Agglomeration in the U.S. auto supplier industry

Thomas H. Klier

Introduction and summary

The General Motors (GM) strike during June and July 1998 showed the extent to which lean manufacturing production methods, such as efforts to keep inventories low and reduce the number of parts suppliers, have taken hold in the U.S. auto sector. As observers tried to assess the ramifications of this event, it became apparent that we know much more about the spatial structure of light vehicle assembly operations and Big Three (Ford, GM, and Chrysler) owned parts plants than of the large number of independent parts suppliers. In an environment of tightly linked supply chains, it is important to understand the spatial nature of these linkages. Such knowledge would help policymakers assess the economic impact of regional shocks, such as a strike. In addition, data on individual customer–supplier linkages would facilitate the study of the geographic extension of supplier networks and offer new evidence on the ability of economic development efforts to attract suppliers to locate in the same state as a large assembly facility.

Lean manufacturing was pioneered by Toyota Motor Company in Japan during the 1950s. It has since become the standard for many manufacturing companies in Japan and around the world. This production system tries to improve on the types of mass production systems that have been prominent in the postwar period. Instead of organizing production according to a preset schedule, it operates on the premise of a so-called pull system, whereby the flow of materials and products through the various stages of production is triggered by the customer. In addition, the production process itself is subject to continuous improvement efforts.

The 1998 strike at two GM-owned parts plants in Flint, Michigan, was about issues related to production rates and health and safety. Strategically, however, it centered on issues pertinent to the implementation of new production methods—more efficient production processes that would reduce the demand for labor in the assembly plant and efforts by the assembly company to outsource more of the production of parts. The strike quickly shut down most of GM's North American assembly operation. In turn, it caused production adjustments at many of the company's independent suppliers.

In this article, I examine the spatial structure of the auto supplier industry and how firms in different locations interact. First, I document the extent to which plants are concentrated geographically, that is, the degree of spatial agglomeration, in the U.S. auto supplier industry. My analysis is based on information on the location of over 3,000 auto supplier plants. I find that the auto supplier industry is concentrated in five states—Indiana, Kentucky, Michigan, Ohio, and Tennessee—that constitute the so-called auto corridor, which is defined by interstate highways 65 and 75, extending south from Michigan to Tennessee. These states are home to 58 percent of the plants in the study. A closer analysis of plant locations reveals the importance of access to highway transportation to ensure timely delivery of production to customers. I find that having suppliers located in the immediate vicinity of the assembly plant is not necessary to maintain a system of tight linkages and low inventories. Comparing the spatial structure of individual assembly networks, I find them to be remarkably similar. The geographic concentration is highest for assembly plants that are located near the heart of the auto corridor, with between 70 percent and 80 percent of supplier plants located within a day's drive of the assembly plant. This suggests a clustering of economic activity at the regional rather than local level.

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Second, I investigate the changing nature of the geographic concentration of this industry over time. This analysis is limited by the cross-sectional nature of the data. However, there are a few cases in which the data allow a comparison of supplier networks of different vintages. In addition, I apply a location rule to a subset of all the supplier plants that allows me to use information on the location of all light vehicle assembly plants in the U.S. from 1950 to 1997. Consistently, I find evidence of increased clustering in the auto supplier industry relative to 30 or 40 years ago.

Literature review

Geographic concentration in U.S. manufacturing has received greater attention in recent years. Krugman (1991) suggests that Silicon Valley-style agglomerations may be more the rule than the exception and that we can learn from them about the source of the underlying forces.[1] Ellison and Glaeser (1997) address the question of how to properly measure industry concentration over and above the general level of concentration in manufacturing. To that end they develop a model that captures both random location effects and those caused by localized industry-specific spillovers and natural advantages. The authors develop indexes of localization and find almost all industries to be somewhat localized. In many industries, however, the degree of localization is small. The authors report that almost all of the most extreme cases of concentration are apparently due to natural advantages.[2] Hewings et al. (1998) analyze the 1993 commodity flow statistics, using a detailed econometric input–output model, to learn about a slightly different issue: To what extent are the states of a specific region (the Midwest) linked economically? They find very strong evidence of industry clusters at the regional level. For example, in the case of the auto industry, an initial loss of automotive production in Michigan would create secondary effects that are heavily concentrated in the Midwest. Specifically, losses in the Midwest would represent 43 percent of the secondary effect outside of Michigan.

Addressing these issues for the U.S. auto industry, several studies suggest that the assembly plants for light vehicles have reconcentrated in the Midwest and Southeast since the mid-1970s (Rubenstein, 1992; McAlinden and Smith, 1993; and Rubenstein, 1997). Rubenstein (1997) attributes this to the demise of the branch plant assembly system, whereby identical models were produced around the country at assembly plants that were located close to population centers. Developments in the supplier industry are not as clear cut. Apparently there has been a migration of especially labor-intensive parts production to the southern U.S. and south of the border; however, parts requiring highly skilled labor, such as engines, transmissions, and large stampings, have remained heavily concentrated in the Midwest. That is especially true for parts plants operated by the auto assemblers themselves (so-called captive suppliers) (see table 1).

As for the potential location effect of lean manufacturing, the prevailing anecdotal evidence suggests that the application of lean manufacturing techniques has resulted in a tiering and consolidation of the supplier base of the auto industry, as well as a higher degree of communication and interaction between suppliers and assemblers (Helper, 1991). Has this resulted in tighter geographical linkages between assembler and supplier plants? Proponents suggest that close linkages work most effectively when supplying and receiving plants are in reasonably close proximity (Estall, 1985; Kenney and Florida, 1992; Mair, 1992; and Dyer, 1994). However, there is also evidence that spatial clustering is not a necessary outcome of lean manufacturing applications. What ultimately matters is the quality of transportation infrastructure in combination with the capability of delivery management systems in ensuring predictable on-time arrival of goods. This might well be achieved with no significant increase in clustering at the industry level.

A set of studies specifically investigates the existence of effects of lean manufacturing on the spatial structure of the auto supplier industry. Rubenstein and Reid (1987) and Rubenstein (1988) analyze the changing supplier distribution of U.S. motor vehicle parts suppliers. Their thorough analysis of supplier plants located in Ohio cannot establish a clear-cut effect of lean manufacturing on plant location, yet the authors find evidence of a change in the locational pattern after 1970.

TABLE 1

Distribution of captive parts plants
(percent)

Assembly company	Share of captive suppliers in MI, IN, and OH: Plants	Employees
General Motors	69.8	73.8
Chrysler	82.3	86.9
Ford	84.6	85.5
Overall	75.6	77.6

Source: ELM International, Inc., 1997, "The ELM GUIDE supplier database," East Lansing, MI, database file, and author's calculations.

Most of the existing analysis of the location effects of lean manufacturing, however, concerns Japanese-owned manufacturing establishments within the U.S. This is not surprising, as these plants generally apply lean manufacturing. In addition, most of them represent new plants established at newly developed, so-called greenfield sites. As their location decision usually does not involve a re-location, they are a preferred object of study. Woodward (1992) investigates what determines the location of Japanese manufacturing start-up plants in the U.S. The author estimates location models of the spatial behavior of Japanese-affiliated manufacturing investments undertaken between 1980 and 1989. While his observations include plants from many different manufacturing industries, he estimates a model specification at the county level for 250 observations in the Michigan–Tennessee automotive corridor. Woodward finds proximity to urban areas not to be important for these plants; however, an interstate connection linking counties to major markets appears to be crucial. Reid (1994) tests the effect of just-in-time inventory control on spatial clustering in observing the level of inputs purchased locally for a set of 239 Japanese-owned manufacturing plants in the U.S. The author performs this analysis at three different levels of aggregation—county, state, and national. He finds differences in the proportion of material inputs purchased locally between plants that use just-in-time inventory control and those that do not only at the county level. This result suggests spatial clustering effects on a very local scale. Smith and Florida (1994) test for the existence of agglomeration effects in the location decisions of over 400 Japanese-affiliated manufacturing establishments in automotive-related industries. They perform a formal analysis for all U.S. counties, as well as an automotive corridor subset, and find that Japanese-affiliated suppliers prefer to locate in close proximity to Japanese automotive assemblers. On a regional scale, they find a concentration of Japanese auto suppliers in the auto corridor.

Spatial characteristics data

In this article, I present evidence on the spatial characteristics of independent auto supplier plants located in the U.S., with particular emphasis on linkages between supplier and assembly plants. First, I document the extent to which plants are concentrated geographically, or the degree of spatial agglomeration, in the U.S. auto supplier industry. Second, I investigate the changing nature of this geographic concentration over time.

