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Plant Productivity, *Keiretsu*, and Agglomeration in the Japanese Automobile Industry: An Empirical Analysis Based on Micro-Data of *Census of Manufactures* 1981-1996

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Plant Productivity, *Keiretsu*, and Agglomeration in the Japanese Automobile Industry: An Empirical Analysis Based on Micro-Data of *Census of Manufactures* 1981-1996*

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Abstract

Using plant-level data underlying the *Census of Manufactures,* total factor productivity (TFP) growth and its determinants are analyzed for the Japanese automobile industry since 1980s. The average annual TFP growth rate from 1981 to 1996 was only about 0.6 percent for the automobile assembly industry and about 1.3 percent for the auto parts manufacturing industry. In the Japanese auto parts manufacturing industry, we found that R&D spillovers from assemblers had a significantly positive effect on the parts suppliers' TFP growth and that parts suppliers located near an assembly plant achieved higher TFP growth.

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Keywords: Automobile Industry, Total Factor Productivity, Keiretsu, Agglomeration, R&D Spillover

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1. Introduction

Little more than a decade ago, Japanese automakers were on top of the world: In the 1970s, they had successfully pioneered the “lean production system” and were expanding their exports rapidly. During the 1980s, their competitiveness was rivalled by no-one, and they were aggressively promoting overseas production.[1,2] However, since the beginning of the last decade, they had to contend with falling production levels and profit rates. As shown in Figure 1, the unit of four-wheel vehicles produced domestically has decreased steadily over recent years, reflecting the prolonged recession at home as well as the shift toward overseas production. As further indications of the malaise, the capital utilization index has also been declining, while the profit rate of the Japanese automobile industry has deteriorated, particularly during the early 1990s (Figure 2). These developments raise the important question whether the recent stagnation in the Japanese automobile industry represents simply a temporary phenomenon caused by the collapse of the Bubble economy and the decrease in domestic capital utilization or whether it is a more structural phenomenon indicating a decline in productivity growth.

In this paper, taking the above issues into account, we analyze the productivity change and its

[1] The “Lean Production System” of the Japanese automakers is analyzed in detail in Womack et al. (1990). Fuss and Waverman (1992) estimate and compare the productivity of the automobile industry in Japan, the United States, Canada, and Germany. According to their estimate, the annual growth rate of Total Factor Productivity (TFP) in the Japanese automobile industry in the 1970s was about 3.9 percent, which was approximately three times the rate of other countries. Approaching the topic from a management perspective, Itami (1994) also provides a detailed analysis of the performance of the Japanese automobile industry up to the early 1990s.

[2] For foreign direct investment and economic performances of foreign affiliates of the Japanese automobile firms, see Okamoto (1999), Cusumano and Takeishi (1991), etc.. Moreover, Okamoto (2001), which is based on our joint project at RIETI, also undertakes empirical analyses from this viewpoint.

determinants in the Japanese automobile industry from 1981 to 1996 based on the plant-level data provided in the Industrial Statistics Survey conducted by the Ministry of Economy Trade and Industry (METI; formerly the Ministry of International Trade and Industry, MITI). Hotly debated issues regarding the Japanese automobile industry have been the efficient production system and *keiretsu* transaction relationships. However, the arguments in most earlier studies have been based on descriptive analyses or case studies. The main contribution of this paper is to conduct a quantitative analysis of the effects that technology spillover through *keiretsu* transactions and agglomeration has on productivity growth, using plant-level Total Factor Productivity (TFP). In order to do so, we focus on the following three aspects.

Firstly, one of the most interesting phenomena regarding recent developments in the Japanese automobile industry is the fact that some automakers experienced a significant deterioration in their market share and profits, while others achieved remarkable growth and kept or expanded their market shares. In other words, a polarization into a lagging and a leading group can be observed. For example, Nissan has seen its market share and production shrink and was forced to close factories; a substantial share of Mazda's stocks was acquired by the Ford Motor Company; Honda has expanded its market share at the expense of Nissan and Mazda; Toyota remained one of the top players worldwide. This paper divides the automakers into two groups – the "better-performing" and the "worse-performing" and investigates whether substantial differences in their productivity levels, price-cost margins, average inventory ratios, etc. can be found. It should be noted that because we base our analysis on the Industrial Statistics Survey data, we are able to concentrate only on plant-level productivity analyses, though the performance of automakers depends not only on efficiencies in production and procurement but also on product planning and sales promotions.

