Geographic concentration in U.S. manufacturing: evidence from the U.S. auto supplier industry

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Abstract: This paper investigates the issue of geographic concentration for the auto supplier industry by means of a large plant-level data set representing information for the year 1997. The industry continues to be highly spatially concentrated, even though its core region has changed over the last few decades and is now represented by the auto corridor, extending south from Michigan to Tennessee. Analysis at the more disaggregate level of individual parts suggests transportation costs, economies of scale and spillover effects as factors underlying the aggregate spatial pattern of the industry.

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1. Motivation:

The issue of industry formation and the underlying forces shaping spatial patterns of industry location have recently seen a resurgence of interest. The two main explanations for observed agglomeration of plant locations within (and across) industries are natural advantages and spillover effects (or external economies). This paper presents detailed evidence on the geographic concentration of one specific manufacturing industry: the automobile supplier industry. It then looks at part-specific data to distinguish between factors explaining the location of supplier plants.

Krugman (1991) gives a broad overview on the relationship between geography and economics in which he argues for the acceptance of economic geography as a major field within economics. His main point is that external economies or increasing returns to scale have a pervasive influence on the economy; in doing so they give a decisive role to history in determining the geography of real economies. Krugman elaborates on that argument at various scales. In the case of localization of particular industries, autos in Detroit and computer chips in Silicon Valley, he refers back to Alfred Marshall, who pointed out in 1920 that businesses localize in response to three factors: pooled labor markets, greater variety and lower costs of intermediate inputs, and technological spillovers. Krugman presents a set of locational Gini coefficients, based on three-digit SIC data, that show the remarkable extent to which industries within the U.S. are localized. That effect is not limited to high technology industries, but includes, for example, carpet production around Dalton, Georgia, and financial services in New York .

In discussing the uneven development of regions, Krugman illustrates his argument with a model of periphery and core. He makes the point that agglomeration is based on externalities that result from market size effects in the face of transportation costs. That's why producers want to be near large markets, and large markets are near where producers concentrate.

Kim (1996) takes a historical perspective to analyze the changing structure of U.S. regions over an extended period of time. In analyzing data from 1860 through 1987 he calculates at various points in time indices of regional specialization as well as industrial location at the 2-digit SIC level. He finds the degree of regional specialization to have increased from 1860 until it peaked between WWI and WWII. Since then it has fallen considerably. His localization indices show significant variation, with some of the 20 manufacturing industries following the pattern of rise and fall in localization and others not. The author points out that he finds little support for a prominent role of external economies. For example his industry-level data show decreasing spatial concentration for high-tech industries such as chemicals and increasing concentration for low-tech industries such as textiles.

In summarizing his findings in broad terms, Kim argues that the historical trends in regional specialization in U.S. industry can be explained jointly by models based on scale economies and resources. Firms adopted large scale production methods, intensive in relatively immobile resources and energy sources, between 1860 and the beginning of the 20th century. The rise in scale and the use of immobile resources caused regions to become more specialized. As factors became increasingly mobile and as transportation costs fell, regional resource differences diminished. The growing similarity of regional factor endowments and a fall in scale economies caused regions to become despecialized between WWII and today. He concludes by stating that his findings explain both the rise and fall of the MW manufacturing belt by changes in the regional advantage of manufacturing rather than the existence of spillovers.

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 location effects due to pure random chance as well as those caused by localized industry-specific spillovers and natural advantages. Based on indices of localization the authors develop they find almost all industries to be somewhat localized. In many industries, however, the degree of localization is small. The authors report that there is no single factor that can explain high levels of concentration. Among the 15 most highly concentrated industries they suggest natural advantages for the wine, carbon black, raw cane sugar, and phosphatic fertilizer industries. A spillover-based explanation may account for the concentration of the various textile industries in the Southeast. The most concentrated industry, fur, is probably explained by the local transfer of knowledge from one generation to the next and as a response to buyers' search costs.

II. Auto supplier industry - industry level analysis

This paper investigates the issue of geographic concentration for one particular manufacturing industry: the auto supplier industry. This industry particularly lends itself to an analysis of its spatial pattern as it draws on a large number of various manufacturing industries. That might help to shed some light on the relative importance of various factors in driving the industry's spatial pattern.

