.238)			
Parts for interior (%)	0.149 (0.312)			
Generic parts (%)	0.186 (0.335)			
Presence of interstate highway	0.787 (0.411)	0.506 (0.50)	0.506 (0.50)	0.506 (0.50)
Share of employment in manufacturing	25.536 (8.218)	23.807 (9.93)	23.807 (9.93)	23.807 (9.93)
High school education (%)	0.74 (0.082)	0.672 (0.105)	0.672 (0.105)	0.672 (0.105)
Population in 1990 (million)	0.515 (1.092)	0.093 (0.227)	0.093 (0.227)	0.093 (0.227)
No. of supplier plants in county	19.355 (31.025)	1.335 (4.818)		
No. of domestic supplier plants in county			1.072 (4.328)	1.072 (4.328)
No. of foreign supplier plants in county			0.263 (0.804)	0.263 (0.804)
No. of assembly plants within 450 miles	37.113 (16.074)	31.223 (16.197)	31.223 (16.197)	31.223 (16.197)
No. of domestic assembly plants in county			22.842 (13.523)	22.842 (13.523)
No. of foreign assembly plants in county			8.381 (3.693)	8.381 (3.693)
No. of observations	3,097	1,607	1,607	1,607

Note: Standard deviations are in parentheses for continuous variables.

TABLE 5

Parts classification

Major subsystem	ELM subsystem	Frequency of parts listed (%)
Engine		27
Engine proper	Engine	11
Engine electrical		
	Ignition systems	1
	Electronic supply	1
	Electronics	3
Engine attached		
	Engine cooling	2
	Climate control	3
	Fuel systems	4
	Exhaust systems	2
Chassis		20
	Chassis electrical	6
	Chassis systems	2
	Suspension	3
	Steering	3
	Braking	4
	Wheels and tires	2
Interior		15
	Interior body	14
	Passenger restraints	1
Body		16
	Body glass	2
	Body components	14
Drivetrain	Drivetrain	5
Generic	Generic	16
		100

Source: ELM and author's calculations.

supplier and assembly companies. However, the county-level variables do not add to the plant-level model of employment (table 6).

Next, I estimate a model of plant location at the *county* level (table 7, p. 12). The dependent variable is the share of supplier plants in a county that opened recently.[25] As the underlying data is cross-sectional in nature, it seems prudent to focus on location decisions of more recently established plants.[26] Going back much further in time could introduce survivor bias to the model. The premise is that county characteristics matter in plant location decisions. The model accounts for the presence of existing assembly and supplier plants to capture possible agglomeration effects within the auto industry.

The number of assembly plants located within 450 miles of a county's centroid measures the size of the market available to a supplier locating in that county. That is an important reference point as the ability to deliver reliably within a day is a key requirement of the just-in-time production system. The distance of 450 miles corresponds to an industry rule of being able to deliver within a day's drive. The model also includes a measure of how many suppliers had previously located in a county to account for agglomeration effects. Finally, the set of county-level controls used in specification 3 of the plant-level model (table 6) is included in the county-level model as well. Table 7 reports the results that utilize information for all counties east of the Mississippi to capture the region of the country most densely populated by the auto industry.[27]

Across all specifications estimated, the presence of an interstate highway in a county is consistently associated with a higher share of recently opened supplier plants in that county. In addition, the size of the market for suppliers, as measured by the number of assembly plants within a day's drive from a county, is related to suppliers choosing a county. Specifications 2 and 3 distinguish domestic and foreign plants, both for the dependent as well as the independent agglomeration variables. It turns out that only the presence of foreign assembly plants within a 450 mile radius is significantly related to the incidence of both domestic and foreign "young" supplier plants locating in a county.