Publicly available data do not provide this level of detail. The obvious data source, the *Census of Manufactures*, can offer only incomplete information, because it does not distinguish between original equipment manufacturers and producers of replacement parts. In addition, because of the large variety of parts that make up an automobile, supplier plants in the auto industry are classified among 18 of the 20 two-digit standard industry classification (SIC) codes. Finally, Census data cannot establish information about linkages between supplier plants and their customers.

The basis for my analysis is the “ELM GUIDE supplier database,” a set of plant-level data on the auto supplier industry put together by a private company in Michigan.[3] The data are for 1997 and cover 3,425 independent supplier plants in the U.S.[4] As the database identifies customers for the individual supplier plants, I was able to categorize these plants by supplier tier: 2,008 plants are tier 1 suppliers, that is, supplier plants that ship their products exclusively to auto assembly plants and not to other supplier plants or other customers; 1,292 are mixed-tier suppliers, that is, in addition to auto assembly plants, their customers include other supplier plants and/or nonautomotive assemblers; and 50 observations were excluded from the analysis because they did not provide information on their customers.[5]

I then added several variables to the database. For tier 1 plants, I obtained start-up year data from various state manufacturing directories and phone calls to individual plants. I added information on foreign ownership available through industry press reports and the Japan Auto Parts Industries Association.[6] Table 2 shows an ownership breakdown of the industry. Accounting for incomplete information on start-up year, I end up with 1,845 individual plant records, representing independent tier 1 supplier plants operational in 1997.[7] Next, I analyze data on these 1,845 plants to test for agglomeration at the industry level, as these plants arguably represent the subset of supplier plants that is most closely linked to the auto assembly plants by way of production and delivery. In addition to the cross-sectional comparisons, information on the vintage of individual plants allows some comparison of location patterns of older and recently opened plants.[8] The analysis of assembly plant-specific networks draws on all the 3,137 records of independent supplier plants.[9]

Industry-level agglomeration

Table 3 presents the distribution of the 3,137 independent supplier plants included in the database.

TABLE 2

Auto suppliers by ownership, 1997
(percent)

	Plants	Employment
Domestic	84.7	81.6
Foreign-owned		
Japanese	9.6	11.2
Other	5.7	7.2

Notes: Calculations are based on 3,137 independent supplier plants open in 1997; numbers do not include captive supplier plants. Industry employment: 901,343 jobs.
Source: See table 1.

TABLE 3

Distribution of auto suppliers, 1997
(percent)

State	Plants	Employment
Illinois	6.9	6.8
Indiana	9.1	10.1
Kentucky	4.0	4.1
Michigan	26.8	19.2
Ohio	13.2	11.2
Tennessee	4.7	5.8
Wisconsin	3.6	3.1
Midwest	59.6	50.4
Auto corridor	57.8	50.4
U.S.	100.0	100.0

Notes: Calculations are based on 3,137 independent supplier plants open in 1997; numbers do not include captive supplier plants. Industry employment: 901,343 jobs. The auto corridor comprises Indiana, Michigan, Ohio, Kentucky, and Tennessee. The Midwest comprises Illinois, Indiana, Michigan, Ohio, and Wisconsin.
Source: See table 1.

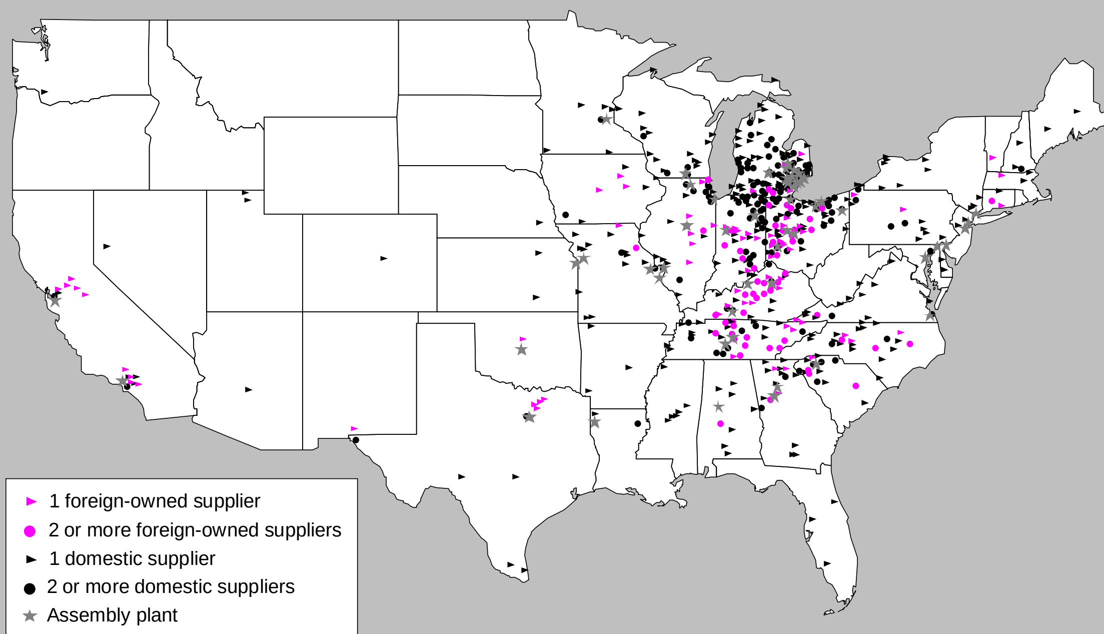
It shows the auto supplier plants and employment to be highly spatially concentrated, with almost 50 percent of all plants located in just three states—Michigan, Ohio, and Indiana. However, it is important to keep in mind that this information represents plants from rather different vintages. For example, the oldest plants in the sample date from the nineteenth century; 38 plants opened prior to 1900. In order to get a better read on recent plant location choices, I focus on the subset of supplier plants that have opened since 1980, marking when lean manufacturing arrived in the U.S.[10] As data on the establishment year are available only for tier 1 supplier plants, I focus on the subset of 820 tier 1 supplier plants that opened in 1980 or after and were still in operation in 1997. While a pure cross-sectional data set prevents me from testing for changes in location patterns over time, concentrating on plants of recent vintage enables me to present the location choices in a lean manufacturing environment in much more detail.

Figure 1 shows the plants that opened between 1980 and 1997 and their concentration among the five states of the auto corridor. Domestic plants are shown in black, foreign-owned plants in color. A circle indicates that two or more plants are located within one zip code. In addition, stars mark the location of light vehicle assembly plants in operation at any point during this period. One can clearly see that plant openings are highly clustered in a north–south direction (in southern Michigan and the four states to the south). Figure 2 adds the grid of interstate highways to the pattern of plant openings. This exercise demonstrates the relevance of the I-65/I-75 corridor.[11] Note, however, that interstate access plays an important role for east–west connectivity as well. For example, Toyota operates a car assembly plant in Georgetown, Kentucky, a recently opened light truck assembly plant in Princeton, Indiana, and an engine plant in Buffalo, West Virginia. All three of these are linked by Interstate 64, highlighting the importance of highway access to ensure timely delivery of shipments in an environment of just-in-time production.

Looking at the auto corridor locations more closely, figure 3 (page 23) reveals a different location pattern for domestic and foreign-owned supplier plants during 1980–97.[12] While they are similarly concentrated among three states, foreign-owned suppliers choose to locate in the southern part of the automotive corridor (that is, Ohio, Kentucky, and Tennessee). Domestic suppliers, on the other hand, locate in the northern part, with Ohio being the only state chosen prominently by both domestic and transplant supplier plants.[13] Does this indicate that the auto corridor is a phenomenon driven by the location of foreign-owned plants? What explains the apparent different spatial pattern in plant locations? Do foreign-owned suppliers respond differently to lean manufacturing conditions than domestic suppliers? Figure 3 and table 4 (page 23) suggest a different explanation: The difference in the spatial distribution of domestic and foreign-owned assembly plants seems to dominate the location choices of supplier plants.[14] As a rule of thumb, between 1980 and 1993 supplier plants located close to assembly plants of the same nationality.[15] This can be seen in figure 3, which distinguishes between domestic (gray) and foreign-owned (colored) assembly plants.