In discussing the industry I distinguish two types of suppliers: parts plants operated by the auto assemblers themselves, the so-called captive plants, and independent parts producers that sell and supply to auto assemblers, either directly or indirectly. As the location decision of both types of supplier plants is related to the location of their primary customer, the auto assembly plant, it is worthwhile to introduce some background information on location and locational changes of auto assembly facilities as well.[1]

During the last 15 years or so light vehicle assembly facilities re-concentrated in the heart of the country to a noticeable extent. This change in location pattern can be explained by changes in transportation cost economics facing the industry. The costs of distributing the final product to the customer have always been important in deciding the location of assembly plants. Henry Ford opened far-flung branch assembly plants to produce identical Model T cars close to the population centers outside the Midwest. According to his rationale, it was cheaper to ship parts to branch assembly plants than to ship finished automobiles all across the country from a centrally located assembly plant. Soon, both General Motors and Chrysler emulated that strategy. For example, GM produced identical Chevrolets in ten different assembly plants across the country during the 1950s. However, by the 1960s the proliferation of car and truck models began to change the conditions that made that location strategy an optimal one. The number of different car and truck models sold in the U.S. increased five-fold, from 30 in 1955 to 142 in 1989, while sales only doubled from about 8 million units to about 16 million units in 1989. With reduced output per model, each model would now most efficiently be produced at a single plant, and, consequently, the argument for an interior location became compelling. By locating in the heart of the country, the assembly company could minimize the cost of distribution the final product to a national market. As a result, auto assemblers have closed their coastal plants and opened facilities in the interior of the country during the last 15 years. Consequently, the share of assembly plants located

1. Incidentally, Ellison and Glaeser (1997) find the largest coagglomeration for the following 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 vehicle, car bodies (SIC 3711). The following section draws heavily on Rubenstein (1997)

in the auto corridor increased substantially during that time period.[2] In 1979 the corridor was home to 47% of all U.S. light vehicle assembly plants, by 1996 that percentage had increased to 67.

This paper intends to characterize the state of agglomeration and possibly identify its underlying forces for the auto supplier industry. A large plant-level data set allows to study patterns of plant location in great detail. The supplier industry had experienced a period of spatial disaggregation, starting in the mid-60s, with the production of labor-intensive parts moving south. More recently, however, the requirements of lean manufacturing for tight linkages between assembler and supplier plants, combined with low levels of inventories, suggest a reinforcement of tight spatial linkages between suppliers and their customers.[3]

Census data

My first attempt to describe the extent of spatial concentration in the auto supplier industry utilizes publicly available census data. At the 4-digit level, SIC 3714, motor vehicle parts and accessories, defines the core of the auto supplier industry. It includes, among other parts, gasoline engines and engine parts for motor vehicles, engine filters, exhaust systems, drivetrain components, wheels; brake parts and assemblies, other new and rebuilt parts for motor vehicles not included elsewhere.

Table 1 shows an industry that extends geographically in a north-south pattern, reaching from Michigan all the way to Texas.[4] Remarkably, the census definition of that industry has remained almost identical over the last 50 plus years.[5] That allows a comparison of the geographical structure of SIC 3714 in 1937 to the one in 1992 (see table 1).While the industry has grown tremendously over that time period (from 936 to 3,246 establishments), it has also become

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2. The auto corridor extends south from Michigan and in addition includes Ohio, Indiana, Kentucky and Tennessee. See next section for more detail.

3. See Klier (1999) for evidence on the spatial extension of individual supplier networks and on the change of distances between assembler and supplier companies.

4. It has been suggested that the prominence of California is due to the inclusion in SIC 3714 of establishments that rebuild engines on a factory basis.

5. What is now referred to as SIC 3714, motor vehicle parts and accessories, in 1937 was named “motor-vehicle bodies and motor-vehicle parts”. While the current definition is more detailed, the extent of overlap is remarkable. According to the definitions listed in the respective Census publications, today’s definition does not include the production of car bodies nor automotive glass; conversely, the 1987 definition includes hoods, whereas the 1937 definition does not.

less spatially concentrated. Most noticeable, however, is the way the locational pattern of the industry changed from one described by an east-west extension, including New York and Pennsylvania in 1937, to a pattern of marked north-south extension, reaching from Michigan all the way to Texas. In other words, this long-term comparison indicates not only the continued existence of agglomeration at the industry level but also suggests a noticeable change in the geographical extension of the supplier region.