Simulation of policy effects

Based on the model results presented in table 7, I perform two simple simulation exercises. The idea is to elicit from the model what the estimated response in the distribution of supplier plants would be to a simulated change in the location of an assembly plant. First, assume that Tennessee has one less light-vehicle assembly plant and Michigan has one more. I assume Spring Hill as the location of the plant in Tennessee, and Grand Rapids for the fictional plant in Michigan. Subsequently, I re-calibrated the variable that measures the number of assembly plants located within a 450-mile radius of each county. To that reconfigured variable and all the others in the model, the estimated coefficients as reported in table 7 were subsequently applied. In doing so one performs what is referred to as an "out-of-sample" forecast. In essence, one can simulate what would happen to the distribution of young supplier plants if Grand Rapids had an assembly plant and Spring Hill did not. Constraining the estimation to result in a zero sum redistribution of supplier plants, the following result emerges. The three states of Michigan, Indiana, and Ohio would increase their count of supplier plants that opened

TABLE 6

Estimation of plant employment

Variable	Specification 1	Specification 2	Specification 3
Distance to Detroit	0.113** (0.027)	0.097** (0.027)	0.107** (0.046)
Vertical distance to Detroit	–0.095 (0.067)	–0.112 (0.067)	–0.144 (0.075)
Single plant company	–5.370 (19.850)	2.270 (19.927)	4.470 (20.022)
Top 150 supplier	152.368** (20.823)	149.414** (21.312)	147.093** (21.356)
Captive supplier	169.406 (108.186)	204.883* (108.325)	204.998* (108.376)
Unionized plant	21.976 (23.711)	25.07 (23.634)	25.253 (23.654)
Headquarters outside North America	79.872** (19.685)	59.633** (19.816)	56.298** (20.002)
Right-to-work state	49.263* (28.268)	49.432* (28.245)	42.641 (32.975)
Top 150 supplier and unionized	293.919** (36.616)	281.682** (36.471)	284.626** (36.544)
Captive supplier and unionized	952.425** (123.098)	926.215** (121.933)	937.641** (122.275)
Chassis %		205.226** (29.870)	199.212** (29.977)
Drivetrain %		90.164 (56.584)	90.000 (56.590)
Interior %		18.102 (30.334)	11.047 (30.473)
Body %		56.473* (31.771)	52.878* (31.815)
Engine %		50.999 (38.084)	41.566 (38.295)
Engine electrical %		304.689** (38.824)	303.297** (38.885)
Engine attached %		141.791** (35.394)	135.461** (35.537)
Presence of interstate highway			29.881 (20.828)
Manufacturing employment (%)			2.016* (1.145)
High school education (%)			–0.897 (1.342)
Population in 1990			–1.24.970 (924.818)
No. of supplier plants in county			–0.546 (0.336)
No. of assembly plants within 450 miles			–0.016 (1.034)
Constant	193.497** (16.850)	114.932** (23.081)	127.432 (134.086)
No. of observations	3,097	3,050	3,050
R squared	0.19	0.22	0.22

**Significant at the 5% level.
*Significant at the 10% level.
Note: Standard errors are in parentheses.

TABLE 7

Supplier plant locations between 1994 and 2003

	All	Domestic only	Foreign only
No. assembly plants w/450 miles	0.001** (0.00)		
No. domestic assembly plants w/450 miles		–0.001 (0.001)	0 0
No. foreign assembly plants w/450 miles		0.004** (0.001)	0.004** (0.001)
No. existing supplier plants	0 (0.001)		
No. existing domestic suppliers		0 (0.001)	–0.001 0
No. existing foreign suppliers		0.003 (0.004)	0.006 (0.004)
Interstate highway	0.03** (0.009)	0.012** (0.006)	0.014** –0.006
Right to work state	0.019 (0.012)	–0.005 (0.009)	0.007 (0.009)
Share of manuf. employment	0.001** 0.000	0.001 0	0 0
Percent high school ed.	0 (0.001)	0.001* 0	0 0
Population, 1990	0.03 (0.021)	0.027* (0.015)	0.011 (0.015)
Distance to Detroit	0 0.000	0 0.000	0 0.000
Constant	–0.62 (0.065)	–0.033 (0.046)	–0.018 (0.045)
Observations	1,607	1,607	1,607
R squared	0.03	0.02	0.02

**Significant at the 5% level.

*Significant at the 10% level.