FIGURE 1

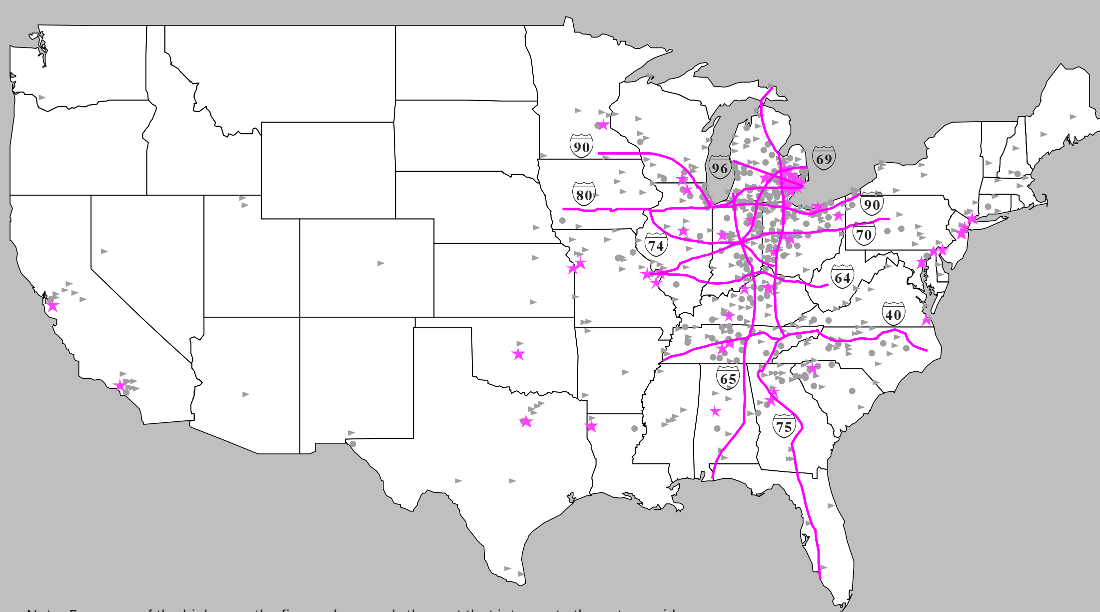
Plant openings by tier 1 suppliers, 1980–97



Source: See table 1.

FIGURE 2

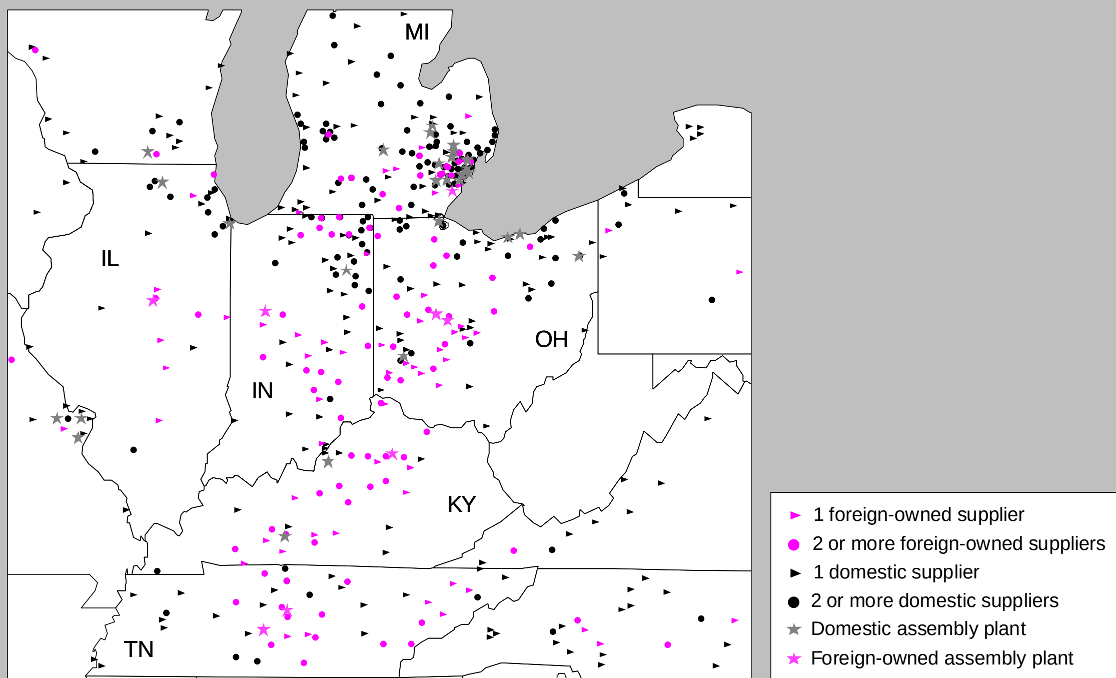
Importance of highway transportation for the auto corridor



Note: For some of the highways, the figure shows only the part that intersects the auto corridor.
Source: See table 1.

FIGURE 3

Plant openings by tier 1 suppliers within auto corridor, 1980–97



Source: See table 1.

Focusing on relationships to primary customers only would provide more conclusive evidence. However, the data do not allow identification of the distribution of output among customers. Instead, I present information on the distribution of supplier plants that report a particular customer mix. Table 4 shows data on domestic suppliers that supply *only* to Big Three assembly plants, as well as data on Japanese transplant suppliers that *do not* supply to any Big Three assembly plants. If the nationality of the assembly plant customer was important to the location choice of the supplier plant, one would expect these two groups to be relatively concentrated in their respective halves of the auto corridor. Table 4 provides evidence

TABLE 4

Percent of supplier plants opened in auto corridor, 1980–97

	Domestic			Japanese-owned	
	Overall	Supplying only to Big Three		Overall	Not supplying to Big Three
Michigan	31.3	40.0	Ohio	20.8	28.6
Indiana	10.9	11.4	Kentucky	18.5	21.4
Ohio	10.4	10.2	Tennessee	13.3	14.3
Tennessee	6.3	4.2	Indiana	11.0	12.9
Kentucky	4.1	1.8	Michigan	9.2	0.0
Top three	52.6	61.6		52.6	64.3
Number of plants	607	166		173	70

Source: See table 1.

of just such a "customer" effect, as each group of supplier plants with a specific customer mix is more concentrated at one end of the auto corridor.[16]

This simple comparison between the location choices of assembly and supplier plants, however, cannot address the issue of timing. Did assembly or supplier plants locate first?[17] The data allow me to shed some light on this question for the Japanese-owned supplier plants. Table 5 shows that 55 percent of these plants opened between 1987 and 1989, well after the first Japanese auto assembly plants had started operating in the U.S.[18] That pattern suggests that in the case of Japanese transplants, the suppliers followed the assemblers (see also Rubenstein, 1992). However, the initial location decision of Japanese assembly plants was undoubtedly influenced by proximity to the existing, that is, mostly domestic, supplier base.[19]

Network data

Next, I discuss the extent to which supplier plants locate near their assembly plant customers. As the data set includes information on customers of the individual supplier plants, I am able to construct supplier networks for specific assembly plants.[20] However, my choice of assembly plants is limited to a set of essentially single-plant assembly companies as the supplier plants' customer information is provided only at the company level. I can construct networks for the following assembly plants: Honda of America, which opened its Marysville, Ohio, plant in 1982 (and added a second assembly plant in nearby East Liberty, Ohio, in 1989); Nissan, which opened an assembly plant in Smyrna, Tennessee, in 1983; NUMMI, a joint venture between Toyota and GM, operating in Fremont, California, since 1984; AutoAlliance, which started as a joint venture between Ford and Mazda in 1987 in Flat Rock, Michigan; Diamond-Star, which started production as a Mitsubishi–Chrysler joint venture in Normal, Illinois, in 1988; Saturn, GM's attempt to capture the efficiencies of lean manufacturing, which started production in 1990 in Spring Hill, Tennessee; BMW, which opened an assembly plant in South Carolina in 1994; and Mercedes-Benz, which opened a plant in Alabama in 1997.

Table 6 presents characteristics of the networks identified from the database.[21] Each network includes all independent supplier plants that list the respective assembler as a customer. Not surprisingly, the networks vary in size, with Honda, the oldest, being the largest, and Mercedes-Benz, the most recently opened assembly plant on the list, the smallest. To measure the networks' spatial characteristics, I calculate the median distance between supplier and assembler and the percentage of suppliers located within both a 100-mile and a 400-mile radius of the assembly plant (table 6, column seven, ranks networks by percentage share of suppliers within 400 miles). The 400-mile radius roughly defines the boundary for a one-day shipping distance, while the 100-mile distance captures plants that locate close enough to allow multiple deliveries using the same truck.[22]

According to these statistics, the individual networks look more alike than different. In general, the spatial concentration increases toward the heart of the automotive corridor. The AutoAlliance and Honda networks are most concentrated within 100 miles (column five); for the 400-mile criterion, the disadvantage from being located at the fringe of the automotive corridor mostly disappears. Two cases in point are the Diamond-Star and Subaru-Isuzu networks, which are, for the larger radius, essentially as concentrated as Honda's and Toyota's. The spatial features of supplier networks reported in table 6 seem to be explained by two factors: where the assembly plant is located relative to the auto corridor and whether the assembly plant is domestic or foreign-owned.