[INSERT Figures1 and 2]

Secondly, it has often been pointed out that in the Japanese machinery industries, including the automobile industry, an assembler and its parts suppliers maintain close relationships involving recurrent transactions, and that the assembler and the suppliers jointly develop new products and accumulate transaction-specific skills or facilities (Asanuma 1989). Particularly in the automobile industry, it is considered that there exits a strong correlation between the productivity of the automaker and that of the parts suppliers for the following reasons: 1) suppliers are often located near the assembly factory due to the high transportation costs of large auto parts; and 2) the outsourcing ratio of Japanese automakers is as high as 70 percent.[3] Therefore, we compare the productivity growth and other performance indices of primary suppliers in the better-performing *keiretsu* groups with those in the worse-performing *keiretsu* groups. Furthermore, we compare the performances of primary suppliers belonging to any *keiretsu* with those of independent primary suppliers, since some previous studies such as Nobeoka (1998) emphasize that independent suppliers who have transaction relationships with many automakers are advantageous to *keiretsu* suppliers in economies of customer scope.

Thirdly, we conduct a regression analysis on the determinants of primary suppliers' productivity growth. We investigate: 1) whether the accumulation of technological knowledge by an automaker has spillover effects on its primary suppliers' productivity growth, and 2) whether the geographical distance between the assembly plant and the primary supplier's plant is relevant to the supplier's productivity growth.

The remainder of the paper is organized as follows. In the next section, we explain our data as well as our method of TFP calculation and discuss the trend over time of TFP in the Japanese automobile manufacturing, auto body manufacturing, and auto parts manufacturing industries. In Section 3, we analyze the productivity gap between the better-performing automakers and the worse-performing automakers. In addition, we compare the performances of the three groups of primary suppliers: Suppliers belonging to the better-performing *keiretsu* groups, suppliers belonging to the worse-performing *keiretsu* groups, and independent suppliers. In Section 4, we carry out an

[3] The definition of outsourcing ratio in *Yuka Shoken Hokokusho Soran (Directory of Financial Report of Listed Companies)* is the ratio of the value of parts and processing services purchased from outside firms to an automaker's total manufacturing cost of producing one vehicle unit.

econometric investigation of the determinants of the TFP growth rate for primary suppliers, focusing on technology spillovers and agglomeration effects. Section 5, finally, offers our conclusion. The Appendix presents the methodology of our calculations of various productivity indices, a description of the variables used in the econometric analysis, and the capital utilization adjustment for each plant.

2. Productivity in the Japanese Automobile Industry: 1981-1996

As suggested in the previous section, the Japanese automobile industry has generally stagnated for most of the past two decades in terms of its production and profitability, particularly in the 1990s. In order to judge whether the recent stagnation is a temporary phenomenon caused by the collapse of the Bubble Economy or whether it is more a structural phenomenon such as a decline in productivity growth, we investigate the capacity-utilization-adjusted TFP and other productivity indices such as the value-added per worker, the average inventory ratio, and the capital utilization ratio.

2.1 Properties of Our Data

We compiled a plant-level panel data set using the micro-data of the Industrial Statistics Survey conducted by METI from 1981 to 1996.[4] The original data cover almost all establishments with thirty or more employees; they are grouped in the following three industrial classifications: Motor vehicles, including motorcycles (industry code: 3111), motor vehicle bodies and trailers (3112), and motor vehicle parts and accessories (3113).[5]

[4] In the Industrial Statistics Survey, the establishment code is re-numbered once every few years, and therefore we need the code number converter in order to compile a panel data set for a long period. However, as the converter was not available for 1980 and before, we limited our analyses to the period from 1981 to 1996.

[5] In the compilation of the panel data for our analysis, we excluded the data for establishments which

Compared aggregate data such as those of the *Census of Manufactures*, micro-data has the following advantages for analyzing productivity growth: 1) It can correct the problem arising from aggregate data that the covered establishments are not identical throughout the period due to the variation of the response ratio or industry classification; 2) it allows an analysis of how the change in output share or productivity of each establishment affects the productivity change in the whole industry; 3) it also permits a detailed analysis of the effects of factors such as *keiretsu* relationships or the research and development (R&D) activities of each enterprise or establishment. On the other hand, there are some drawbacks. For example: 1) panel data cannot include some samples of which data are not available continuously due to non-response or a change in industry classification, 2) output or intermediate input price-deflators and other data are not available at the establishment-level and, therefore, we need some strong assumptions that the same price or other economic indices are applicable to all the establishments. The coverage of the panel data used in this study is summarized in Appendix Table 1. In the automobile manufacturing industry, the coverage is nearly 100 percent, while in the auto parts manufacturing industry it is rather low at about 70 percent. The low coverage in the auto parts manufacturing industry might be explained by the following reasons: 1) most of establishments in this industry are relatively small and the response ratio tends to be low for small scale establishments; 2) since the scale of small establishments often varies around the cut-off point of 30 employees, they may be included in one year but not in the next; 3) establishments often change