Notes: Standard errors are in parentheses. Observations: 1,607. Model is estimated for all counties east of the Mississippi.

between 1995 and 2003 by 42, from 122 to 164. The three states of Kentucky, Tennessee, and Alabama would see their count of young supplier plants fall by 37, from 65 to 28. The simulated redistribution represents about 14 percent of all young supplier plants opened during the last 10 years. That represents a significant impact.[28]

A second experiment consisted allocating a *foreign* assembly plant in Michigan (again, Grand Rapids), instead of Spartanburg, South Carolina, and estimating the effect on the distribution of foreign-owned young supplier plants (there were 107 of them that opened between 1995 and 2003). Michigan, Indiana, and Ohio would gain young foreign suppliers. The count for the three states would increase by 27 from 30 to 57. By the same token, South Carolina and the surrounding auto corridor states North Carolina, Kentucky, Tennessee, Alabama, and Georgia would have received fewer recently opened foreign suppliers: Their plant count of foreign young would go down by 26 from 57 to 31.[29] According to this simulation, placing one foreign assembly plant into Michigan instead of South Carolina would affect the location of a quarter of all foreign supplier plants opened between 1995 and 2003.

Conclusion

This study set out with the intent to shed more light on the geography of the auto parts sector which is far less understood than that of the auto assembly sector of the auto industry. The analysis of a rich plant-level data set with records of almost 3,800 auto supplier plants located in the U.S. and Canada shows an industry that is very spatially concentrated. Today Detroit remains the center of a highly clustered auto region that extends north–south from Michigan, reaching up into Ontario, west to Chicago, and south to northern Alabama and into the Carolinas. While the

analysis is purely cross-sectional, it reveals a surprising amount of variation in the location pattern exhibited along a number of dimensions. The study confirms the north–south split within the auto region by nationality of plant: Plants of domestically headquartered suppliers are concentrated in the northern end of the auto corridor and plants of foreign-headquartered suppliers are concentrated in the southern end. Overall, employment and plants are distributed quite similarly.

A plant-level model of employment shows that plants located farther from Detroit tend to have greater employment, as do tier 1 and foreign-owned plants. In addition, we find plant size to vary by type of part produced. A simple model of recent supplier plant openings at the county-level points out the importance of regional transportation infrastructure. The presence of interstate highway access in a county is consistently related to a higher share of recently located supplier plants. Furthermore, the number of assembly plant customers reachable within a day's drive is also related to supplier location choices. This finding points to the continued importance of agglomeration in this industry.

A policy simulation asks what the effect of a change in the location of one assembly plant would be on the geography of recent supplier plant openings. Two different simulations are presented, one moving an assembly plant from Tennessee to Michigan, the other moving a foreign assembly plant from South Carolina to Michigan. Both suggest a sizable regional effect on the location of supplier plants. A number of them would have located closer to the "new" location of the assembly plant as they need to be within 450 miles of their assembly plant customers.

NOTES

[1]U.S. motor vehicle parts employment is about four times as large as employment in motor vehicle assembly.

[2]Many different manufacturing sectors contribute to the production of vehicles and at the same time supply non-automotive customers. Furthermore, the census data on shipments do not distinguish between producers of parts for the aftermarket and the original equipment market. The 2002 *Census of Manufacturing*, however, reports the cost of materials used in U.S. light-vehicle assembly plants at $152.5 billion. That measure includes imported parts.

[3]In addition, factors such as the continuing consolidation and internationalization within the supplier industry also affect its spatial structure.

[4]The northern end of the auto corridor is home to over half of all light-vehicle assembly plants in the U.S., 81 percent of these are Big Three facilities. Conversely, the southern end of the auto region is home to about 20 percent of all light-vehicle assembly plants; half of these are foreign producer facilities. Testa, Klier, and Mattoon (2005) identify such a regional shift as the most likely structural threat to the Midwest's economy.

[5]See the speech of Michigan's Governor Granholm from August 4, 2004, in which she outlines a framework on how Michigan should respond to the current challenges facing its most important manufacturing sector. See also McAlinden and Hill (2003).

[6]The role of the border is not addressed in this article. Post 9/11, elevated national security concerns have exacerbated demands on the already strained border infrastructure between the U.S. and Canada, potentially affecting plant location decisions in an industry that continues to be very tightly integrated and has straddled both sides of the border for many years (see Simon, 2004, and Klier and Testa, 2002).

[7]"Domestic" refers to supplier companies which are headquartered in either the U.S., Canada, or Mexico, "foreign" to companies headquartered elsewhere.

[8]The term light vehicles refers to passenger cars and light trucks, which include minivans and sport utility vehicles.