TABLE 5

Japanese transplant tier 1 supplier plants

Start-up year	Number of plants	Percent
1980	5	3
1981	1	1
1982	3	2
1983	1	1
1984	5	3
1985	8	5
1986	17	10
1987	34	20
1988	36	21
1989	24	14
1990	9	5
1991	5	3
1992	4	2
1993	2	1
1994	4	2
1995	9	5
1996	2	1
1997	4	2
	173	100

Note: Column labeled "Percent" may not total due to rounding.
Source: See table 1.

TABLE 6

Spatial characteristics of supplier networks, 1997

Assembly company	Start-up year	Number of suppliers	% Domestic	Median distance	Network %<100 miles	Industry %<100 miles	Network %<400 miles	Industry %<400 miles
A.								
Honda	1982	507	65	251	17	9.4	77	74.8
Toyota	1988	452	69	285	10	4.2	76	75.7
Subaru-Isuzu	1987	292	60	245	9	6.2	76	71.8
Diamond-Star	1988	286	63	309	5	1.7	72	69.3
AutoAlliance	1987	360	71	242	29	24.7	65	66.4
Nissan	1983	460	70	423	10	3.8	45	36.7
BMW	1994	119	75	477	20	3.7	42	26.6
Saturn	1990	300	81	462	8	3.4	35	32.4
Mercedes-Benz	1997	77	68	610	8	0.8	34	17.5
NUMMI	1984	178	60	1,966	6	0.8	11	2.4
B.								
Flint (1950)	1907	126	72	192	28		77	
Ford (1970–80)	N.A.	222	89	405	18		55	
Ford (1983–93)	N.A.	301	77	200	31		66	

Note: N.A. indicates not applicable.

Sources: G. Rex Henrickson, 1951, *Trends in the Geographic Distribution of Suppliers of Some Basically Important Materials Used at the Buick Motor Division, Flint, Michigan*, Ann Arbor, MI: University of Michigan, Institute for Human Adjustment; ELM International, Inc., 1997, "The ELM GUIDE supplier database," East Lansing, MI, database file; and author's calculations.

For example, figure 4 shows how Honda's independent supplier plants cluster around its two Ohio assembly plants. The three circles envelop the first three quartiles of the distance distribution of supplier plants in the network. The figure shows an assembly operation that is centrally located in the auto corridor. It turns out to be the most spatially concentrated network: 17 percent of Honda's 507 suppliers are located within 100 miles and 77 percent within 400 miles of the assembly plant.

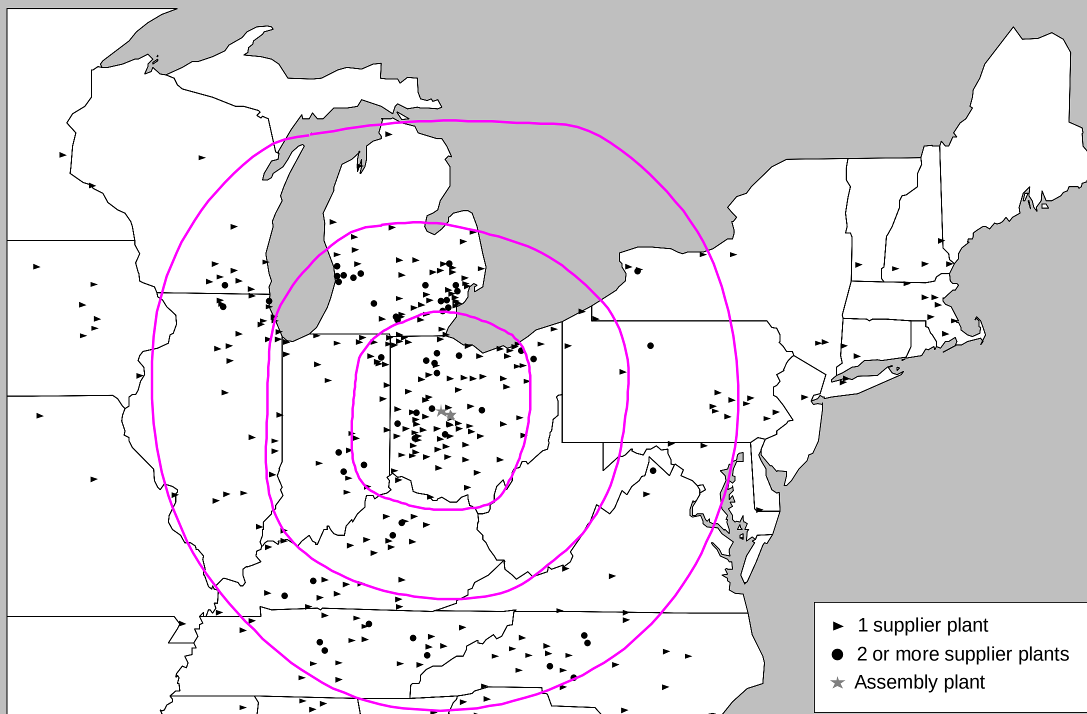
In contrast, Diamond-Star is located at the western edge of the auto corridor (see figure 5). Therefore, it is able to attract only 5 percent of its suppliers to locate within 100 miles. However, that disadvantage disappears at the 400-mile radius, which, for Diamond-Star as for Honda, includes 77 percent of its supplier plants.

The case of Saturn presents yet a different picture. Its suppliers are relatively dispersed (see figure 6). Notice the large diameter of the first quartile. Only 35 percent of Saturn's supplier plants are operating within 400 miles of Spring Hill, Tennessee. This reflects the fact that Saturn most strongly relies on domestic suppliers, which are located at the northern end of the auto region. Its assembly plant, however, is located at the southern end of the corridor.

Alternatively, one can analyze the concentration of individual supplier networks relative to the distribution of all the supplier plants. In calculating what share of the entire industry is located within a certain radius of the assembly plant, one can then assess a network's degree of concentration relative to the industry baseline. Table 6, panel A, shows this information for both the 100-mile and the 400-mile radius. Columns five and six show that for every single assembly plant analyzed, a greater share of suppliers is concentrated within 100 miles than the overall industry distribution would suggest. At the 400-mile radius (see columns seven and eight of table 6), one can distinguish two network groups. The supplier networks of assemblers located in the northern end of the auto corridor plus Kentucky represent very closely the industry's overall spatial distribution. However, the five assembly plants located in Tennessee, Alabama, South Carolina, and California are far more concentrated than the industry, even at that relatively large radius. What drives that result is the large number of suppliers operating at the northern end of the auto corridor. For example,

FIGURE 4

Honda's supplier network, 1997



Note: The circles around the assembly plant indicate the closest 25 percent, 50 percent, and 75 percent of the supplier network, respectively.
Source: See table 1.

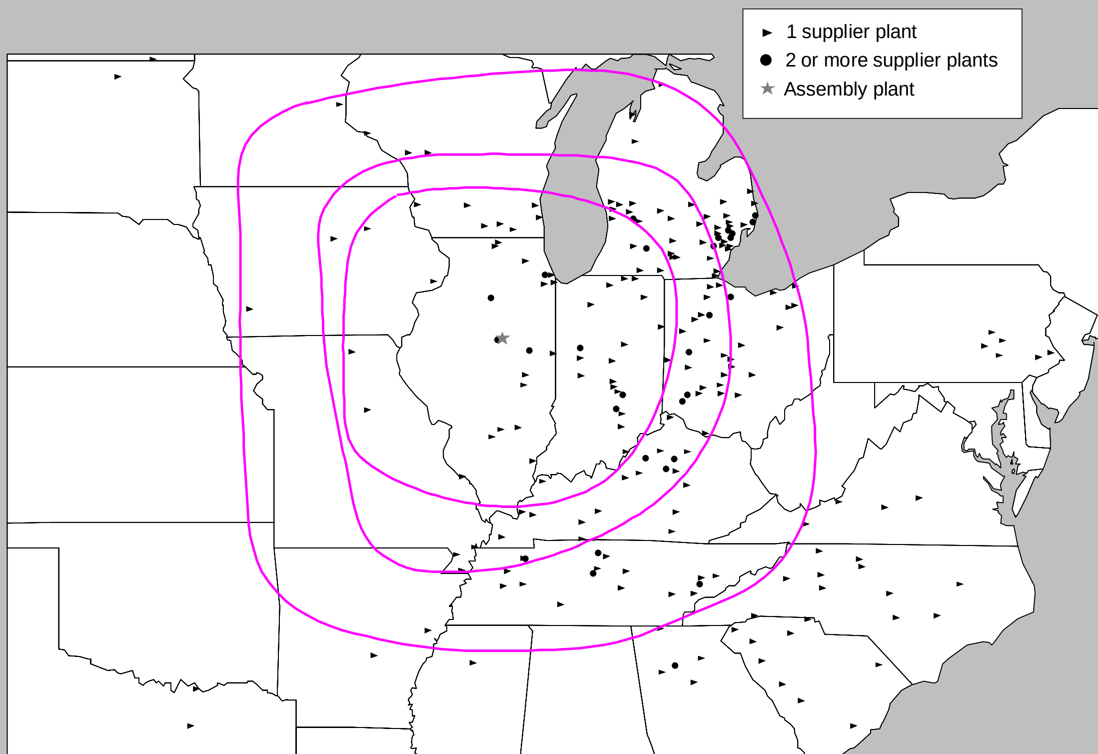
suppliers in Nissan's network that are located within 400 miles of the Tennessee assembly plant represent a far greater concentration of auto suppliers in the region than indicated by the distribution of all supplier plants.