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changed their main product line and their industrial classification during the period from 1981 to 1996. Moreover, we dropped data for those establishments for which at least one data item was missing or data were not available continuously. In addition, we should note that some of the parts suppliers that produce electrical auto parts are classified in the electrical parts and accessories industry rather than the motor vehicle parts industry and are not covered by this study. As a result, the data used in this paper only include those establishments which have been operating continuously over the period from 1981 to 1996, or which were either established or closed during the period but for which data were otherwise available throughout. For the new establishments, we dropped the data of the initial year in order to enhance the data credibility.

their industrial classification, as a result of a change in product composition and their line of business.

2.2 Measurement of the Plant TFP and the Industry TFP Levels

Using the establishment-level data of the Industrial Statistics Survey conducted by METI, we constructed an annual index of plant-level TFP for each plant from 1981 to 1996. A multilateral index which was developed by Caves et al. (1982) is useful for measuring the inputs, outputs, and TFP in plant-level data. The multilateral index relies on a single reference point that is constructed as a hypothetical plant with input revenue shares that equal the arithmetic mean revenue over all observations and input levels that equal the arithmetic mean of the log of the inputs over all observations. Each plant's TFP in each year is measured relative to this hypothetical plant and the multilateral index provides transitive comparisons between any subset of the observations. Good et al. (1997) extended this approach and modified it to make it applicable to panel data. They constructed a hypothetical plant for each cross-section and then the hypothetical plants together over time. This productivity index is particularly useful because it provides a consistent way of summarizing the cross-sectional distribution of plant TFP and how the distribution moves over time. Aw et al. (1997) also used this index to measure firm-level productivity for the Taiwanese manufacturing industry. The TFP measure relative to the hypothetical plant in the base time period can be constructed as in Equation (1):

$$\begin{aligned}\ln TFP_{ft} &= \left(\ln Y_{ft} - \overline{\ln Y_t}\right) + \sum_{s=2}^{t}\left(\overline{\ln Y_s} - \overline{\ln Y_{s-1}}\right) \\ &- \left[\sum_{i=1}^{n}\frac{1}{2}\left(S_{ift} + \overline{S_{it}}\right)\left(\ln X_{ift} - \overline{\ln X_{it}}\right) + \sum_{s=2}^{t}\sum_{i=1}^{n}\frac{1}{2}\left(\overline{S_{is}} + \overline{S_{is-1}}\right)\left(\overline{\ln X_{is}} - \overline{\ln X_{is-1}}\right)\right] \qquad (1)\end{aligned}$$

where plant *f*'s output in year *t* is Y_{ft}, and a vector of *i-th* factor input is X_{ift} (i=1,2,…,n). The input weights S_{ift} are the share of plant *f*'s expenditure share of *i*-th factor input. The overbars denote the average value over all plants in year *t*.[6]

[6] As shown in Figure 2 in the previous section, the capacity utilization ratio tends to decline throughout the

The industry TFP level is defined as a weighted average of each plant's TFP level and is calculated using Equation (2):

$$\ln TFP_t = \sum_f \theta_{ft} \ln TFP_{ft} \qquad (2)$$

where θ_{ft} denotes the output share of plant *f* in year *t*.

The estimated TFP level by industry is as shown in Figure 3. The trend of the TFP level presents a movement that more or less parallels the business cycles.[7] TFP is low around 1986, a year when the industry was experiencing a recession due to yen appreciation, but improves afterwards. TFP hits its peak around the year 1990, then declines, but again picks up after 1994. In the automobile manufacturing industry, the TFP level in 1996 is about 0.1, which means that the TFP increased only about 10 percent during the 16-year-period studied. Even in the auto parts manufacturing industry which shows the highest TFP growth, the average annual TFP growth rate is only approximately 1.3 percent. Taking into account that in previous studies estimates for the average annual TFP growth rate

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period. When we calculate TFP without any adjustment for capacity utilization adjustment, the TFP is underestimated in the period with low capacity utilization, while it is overestimated in the period with high capacity utilization. Therefore, we first estimate the level of capacity utilization of capital and facilities for each plant, then we calculate the capacity-utilization-adjusted TFP. The methodologies to estimate capital stock and capital cost for each establishment are described in Appendix 1. For the capital utilization adjustment, see Appendix 2.