[9]See White (2005) on the recent restructuring of the original agreement between Ford and Visteon.

[10]Data are available at the plant and company level. However, plants producing primarily for the aftermarket are not part of database, nor are plants that produce raw materials, such as steel and paint. The ELM data were purchased at the end of 2003. The database is continuously updated by the vendor.

[11]Plants for which no matching records were found were contacted by phone.

[12]Based on the location of company headquarters, the article distinguishes North American (U.S.-, Canadian-, or Mexican-owned plants), Japanese, as well as other foreign-owned plants.

[13]Thanks to my colleague Jim Rubenstein who shared his plant-level data for the 150 largest supplier companies.

[14]Mexican data are available for 601 plants, but have not yet been scrutinized to the same extent.

[15]I construct that variable from the database, utilizing plant names and company information. It is possible that some of these single-plant companies have plants that are not included in the database.

[16]A map of employment, instead of plant count, looks virtually identical.

[17]Based on the shape of the core auto region, I define the "auto corridor" to be the states and Canadian provinces that represent the contiguous north–south cluster visible in figure 1. They are Alabama, Georgia, Illinois, Indiana, Kentucky, Michigan, Mississippi, North Carolina, Ohio, Ontario, South Carolina, Tennessee, and Wisconsin. Mississippi and Alabama are included as they recently received new assembly plants.

[18]Maquiladora plants in northern Mexico were established by the 1965 Border Industrialization Program. This program allowed U.S. companies to assemble products in Mexico destined for export elsewhere. Later companies from other countries also established such plants near the northern Mexico border.

[19]Of all domestic assembly plants operating in the U.S, 38 percent are located within 100 miles of Detroit. The corresponding figure for foreign-owned assembly plants is only 7 percent.

[20]Note that 17 percent of plants have no information on their union status. Therefore, this comparison (see columns 6 and 7) only applies to 83 percent of the records.

[21]The geographic coordinates for the zip code centroids come from the Maptitude GIS program. The distance between the two sets of coordinates is given by the following formula: $acos(\sin(la1)*\sin(las) + \cos(la1)*\cos(la2)*\cos(lo2 - lo1))*6370*.62$, where $la1$ and $lo1$ are the latitude and longitude (in radians) of the zip code centroid of the supplier plant and $la2$ and $lo2$ are the coordinates for the zip code centroid of downtown Detroit.

[22]As explained earlier, tier 1 suppliers are the ones that interact directly with the assembler. One would have to know the identity of a supplier's customer plants in order to identify that group. The top 150 variable tries to proxy for that relationship in the absence of such detailed customer information. The underlying assumption is that the vast majority of tier 1 suppliers happen to be large companies.

[23]In the estimation we treat plants with unknown union status as not unionized. Based on size and location these plants are very similar to plants identified as nonunion.

[24]The ELM data provide information on what parts an individual plant produces in a very detailed way. Unfortunately, it does not provide the distribution of actual output across the various parts. The ELM parts classification system distinguishes 20 subsystems in a car (table 5). Altogether, it identifies 492 individual parts. Utilizing the relative frequency of the detailed parts listed for each plant, we converted this information on what each plant produces into a more aggregate system that distinguishes only 8 subsystems. They are body, chassis, drivetrain, engine attached (such as the exhaust system), engine electrical, engine proper, generic parts, as well as interior parts. The subsystem variables measure the share of individual parts codes in each of these by plant.

[25]A small downside of utilizing the information on plant age is that it is missing for 19 percent of the data. However, there seems to be no relation between that and the location of plants. For a slightly different treatment of such an estimation, see Klier, Ma, and McMillen (2004).

[26]Table 7 reports results for supplier pants that were not older than 10 years in 2003 (1994-2003). Estimating the model for a smaller set of "young" plants, the ones that opened between 1999 and 2003, yields robust results.

[27]Estimating the county-level model for the auto corridor only as well as for the entire U.S. produces robust results.

[28]To test for robustness of this exercise, I performed the same experiment on the model that estimates the location determinants for all supplier plants that opened between 1999 and 2003. The resulting redistribution of suppliers, while different in absolute numbers, represents a relative change of a similar order of magnitude as described above.

[29]That result is found to be robust when basing it on the locations of foreign supplier plants that opened since 1999 instead.

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