The different spatial distribution of domestic and foreign-owned supplier plants across the auto corridor is reflected within the individual networks as well. Foreign-owned supplier plants are clustered much more densely around Japanese assembly plants than domestic suppliers (see, for example, Honda, Toyota, and Nissan in table 7 on page 29). Yet even for that group, less than one-third of suppliers are located within a two-hour drive, or 100 miles, of the assembly plant. This represents a considerably smaller degree of spatial concentration within lean manufacturing than previously reported in the literature.[23] The case of Saturn represents a domestic auto assembler whose network is not very spatially concentrated. This applies to both its domestic and foreign-owned supplier plants (quite in contrast to Nissan, which is located not very far from Saturn). Finally, AutoAlliance shows the effect of being located in the heart of the traditional U.S. auto region. Its network includes by far the largest percentage of suppliers within a 100-mile radius. At 31.9 percent, that share is significantly higher for domestic suppliers than for foreign-owned suppliers (21.9 percent).

The analysis of the regional concentration of supplier networks at that disaggregate level can again be complemented by a comparison with the industry level of spatial concentration. For the 100-mile radius, table 7 (columns three and four) shows a higher degree of concentration for both domestic and foreign-owned suppliers within each network than is indicated by the overall distribution of the industry. At the 400-mile radius (columns five and six), the differences between these two measures of spatial concentration disappear in most cases. Noteworthy exceptions are the most recently opened assembly plants to the south and east of the auto corridor (Mercedes and BMW) and NUMMI. Saturn is the only domestic assembly plant in the study. Its network shows a smaller percentage of within-network foreign-owned suppliers within 400 miles of the assembly plant than the overall industry

FIGURE 5

Diamond-Star's supplier network, 1997



Note: The circles around the assembly plant indicate the closest 25 percent, 50 percent, and 75 percent of the supplier network, respectively.
Source: See table 1.

level would suggest. The spatial distribution of Saturn's network presents a stark contrast to that of Nissan, the other assembly plant in Tennessee.

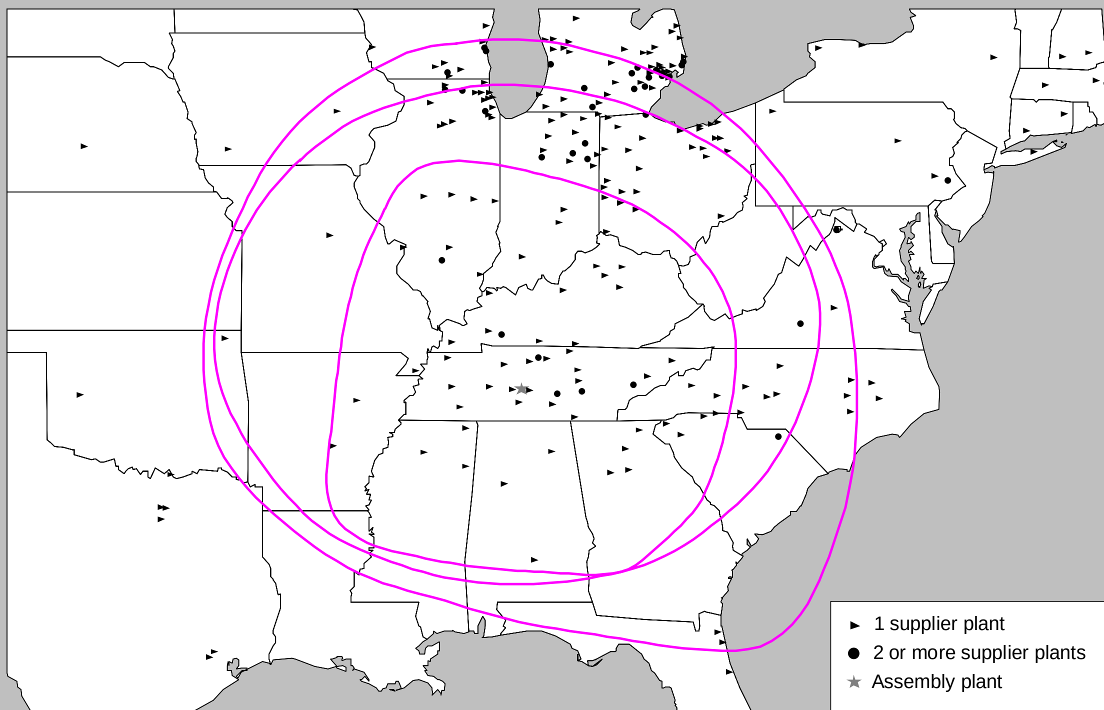
Changing industry structure?

To what extent are these observations indicative of changes in the spatial pattern of auto supplier plants? I address that question in three different ways. First, I compare the structure of different networks over time. From Henrickson's (1951) analysis of the supplier structure of the Buick city assembly plant in Flint, Michigan, it is possible to reconstruct that assembly plant's supplier network (see table 6, panel B, page 25) and compare it with a current network (Honda) that operates based on a different manufacturing system.[24] It turns out that the median distance is statistically different for these two networks; however, the percentages within 400 miles are not statistically different. In other words, during the prime of the manufacturing system perfected by Henry Ford, one of its showcase plants, GM's Buick city plant, had a supplier structure that was remarkably spatially concentrated. However, it is important to keep in mind that such a comparison is not adjusted for different degrees of vertical integration, changes in the mode and speed of transportation, as well as quality of the transportation infrastructure since 1950. In other words, a 400-mile radius in 1950 in all likelihood represented a smaller degree of spatial concentration than the same radius in 1997.

Second, I test for differences in spatial concentration for one network over time, using data on one of the Big Three assemblers, Ford. Instead of constructing networks for each of Ford's individual assembly plants, I use Dearborn, Michigan, as the center of Ford's assembly operations. Since 1970 there have been two decades, 1970–80 and 1983–93, during which Ford neither opened nor closed an assembly plant.[25] Juxtaposing these two periods allows for an interesting comparison of the changing spatial pattern of Ford's supplier network (see table 6, panel B on page 25 and figure 7 on page 30). It shows a marked

FIGURE 6

Saturn's supplier network, 1997



Note: The circles around the assembly plant indicate the closest 25 percent, 50 percent, and 75 percent of the supplier network, respectively.
Source: See table 1.

increase in concentration of Ford's supplier base around southern Michigan. During the more recent decade, 31 percent of newly opened supplier plants located within 100 miles of Dearborn (versus only 17 percent during the earlier decade). Comparing 1970–80 and 1983–93, the closures of two California plants and a New Jersey plant in the intervening years might have reduced average distances to Dearborn somewhat (for example, by reducing the percentage of plants greater than 400 miles away). However, one would not expect that alone to contribute to the simultaneous increase in plants located within 100 miles of Dearborn.[26] Comparing 1970–80 and 1983–93, the statistical tests show all three measures of spatial concentration reported in table 6 to be different at the 99 percent confidence level, providing strong evidence of increasing spatial concentration within one of the Big Three supplier networks.