[7] Basu (1996) as well as Burnside et al. (1995) demonstrate that the positive correlation between productivity and business cycles becomes insignificant after the variation of capacity utilization is adjusted for. In Figure 3, some positive correlation between the two still remains. This might be because we could adjust the capacity utilization for facilities but not for labor. As data on working hours for each plant are not available, the working hours are assumed to be same for all the plants in this study. In future studies, we would like to consider capacity utilization adjustment for labor in some way.

before the 1980s ranged from 3.9 to 4.7 percent, our estimate of a 1.3 percent growth rate for the period after 1981 is remarkably low.[8]

[INSERT Figure 3]

3. Plant-Level Productivity of the Automakers and Primary Auto Parts Suppliers

3.1 The Productivity Gap between Better-Performing Automakers and Worse-Performing Automakers

Our estimates show that in the automobile manufacturing industry the average annual TFP growth rate was only about 0.6 percent from 1981 to 1996. In the following sections, we will examine economic performance of each plant owned by the automakers and primary auto parts suppliers during this period of minimal growth. In order to investigate the determinants of productivity growth, we first analyze the productivity gap between the better-performing automakers and the worse-performing automakers.

We will label as "Group A" three Japanese automakers which increased their industry shares in terms of the total units produced and the sales amount during the period from 1981 to 1996. Then, we compare the performance of the assembly plants owned by "Group A" automakers with that of the other automakers' plants ("Others"). We calculate the average value of various productivity indices for each group, and conduct t-tests in order to investigate whether or not there is a significant difference in productivity between the two groups. Table 1 presents the results. The Table shows that most of the productivity indices for Group A are substantially superior to those for "Others" in every

[8] Fuss and Waverman (1992) estimate that the average annual TFP growth rate in the Japanese automobile industry in the 1970s was about 3.9 percent. In contrast, Yoshioka (1989) estimated that the average annual TFP growth rate in the Japanese transport equipment industry from 1964 to 1982 was about 4.7 percent.

period. For most of the productivity indices, the difference in the average values between the two groups is statistically significant. However, the difference in average monthly wages between the two groups is not significant in the periods from 1981 to 1986 and from 1986 to 1991, while the difference is significant in the period from 1991 to 1996. This may imply that the group of other companies lowered wages as part of restructuring efforts during the 1990s. Moreover, the gap in the average price-cost margin between the two groups is getting larger over time. As for the TFP, Group A shows a significantly higher TFP level than Others in every period. Therefore, from Table 1, we clearly find that the better-performing automakers (Group A) were significantly more productive than the other automakers (Others) during the period from1981 to 1996.

[INSERT Table 1]

3.2 Transaction Relationships between Automobile Manufacturers and Auto Parts Suppliers

In the previous sub-section, we found that the assembly plants of better-performing automakers (Group A) showed a significantly higher productivity than those of the other automakers. This should be a result of the productivity improvements by automakers themselves. However, we consider that the productivity of automakers to a considerable extent also depends on the productivity of the auto parts suppliers particularly in the Japanese automobile industry, where at about 70 percent the outsourcing ratio is fairly high. Therefore, we now focus on the performances of the auto parts suppliers. In fact, a persistent argument in many previous studies has been that the high performance of the parts suppliers and the efficient organization of the supplier system have been a crucial source of competitiveness in the Japanese automobile industry.[9] Highlighted in particular as important characteristics of the Japanese supplier system have been relationships based on long-term recurrent transactions as well as the high technical capabilities of parts suppliers (Asanuma 1984; Cusumano

[9] There are many previous studies on the Japanese automobile supplier system. For example, see Fujimoto (1995).

and Takeishi 1991). A noted difference with auto parts suppliers in the United States or in Europe in the 1980s was that most of the primary auto parts suppliers in Japan had their own product development capabilities (Clark and Fujimoto 1991). A distinguishing feature of the longstanding transaction relations as pointed out by Asanuma (1989), therefore has been that the Japanese automakers and auto parts suppliers engage in joint product development efforts and benefit from accumulated "relation-specific skills."[10] The Japanese automakers provide careful guidance and technical assistance to auto parts suppliers both at the stages of product development and production. Moreover, the Japanese automakers and their suppliers engage in frequent face-to-face contacts and information sharing. According to case studies carried out in Japan and the United States, in Japan auto parts suppliers tend to be located nearer to their automaker's assembly plant and spend more hours in face-to-face contacts with their customers (Dyer 1996).[11] It has been reported that these features are most distinct in the Toyota Group and that Toyota has a superior ability to effectively create and manage knowledge-sharing network (Dyer and Nobeoka 2000).