Industry data

For the remainder of the paper I refer to a privately assembled database. The basis for the 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.[6] The data represent the year 1997 and cover 3,425 independent supplier plants located in the U.S.[7] As the database identifies customers for the individual supplier plants, I was able to categorize these plants by supplier tier: 2,008 plants were found to be tier 1 suppliers, i.e. supplier plants that ship their products exclusively to auto assembly plants and not to other supplier plants or other customers; 1,292 were classified as mixed-tier supplier, i.e. shipping to other supplier plants and/or non-automotive assemblers as well as auto assembly plants; 50 observations had to be excluded from the analysis as they did not provide information on which customer(s) they were shipping to.[8]

Several variables were then added to the database: Information on the plant's start-up year was obtained for the tier 1 plants from various state manufacturing directories, as well as through phone calls to individual plants. For these records, information on foreign ownership was obtained from industry press as well from the Japan Auto Parts Industries Association.[9] Accounting for incomplete information on start-up year, I end up with 1,845 individual plant records representing

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6. It identifies for each of these the address, the list of products produced as well as the production processes used, employment, as well as the plants' customers (at the company level).

7. 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.

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

9. Japan Auto Parts Industries Association (1997).

independent tier 1 supplier plants operational in the year 1997.[10]

Evidence on agglomeration

Parts plants operated by the auto assemblers themselves, which generally produce items such as engines, transmissions, and large stampings, have remained heavily concentrated in the Midwest (see Rubenstein 1992). Table 2 illustrates the continued spatial concentration of that set of 152 supplier plants. It suggests a knowledge spillover explanation, as the parts produced in the "captive" parts plants tend to require highly skilled labor.

Table 3 presents the distribution of the 3,137 independent plants included in the database. It shows the auto supplier plants and employment to be highly spatially concentrated, with about 50% 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 19th 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 opened since 1980. That year represents the point in time when a new manufacturing system, so-called lean manufacturing, began to arrive and to be implemented in the U.S.[11] Among many other things, lean manufacturing can influence the location decision of the supplier plant as it puts a much greater weight on transportation costs. Consequently, one would expect suppliers to locate/relocate closer to their respective customers.[12] As assembly plants have reconcentrated in the auto corridor, this would result in a similarly defined auto supplier region. As data on the establishment year are available only for tier 1 supplier plants, I will focus on the subset of 820 tier supplier plants that opened since 1980 and were still in operation in 1997.[13] While a pure cross-section 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 the

10. About 8.1% 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 were therefore not included for the subsequent analysis.

11. 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.

12. See Klier (1999).

13. Tier 1 supplier plants arguably represent the subset of supplier plants that is most closely linked to the auto assembly plants by way of production and delivery.

current manufacturing environment in much more detail.

In distinguishing the older from the more recently opened supplier plants, one finds evidence of a change in the extension of the auto supplier region that are consistent with table 1. Specifically, figures 1 and 2 show the distribution of all tier 1 supplier plants that were operational in 1997 by their opening date. The first figure captures all the older plants, established prior to 1980. The second figure depicts the set of plants that opened since 1979. Both maps distinguish the location of a single supplier plant -- marked by a triangle -- from cases where more than one plant is located in the same zipcode -- marked by a circle. In comparing the geographic areas in which plant locations concentrate, we again find evidence for an industry that, with individual plants relatively dispersed across most of the eastern U.S., shows a marked east-west extension of a concentrated band of supplier plant locations that starts at the Chicago area and extends through Michigan all the way to Pennsylvania and New York state. Figure 1 sharply contrasts with the emergence of the auto corridor, shown in figure 2. A high percentage of supplier plants that opened during the last two decades located in a rather well defined narrow band of states that extends south from Michigan all the way to Tennessee

Figure 3 adds the grid of interstate highways to the pattern of plant openings. This exercise demonstrates the relevance of interstate access to the auto corridor.[14] Note, however, that interstate access plays an important role not only for north-south but also for east-west connectivity. 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. This illustrates the importance of highway access to assure timely delivery of shipments in an environment of Just-in-time production.

Figures 4 and 5 provides a closer look at the auto corridor locations. They reveal additional information in showing a different location pattern for domestic and foreign-owned supplier plants during that time period.[15] While similarly concentrated among three states, foreign-owned suppliers (figure 4) choose to locate in the southern part of the automotive corridor (i.e. Ohio, Kentucky, and Tennessee). Domestic suppliers (figure 5), on the other hand, locate in the

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14. See also Woodward (1992) who finds evidence on the importance of highway access at the county level in attracting plant openings.