Third, I ignore the customer information provided by the database and employ a simple location algorithm, motivated by a Weberian model of plant location, to link suppliers with assembly plants.[27] By applying a uniform location rule across time for supplier plants, I can test whether their location decisions changed over time. To perform this test, I break the sample into two periods: plants that have opened since 1980, whose location decisions were presumably influenced by lean manufacturing constraints, and plants that opened between 1950 and 1979, when supplier location decisions were influenced by the need to be close to Big Three operated parts distribution facilities. Comparing plant locations for these two samples, I can test for a change in location pattern in two directions. That is, I can ask if the pattern exhibited by the younger plants fits that of the older ones and vice versa. Specifically, for the most recent period I apply two versions of a location rule that minimizes the distance between supplier and assembly plant.[28] This approach represents the influence of just-in-time production; supplier plants in that environment want to be located closer to the assembly plant to minimize production and transportation costs. It links the supplier to the closest operational assembly plant. I do not incorporate information provided in the database (and used above)

TABLE 7

Spatial characteristics of supplier networks by supplier type, 1997

Assembly company	Supplier type	Median distance	Network %<100 miles	Industry %<100 miles	Network %<400 miles	Industry %<400 miles
Honda	Domestic	280.6	12.7[a]	8.6[a]	73.1[b]	74.6
	Foreign	175.2	26.3[a]	13.6[a]	83.4[b]	76.2
Toyota	Domestic	311.3	5.1[a]	2.9[a]	73.1[b]	74.8[b]
	Foreign	199.2	19.4[a]	11.3[a]	83.5[b]	80.8[b]
Subaru-Isuzu	Domestic	260.4	6.8[a]	5.8[a]	69.9[b]	71.5
	Foreign	206.7	12.1[a]	8.8[a]	84.5[b]	73.2
Diamond-Star	Domestic	333.3	2.8[a]	1.4[a]	69.3	69.3
	Foreign	280.3	8.5[a]	3.3[a]	78.3[a]	69.5
AutoAlliance	Domestic	187.7	31.9[a]	26.4[a]	66.9	67.5[b]
	Foreign	286.4	21.9[a]	15.5[a]	61.9[a]	60.3[b]
Nissan	Domestic	447.1	7.1[a]	2.9[a]	36.6[b]	32.4[b]
	Foreign	272.1	16.7[a]	8.6[a]	64.5[b]	60.7[b]
BMW	Domestic	494.6	18.2[a]	3.3[a]	39.7	22.6[b]
	Foreign	398.0	23.3[a]	6.1[a]	50.0[a]	48.5[b]
Saturn	Domestic	465.8	7.4[a]	2.7[a]	32.8	28.2[b]
	Foreign	435.9	8.9[a]	7.3[a]	42.9[a]	55.6[b]
Mercedes-Benz	Domestic	638.7	5.8[a]	0.7[a]	26.9	15.2[b]
	Foreign	435.4	12.0[a]	1.3[a]	48.0[a]	30.8[b]
NUMMI	Domestic	1,946.6	6.6[a]	0.6[a]	11.3	2.1
	Foreign	1,975.5	7.0[a]	1.9[a]	9.9[a]	4.0[a]

[a]Indicates too few observations.
[b]Indicates a difference in the percentages of domestic and foreign-owned suppliers at the 99 percent level of confidence.
Source: See table 1.

on actual assembler–supplier linkages. However, in applying a general location rule I am no longer restricted to the number of assembly plants listed in table 6, but can consider all light vehicle assembly plants in the U.S.[29] A slightly different version averages the three shortest distances between a supplier and operational assembly plants. I apply the location rule to both sets of supplier plants, resulting in a distribution of distances for each sample. I then test if the median of the more recent sample is statistically different from the median of distances for the older plants.[30] If I find no statistical difference, then the just-in-time location rule describes both time periods equally well, and there is no evidence for change in location pattern. However, if there is evidence of a difference in the pattern, I interpret this as a strong signal for a change in the location pattern, as it is established by applying the same decision rule for both periods. The test results are described in table 8, panel A (page 31). Under both versions of the just-in-time rule, median distances decrease over time. In fact, the differences in the median are significant at the 99 percent level, according to a Wilcoxon signed-rank test.

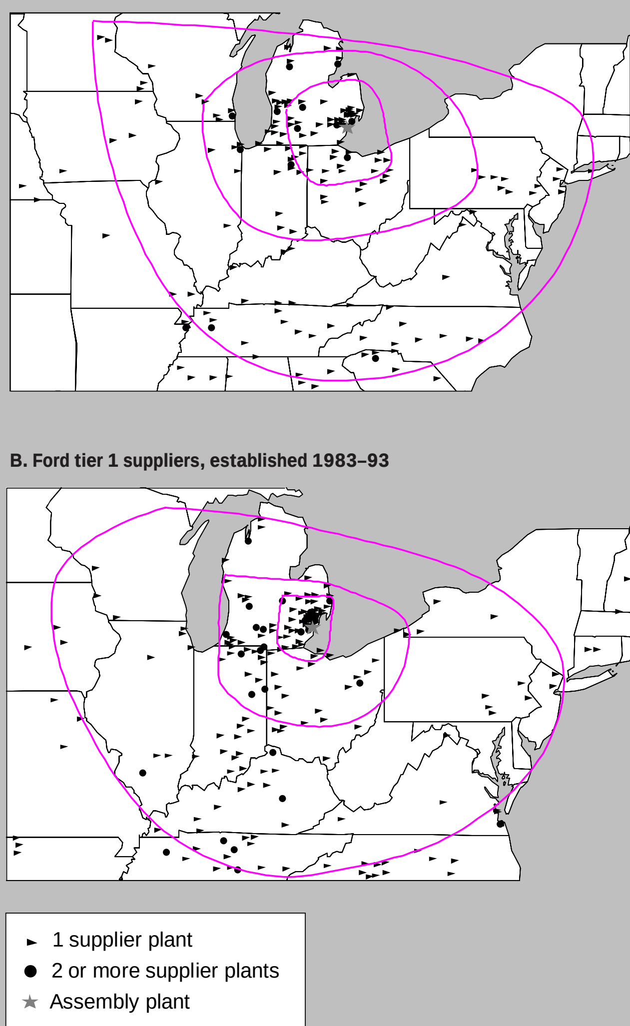
In testing for a change in location pattern in the opposite direction, I use the following rule to approximate decisions made by the older supplier plants: minimize distance to Detroit.[31] Prior to the tiering of the supplier industry, supplier plants would usually ship their output to a regional parts distribution center operated by the Big Three, which in turn directed the parts to assembly plants around the country. In recognition of the spatial clustering of auto supplier plants in southeast Michigan, northern Indiana, and Ohio, I calculate the distance to Detroit for each plant that opened during the earlier period. These results

FIGURE 7

Increase in concentration of Ford's supplier network over time

A. Ford tier 1 suppliers, established 1970–80

B. Ford tier 1 suppliers, established 1983–93



Note: The circles around the assembly plant indicate the closest 25 percent, 50 percent, and 75 percent of the supplier network, respectively.
Source: See table 1.

are presented in panel B of table 8. The actual distances to Detroit increased from 1980 onward, which is not surprising considering the changing shape of the auto region in that period. Again, I find the median distances to be statistically different at the 99 percent level, complementing the result of the first part of the test for a change in location patterns over time. To summarize, I find symmetrical evidence for structural change in the way supplier plants locate around assembler plants. Both tests suggest an increase in the clustering of suppliers around assembly plants since 1980 relative to 30 or 40 years ago.

Conclusion

By refining a commercially available database, this article provides a detailed look at the supplier networks of some recently opened auto assembly plants in the U.S. My analysis focuses on a description of existing spatial relations between assembly plants and their tier 1 supplier plants. This study supports earlier findings about regional agglomeration of supplier plants in the I-65/I-75 automotive corridor. For supplier plants of recent vintage, the five auto corridor states, Michigan, Indiana, Ohio, Kentucky and Tennessee, represent the preferred location. Within that region, however, domestic and foreign-owned supplier plants locate in noticeably different patterns, apparently due to differences in the location of domestic and foreign-owned assembly plants.

The evidence I present on the auto industry supports the view that agglomeration economies play out at the regional level (see Hewings et al., 1998). It does not support the notion that immediate proximity to the assembly plant is necessary for operating a system based on tight linkages and low inventories.[32] In analyzing the extent of localization of production around individual assembly plants, I find networks to be remarkably similar, with about 70 percent to 80 percent of suppliers located within one day's drive of the assembly plant. Differences seem to be explained by the location of the assembly plant in relation to the heart of the auto corridor as well as by nationality of the assembly plant. Within individual networks, the spatial concentration differs across domestic and foreign-owned supplier plants.

This evidence on spatial agglomeration has relevance for economic development (see table 9). The economic development literature has generally reported on the effects of locating a new assembly plant on either its immediate and surrounding counties (see, for example, Fournier and Isserman, 1993) or on the host state (see, for example, Marvel and Shkurti, 1993). However, the analysis presented here

TABLE 8

Median distances (miles) between supplier and assembly plant, 1997

	Supplier plants opened	
	1950–80	**1980–97**
A. Just-in-time location rule		
Shortest distance		
All	60.4[a] (649)	52.2[a] (806)
Domestic	59.6[a] (605)	47.1[a] (594)
Closest three avg.		
All	108.2[a] (649)	84.3[a] (806)
Domestic	105.0[a] (605)	73.2[a] (594)
B. Distance to Detroit rule		
All	97.2[a] (649)	296.7[a] (806)
Domestic	188.6[a] (605)	203.0[a] (604)

[a]Indicates that the median distances are significantly different at the 99 percent confidence level, according to a Wilcoxon signed-rank test.
Note: Numbers in parentheses indicate number of observations.
Source: See table 1.

TABLE 9

Incentives to attract new auto assembly plants

			1997 employment[a]	
Company	**State**	**State investment**	**Entire network**	**Since plant opened[b]**
		($ mil.)	*(------------percent----------)*	
Honda	Ohio	21	23.4	27.0
Honda	Ohio	67		
Nissan	Tennessee	33	11.2	21.1
AutoAlliance	Michigan	49	21.1	14.6
Diamond-Star	Illinois	83	12.9	4.0
Toyota	Kentucky	150	14.8	28.9
Toyota	Indiana	72		
Saturn	Tennessee	80	12.1	71.3
Subaru-Isuzu	Indiana	86	17.6	22.7
BMW	S. Carolina	130	18.1	53.6
Mercedes	Alabama	252	16.5	0.0

[a]Since I do not have information on the distribution of a supplier's output across its customers, I adjust the reported plant-level employment by dividing it by the number of customers per supplier plant. In essence, I am treating all customers as of equal importance to a supplier. The last two columns report the percentages of supplier employment in the state of the assembly plant based on these adjusted employment figures.
[b]Percentages in this column refer to tier 1 suppliers only as I do not have information on the start-up year of mixed-tier supplier plants.
Sources: R. Perrucci, 1994, *Japanese Auto Transplants in the Heartland*, New York, De Gruyter; ELM International, Inc., 1997, "The ELM GUIDE supplier database," East Lansing, MI, database file; and author's calculations.

allows us to investigate the extent of the regional distribution of related upstream plant employment in much greater detail. Take, for example, the case of the Mercedes plant that opened in 1993 in Alabama. The state provided incentives worth about $250 million to attract that plant. However, the evidence presented on the spatial extension of supplier networks suggests that suppliers to Mercedes will locate not just in Alabama, but more likely in Tennessee, Kentucky, and even further north.[33] In fact, to date only 35 percent of Mercedes's suppliers are located within 400 miles of the assembly plant, and only 16.5 percent of its supplier employment resides in Alabama.[34] In Mercedes' case, attractive targets for location efforts seem to have been foreign-owned companies (see table 7 on page 29). In short, this type of analysis suggests that subsidies that are offered by a state not in the auto corridor are considerably less effective in terms of attracting a significant portion of the related supplier employment to that state.

In the case of Toyota's Kentucky assembly plant, a comparison of my network data on the distribution of supplier jobs with forecasts projected by a 1992 study also suggests a greater degree of spatial dispersion of supplier employment than expected.[35]

Finally, several tests address the question of structural change in the spatial pattern of supplier plant locations. While limited by the cross-sectional nature of the data available, these results suggest that the degree of spatial concentration of supplier plants around assembly plants has increased since 1980. The timing of that change is consistent with the application of lean manufacturing techniques and just-in-time production linkages. However, the order of magnitude of the increased concentration does not support the concept of a supplier base that is tightly clustered around its customers. Within the auto corridor, the existing infrastructure apparently allows for frequent deliveries to multiple customers from a single supplier plant location.

NOTES

[1]Marshall (1920) identified three reasons for localization: An industrial center allows a pooled labor market for workers with specialized skills; an industrial center allows provision of non-traded inputs specific to an industry in greater variety and at lower cost; and an industrial center generates technological spillovers as information flows more easily locally (Krugman, 1991, pp. 36–37).

[2]The authors find the largest coagglomeration for the following two upstream–downstream industry pairs: motor vehicle parts and accessories (SIC 3714) and motor vehicles, car bodies (SIC 3711); and automotive stampings (SIC 3465) and motor vehicles, car bodies (SIC 3711).

[3]It identifies for each of these the address, the list of products produced as well as the production processes used, employment, and the plants' customers (at the company level). See ELM International, Inc. (1997).

[4]My analysis does not cover the so-called captive supplier plants. An earlier paper (Klier, 1995) presented a much more limited analysis of the same issues for a comparatively small set of data for independent supplier plants operational in 1993.

[5]It is difficult to accurately assess the coverage of this database, since the size of the true population is unknown.

[6]Japan Auto Parts Industries Association (1998).

[7]About 8.1 percent of the 2,008 tier 1 plant records as provided by the ELM database could not be tracked down, either in the manufacturing directories or by phone, and are therefore not included in the subsequent analysis.

[8]However, this is not equivalent to a time-series analysis since the sample only contains plants operating during 1997 and not those plants that were shut down in earlier years.

[9]They represent 1,845 tier 1 and 1,292 mixed-tier plants.

[10]Honda opened its first auto assembly plant in the U.S. in Ohio in 1982. McAlinden and Smith (1993) refer to the 1980s as a period of significant structural change for the U.S. automotive parts industry.

[11]Woodward (1992) presents empirical evidence of the importance of highway access at the county level in attracting plant openings.

[12]About 63 percent of foreign-owned plants are Japanese; see table 2.

[13]Automobile assembly and component plants that are fully or partly owned by foreign companies are generally referred to as transplants.

[14]Smith and Florida (1994) find evidence for such an effect for their sample of Japanese-owned supplier plants.

[15]In the case of Japanese assembly plants, this has been well documented in the context of corporate ties between assembly and supplier companies (see Reid et al., 1995). For example, Ohio is perceived by both Japanese assemblers and bankers as "Honda's state" (see Rubenstein, 1992).

[16]There were too few observations for the following two categories to be reported in the table: domestic suppliers not supplying to Big Three assembly plants (16 plants) and Japanese suppliers only supplying to Big Three facilities (nine plants). However, in both cases the evidence is consistent with table 4. Plants in these two categories are noticeably less concentrated in the top three states (31.2 percent for the domestic supplier plants and 33.3 percent for the Japanese-owned plants).

[17]See Rubenstein (1997) on the reconcentration of auto assembly plants in the Midwest and Southeast.

[18]Only two of the Japanese-owned assembly plants in the study opened after 1987—Diamond-Star and Toyota, both in 1988.

[19]Reid et al. (1995) suggest that was one of the ways Japanese assemblers minimized risk and uncertainty related to their direct foreign investment in the U.S.

[20]The vast majority of supplier plants (over 90 percent) ship to multiple customers.

[21]The tables and maps refer only to supplier plants located in the U.S. The overwhelming majority of independent suppliers located in Canada are concentrated in southwest Ontario, between Windsor and Toronto. These plants are well connected to assembly plants in Canada and the northern end of the U.S. auto corridor via route 401.

[22]All distances are calculated between the respective coordinates of a plant's zip code; they are not adjusted for actual travel routes.

[23]For example, Kenney and Florida (1992) report data on approximately 70 Japanese-owned auto supplier plants in the auto corridor and show 41.4 percent of plants within 100 miles of their respective assembly plants. In contrast, the highest concentration of Japanese-owned suppliers around Japanese assemblers I can find applies to the Honda network, with 29.3 percent of Japanese-owned suppliers within 100 miles of the assembly plant, followed by Toyota (22.9 percent) and Auto Alliance (22.5 percent).

[24]The Buick plant in Flint was at the time one of the largest integrated automotive plants in the world. It employed about 22,000 people and produced about 2,000 cars a day. Henrickson's data include both independent and captive suppliers of metal auto parts, tire and tube supplies, and mechanical rubber goods.

[25]Between 1980 and 1983, three Ford assembly plants closed (two in California and one in New Jersey). In 1992, a body plant for Ford's large vans in Avon Lake, Ohio, added an assembly line for the production of the Mercury Villager/Nissan Quest.

[26]As the opening of the Avon Lake assembly line in 1992 could possibly explain some of the increase in supplier plants locating close to Dearborn, Michigan, I checked for robustness of my results by shortening the second time period to end in 1991. The exercise leaves the spatial distribution of Ford suppliers that opened during the 1980s essentially unchanged. This strongly suggests that the opening of the Avon Lake assembly line is not driving the reported reconcentration.

[27]I would like to thank David Marshall, who suggested using this technique.

[28]In calculating these distances, I consider only assembly plants that were operational when the supplier plant opened.

[29]From 1950 to 1979, that corresponds to 77 light vehicle assembly plants; for the later time period, there are 76 plants.