15. About 63% of foreign-owned supplier plants are Japanese.

northern part, with Ohio being the only state chosen prominently by both domestic and transplant supplier plants. 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? Is it that foreign-owned suppliers respond differently to lean manufacturing conditions than domestic suppliers? Figure 4 and Table 4 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.[16] As a rule of thumb, between 1980 and 1993 supplier plants located close to where assembly plants of the same nationality were located.[17] This can be seen in Figure 3 which distinguishes domestic and foreign-owned assembly plants.

A more conclusive answer to this question could be obtained by focusing on relationships to primary customers only. However, the data do not allow identification of the distribution of output among customers. Instead, in table 4 I also provide information on the distribution of supplier plants that report a particular customer mix. I present 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 assembly plant customer is important for the location choice of the supplier plant, one would expect these two subgroups to be more concentrated in their respective half of the auto corridor. Table 4 reports evidence of such a "customer" effect, as each subgroup of supplier plants with a specific customer mix is more concentrated at one end of the auto corridor.[18] [19]

panel info

16. See Smith and Florida (1994) who find evidence for such an effect for their sample of Japanese owned supplier plants.

17. 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).

18. There were too few observations for the following two categories to be reported in that table: domestic suppliers not supplying to Big Three assembly plants (16 plants) , and Japanese-owned suppliers only supplying to Big Three facilities (9 plants). However, in both cases the evidence is consistent with table 4: plants are noticeably less concentrated in the top three states (31.2% for the domestic supplier plants and 33.3% for the Japanese-owned plants).

19. This simple comparison between the location choices of assembly and supplier plants, however, cannot address the issue of timing; i.e. did assembly or supplier plants locate first? The data at hand allow to shed some light on this question for the Japanese-owned supplier plants. Table 5 shows that 60% of these plants opened shop between 1987 and 1989, well after the first Japanese auto assembly plants had started operating. That pattern suggests that in the case of Japanese transplants the suppliers were the ones that followed the assemblers (see also Rubenstein 1992) . However, the initial location decision of Japanese assembly plants was undoubtedly influenced by proximity to the already existing, i.e. mostly domestic, supplier base. Reid et al. (1995) suggest that was one of the ways Japanese assemblers minimized risk and uncertainty of their direct foreign investment in the U.S.

The ELM data information is available to me for the years 1993 (1,971 observations on independent supplier plants) and 1997 (3,137 observations on independent supplier plants). I can therefore gain some information on recent changes in the industry location pattern by comparing the location of plants that exited the database since 1993 to plants the entered since 1993. Table 5 lists the percentages of entrants and exiters located in the Midwest and auto corridor, respectively. It shows evidence for a strengthening of the north-south extension of the industry in the 2nd half of the nineties. For the Midwest it lists exit rates higher than entrance rates; this is driven at the state level by Michigan, Illinois and Wisconsin, all of which have a greater percentage of exiter than entrant plants. The higher entrance rates for the auto corridor are attributable to higher entrance rates for Kentucky and Tennessee.

parts effects

This section discusses initial evidence on agglomeration at the level of individual parts. As the auto industry draws on a very rich mix of parts, this exercise might uncover evidence that helps sort out the various forces at work in shaping the spatial structure of the industry in general. Figures 6-8 and table 6 refer to information from all 3,137 observations from the 1997 plant-level database. I present information on two different levels. Figures 6 through 8 represent the spatial distribution of supplier plants for a particular part in relation to the light vehicle assembly plants operational during 1997. Table 6 reports on a measure of localization. For nine different parts I calculated the distance between each of the parts plants and every light vehicle assembly plant operational in the U.S. in 1997 (54 plants).[20] This algorithm generates a metric to measure the spatial distribution of supplier plants in relation to the distribution of assembly plants. The table reports two values of the distribution of distances generated by this exercise: the median of all the shortest distances between one supplier and the assembly plants, as well as the median of the average of the closest three distances.

This preliminary evidence demonstrates the effects of the following on location of supplier plants in relation to assembly plants. Lean manufacturing characteristics: As a result of lean manufacturing practices, transportation costs rate higher as a decision factor in plant location

20. These distances are calculated at the zipcode level of resolution and they refer to straight distances, unadjusted for transportation infrastructure, between two x,y coordinates.

decisions of suppliers. However, this effect is not expected to be constant across parts. For example, parts that are bulky or have a low price relative to unit shipping costs are now more uneconomical to ship over long distances. The evidence on seats strongly supports that assertion. Figure 7 shows how the 73 seat plants are located almost exclusively in the auto corridor, in very close distance to the assembly plants. Table 6 lists by far the shortest distances between seat plants and assembly plants, according to both localization measures. The next two parts in that table, transmissions and axles, further support the importance of transportation costs for the production of bulky parts. Similarly, parts that need to be produced in a large variety, in synchronicity with the production schedule of the assembly plant customer, are best produced locally in order to avoid costly supply interruptions. Car seats are representative of that category as well. In fact, in the auto industry press it has been widely reported that car seats are now commonly shipped every hour from the supplier plant to the assembly plant, sequenced to match exactly the product requirements of the assembly line for the vehicle.