[30]The Wilcoxon signed-rank test is a nonparametric test that can be used to test whether the median of a set of observations equals some prespecified value. The test is based on calculating, ranking, and signing the differences between the actual observations and the constant. In panel A of table 8, I report the results from testing whether the median of the more recent distances between assembly and supplier plants (52.2 miles in the case of all observations) is different from the median of the distribution of distances for the older set of observations (60.4 miles). The test statistic *T*, which is distributed approximately normally, is obtained by taking the differences $D_i = x_i - median_{80-97}$, where x_i represents the actual distances observed in the older data set. These differences are then ranked and signed; the test statistic *T* represents the sum of the signed ranks. The null hypothesis states that the median difference D_i equals zero. If it cannot be rejected, it follows that the median distances for both data sets are equal.

[31]I would like to thank Jim Rubenstein, who suggested this approach.

[32]See Reid (1994), Mair (1993), and Kenney and Florida (1992), who seem to suggest the need for very close proximity between assembler and suppliers.

[33]Elhance and Chapman (1992) find similar evidence in analyzing the labor market of the Diamond-Star assembly plant in central Illinois. They find that the labor market for that plant covers a large geographical area, stretching over 15 states. They take this as evidence to suggest that the benefits of incentive packages intended to attract large manufacturing plants will not remain within the communities or states providing such incentives.

[34]As table 9 shows, the percentage of supplier employment residing within the state of the assembly plant tends to increase if calculated for the set of supplier plants that opened after the respective assembly plant. In a couple of cases the percentages increase dramatically, but it is important to point out that these changes are in reference to only a small number of supplier plant openings. In Mercedes' case, no supplier plant opened during 1997.

[35]The Center for Business and Economic Research's (1992) analysis of the economic impact of Toyota's assembly plant on the other auto corridor states plus Illinois employs a specific input–output model (RIMS II) and its multipliers. Comparing the distribution of jobs associated with the production of inputs for Toyota's assembly plant, information from my network data shows the overall network employment at about 36 percent of that estimated in the earlier study. However, one needs to point out that the numbers are not directly comparable, as the ELM database does not include purchases of raw materials and production equipment. With that caveat, a comparison of the distribution of employment by state suggests that Toyota's supplier network might actually be more dispersed than originally estimated. Specifically, based on information presented in this article, the share of jobs in Michigan and Indiana is lower than estimated, while Illinois, Ohio, and Tennessee report a relatively higher share.

REFERENCES

Center for Business and Economic Research, 1992, "The economic significance of Toyota Motor manufacturing, U.S.A. Inc., in Kentucky," *Review and Perspective*, University of Kentucky, December.

Database Publishing Co., 1997, *Arizona and California Manufacturers Register*, Phoenix, AZ.

Dyer, Jeffrey H., 1994, "Dedicated assets: Japan's manufacturing edge," *Harvard Business Review*, November–December, pp. 174–178.

Elhance, Arun P., and Margaret Chapman, 1992, "Labor market of a U.S.–Japanese automobile joint venture," *Growth and Change*, Vol. 23, No. 2, pp. 160–182.

Ellison, Glenn, and Edward L. Glaeser, 1997, "Geographic concentration in U.S. manufacturing industries: A dartboard approach," *Journal of Political Economy*, Vol. 105, No. 5, pp. 889–927.

ELM International, Inc., 1997, "The ELM GUIDE supplier database," East Lansing, MI, database file.

Estall, R. C., 1985, "Stock control in manufacturing: The just-in-time system and its locational implications," *Area*, Vol. 17, No. 2, pp. 129–132.

Fournier, Stephen F., and Andrew M. Isserman, 1993, "Putting it all together: The effects of the Honda plant on its host county and rural hinterland," West Virginia University, Regional Research Institute, research paper, No. 9305.

Glasmeier, Amy, and Richard McCluskey, 1987, "U.S. auto parts production: An analysis of the organization and location of a changing industry," *Economic Geography*, Vol. 63, No.2, pp. 142–159.

Helper, Susan, 1991, "How much has really changed between U.S. automakers and their suppliers?," *Sloan Management Review*, Vol. 15, No. 3, pp. 15–28.

Henrickson, G. Rex, 1951, *Trends in the Geographic Distribution of Suppliers of Some Basically Important Materials Used at the Buick Motor Division, Flint, Michigan*, Ann Arbor, MI: University of Michigan, Institute for Human Adjustment.

Hewings, Geoffrey J. D., Philip R. Israilevich, and Graham R. Schindler, 1998, "Interstate trade among Midwest economies," *Chicago Fed Letter*, Federal Reserve Bank of Chicago, May, No. 129.

Japan Auto Parts Industries Association, 1998, *Membership Directory*.

Kenney, Martin, and Richard Florida, 1992, "The Japanese transplants—Production organization and regional development," *Journal of the American Planning Association*, Vol. 58, No. 1, pp. 21–38.

Klier, Thomas, 1995, "The geography of lean manufacturing: Recent evidence from the U.S. auto industry," *Economic Perspectives*, Federal Reserve Bank of Chicago, Vol. 19, No. 6, pp. 2–17.

Krugman, Paul, 1991, *Geography and Trade*, Cambridge, MA: MIT Press.

Mair, Andrew, 1994, *Honda's Global Local Corporation*, New York: St. Martin's Press.

________, 1993, "New growth poles? Just-in-time manufacturing and local economic development strategy," *Regional Studies*, Vol. 27, No. 3, pp. 207–221.

________, 1992, "Just-in-time manufacturing and the spatial structure of the automobile industry: Lessons from Japan," *Tijdschrift voor Econ. en Soc. Geografie*, Vol. 82, No. 2, pp. 82–92.

Mair, Andrew, Richard Florida, and Martin Kenney, 1988, "The new geography of automobile production: Japanese transplants in North America," *Economic Geography*, Vol. 20, October, pp. 352–373.

Manufacturers' News Inc., 1997, *Alabama, Georgia, Florida, Illinois, Indiana, Iowa, Kentucky, Missouri, Nebraska, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and Wisconsin Manufacturers Register*, Evanston, IL.

Marshall, Alfred, 1920, *Principles of Economics*, London: Macmillan.

Marvel, Mary K., and William J. Shkurti, 1993, "The economic impact of development: Honda in Ohio," *Economic Development Quarterly*, Vol. 7, No. 1, pp. 50–62.

McAlinden, Sean, and Brett Smith, 1993, "The changing structure of the U.S. automotive parts industry," University of Michigan, Transportation Research Institute, research paper, No. UMTRI 93-6.

Perrucci, R., 1994, *Japanese Auto Transplants in the Heartland: Corporatism and Community*, New York: De Gruyter.

Pick Publications, 1997, *Michigan Manufacturers Directory*, Southfield, MI.

Reid, Neil, 1994, "Just-in-time inventory control and the economic integration of Japanese-owned manufacturing plants with the county, state, and national economies of the United States," *Regional Studies*, Vol. 29, No. 4, pp. 345–355.

Reid, Neil, Andrew Solocha, and Breandán Ó hUallacháin, 1995, "Japanese corporate groups and the locational strategy of Japanese auto and component parts makers in the United States," in *The Location of Foreign Direct Investment*, Milford B. Green and Rod B. McNaughton (eds.), Aldershot, UK: Avebury, pp. 107–120.

Rubenstein, James M., 1997, "The evolving geography of production—Is manufacturing activity moving out of the Midwest? Evidence from the auto industry," *Assessing the Midwest Economy*, Federal Reserve Bank of Chicago, working paper, No. SP-3.

________, 1992, *The Changing U.S. Auto Industry—A Geographical Analysis*, London: Routledge.

________, 1988, "Changing distribution of American motor vehicle parts suppliers," *Geographical Review*, Vol. 18, No. 3, pp. 288–298.

Rubenstein, James M., and Neil Reid, 1987, "Ohio's motor vehicle industry—Industrial change and geographical implications," Miami University, geographical research paper, No. 1.

Smith, Donald, and Richard Florida, 1994, "Agglomeration and industrial location: An econometric analysis of Japanese-affiliated manufacturing establishments in automotive-related industries," *Journal of Urban Economics*, Vol. 36, No. 1, pp. 23–41.

Tower Publishing, 1997, *Massachusetts, Maine, New Hampshire, and Vermont Directory of Manufacturers 1997*, Standish, ME.

Ward's Communications, 1950–98, *Ward's Automotive Yearbook*, Overland Park, KS.

Woodward, Douglas P., 1992, "Locational determinants of Japanese manufacturing start-ups in the United States," *Southern Economic Journal*, Vol. 58, No. 3, pp. 690–708.