Economies of scale are also expected to influence the plant location decision. The larger the level of scale economies is for a given plant, the more likely it will serve its customers from a single location that need not be particularly close to any of them. The part that illustrates that factor are tires. Figure 8 shows tire plants to be fairly concentrated in the center of the country, however, they tend not to be located particularly close to their customers. I submit that the large economies of scale in the production of tires explain that location pattern. The average employment at the 24 tire plants shown in figure 8 is 1,560. Compared with an average plant size of 287 employees for the entire database.

Finally, I would argue the location pattern of sensor plants shows the influence of spillover effects within an industry. Sensors are representative of the growing electronic content in today's vehicles. The parts list from the ELM database identified 21 different sensors, ranging from airbag to temperature sensors. As figure 6 shows quite clearly, one can see the 55 sensor plants to be located not just in the auto corridor, but also on both coasts, around the silicon valley area in California and close to the Boston area in the East.

3. Conclusion

In investigating the geographic characteristics of the automobile supplier industry, this paper finds strong evidence for continued spatial concentration within the industry. In addition, by way of a long-term comparison, the region that best describes the industry today, the auto corridor, extending south from Michigan to Kentucky and Tennessee, is noticeably different from the way the industry was distributed several decades ago. Within the auto corridor, foreign-owned (domestic) supplier plants locate close to foreign assembly (domestic) plants, demonstrating a customer effect of the location choice of the supplier plant.

Analysis of the data at the more disaggregate level of specific parts helps uncover some of the underlying factors responsible for the observed location choices. Lean manufacturing and its emphasis on transportation costs favors a close location for bulky parts with low values relative to shipping costs. Economies of scale at the supplier plant, on the other hand, favor a more central location. Finally, the location of parts producing electronic sensors for the automobile suggests spillover effects within the electronics industry, as these plants are noticeably more dispersed.

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Table 1: Distribution of establishments in SIC 3714

1937 Census [936]		1992 Census [3246]	
state	*% of establishments*	*state*	*% of establishments*
MI	16.0	CA	13.9
CA	11.9	MI	13.4
NY	11.2	OH	7.6
IL	8.9	IN	6.7
OH	8.7	TX	5.3
PA	6.4	IL	4.1
IN	6.0	TN	3.4
	69.1		54.4

Source: U.S. Department of Commerce (1937a and b) and (1992)

Table 2: Distribution of captive parts plants

Assembly company	share of its captive suppliers in MI, IN, and OH	
	% plants	% employees
GM	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.

Table 3: Distribution of auto supplier industry, 1997

State	% of independent supplier plants	% of 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	50.2
U.S.	100	100

Note: calculations are based on 3,137 independent supplier plants open in 1997; numbers do not include Big Three supplier plants. Industry employment: 901,343 jobs.

Source: see table 2.

Table 4: Supplier plants that opened between 1980 and 1997 -- distribution among auto corridor states

	Domestic			*Japanese-owned*	
	overall	*supplying only to Big 3*		*overall*	*not supplying to Big 3*
	[607]	*[166]*		*[173]*	*[70]*
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 3	*52.6*	*61.6*		*52.6*	*64.3*

Source: see table 2.

Table 5: Comparing 1993 and 1997: regional entry and exit of supplier plants

	Entrants	Exiters
% in Midwest	52.1	66.2
% in auto corridor	66.7	61.5
All observations	218	123

Source: see table 2.

Table 6: Localization of supplier plants by selected parts

part	median distance to closest assembler		median distance to closest 3 assemblers	
seats	23.4	miles	58.3	miles
transmissions	37.0		64.0	
axles	40.0		63.3	
air cond.	50.5		82.5	
wheels	52.3		102.0	
carpets	57.7		88.9	
valves	58.8		87.6	
sensors	60.5		112.5	
tires	81.7		133.2	

Source: see table 2.