On the other hand, Nobeoka (1998) shows that independent suppliers, who have transaction relations with several automakers and do not concentrate on transactions with one particular automaker, tend to have a higher profitability. According to Nobeoka, the wider range of customers means that by constructing cooperative relationships with more automakers, the suppliers can benefit

[10] According to Asanuma (1989), some surplus value-added is generated by the "relation-specific skills", and this surplus value-added corresponds to the relational quasi-rent introduced by Aoki (1988).

[11] Dyer (1996), based on the results of his survey on the U.S. "Big Three" as well as Toyota and Nissan, found that the difference in the assembler-supplier relationships between Japan and the United States is statistically significant. Toyota's supplier plants are located at an average distance of 59.2 miles from Toyota's assembly plants, while Nissan's suppliers were an average distance of 113.9 miles away. In contrast, "Big Three" supplier plants were on average roughly 500 miles from the automakers' plants. Moreover, Toyota's suppliers had an average number of 6.8 guest engineers compared with 1.8 for Nissan and less than one for each of the U.S. "Big Three."

from greater learning opportunities. That is, suppliers, who have their own product development capabilities and organizational management skills and who are able to propose an effective use of common parts to several different automakers, enjoy a greater competitiveness.[12]

The findings of the previous studies mentioned suggest that there is a strong correlation between the productivity of automakers and that of auto parts suppliers. Therefore, in the succeeding sub-section, we compare productivity levels between *keiretsu* suppliers of Group A (the three better-performing automakers) and the *keiretsu* suppliers of other automakers. In addition, we compare productivity levels between suppliers belonging to any *keiretsu* and independent suppliers.[13]

3.3 Comparison between *Keiretsu* Suppliers and Independent Suppliers

Based on the information provided in Auto Trade Journal (1997), we classify suppliers into *keiretsu* suppliers of Group A, *keiretsu* suppliers of other automakers, and independent suppliers.[14] In the same way as in Section 3.1, we conduct statistical examinations on the average productivity of the

[12] When a supplier participates in the product development process for several automakers, knowledge diffusion among automakers should be promoted. At the same time, however, it is accompanied by some risks such as free-riding. For rules or incentive problems to overcome such risks, more research into both the theoretical and the empirical aspects would be desirable.

[13] The comparison of the productivity of auto parts suppliers is limited to primary parts suppliers because of the availability of firm information.

[14] We identified the *keiretsu* relationships using the information on capital and transaction relationships recorded in Auto Trade Journal (1997). Our definition of *keiretsu* suppliers is that 1) 20 percent or more paid-in capital are owned by an automaker, or 2) an automaker’s capital participation rate is less than 20 percent, but more than 30 percent of the output of the supplier is sold to the automaker. Our definition of independent suppliers is that an automaker’s capital participation rate is less than 20 percent, and the output of the supplier is sold to several automakers.

auto parts suppliers. Table 2 shows the comparison of productivity measures between Group A *keiretsu* suppliers and other *keiretsu* suppliers, while Table 3 shows the comparison between *keiretsu* suppliers and independent suppliers. Although we found strongly significant productivity differentials between Group A automakers and other automakers in the analysis in Table 1, we cannot find such significant differences in the performance between Group A *keiretsu* suppliers and other *keiretsu* suppliers. However, we should note that Group A *keiretsu* suppliers show a significantly higher TFP growth rate from 1981 to 1996.

However, as Table 3 indicates, independent suppliers generally show a higher performance than *keiretsu* suppliers, and particularly in 1991, the difference in performance is statistically significant. This seems to support Nobeoka's findings that independent suppliers are more profitable (Nobeoka 1998).

Each auto parts supplier, however, makes various kinds of products and the strength of the relationships with an automaker varies among suppliers. This means that we should not rely only on a statistical test on the mean. In the next section, we conduct a regression analysis on the determinants of auto parts suppliers' TFP growth.

[INSERT Tables 2 and 3]

4. Econometric Analysis on Determinants of Auto Parts Suppliers' TFP Growth

4.1 The Model

As mentioned above, Asanuma (1989), Aoki (1988), and others argue that there exist long-term recurrent transaction relationships between an automaker and its *keiretsu* suppliers, and that primary *keiretsu* suppliers possess accumulated "relation-specific skills" as a result of joining the automaker's product development from an early stage. Following from this argument, we posit the hypothesis that suppliers which are located near the automaker and utilize technological knowledge jointly with the automaker will achieve higher productivity growth (Hypothesis I).

Nobeoka (1996, 1998), in contrast, insists that an automaker and its *keiretsu* suppliers should create an open transaction network and utilize economies of customer scope. According to his argument, profitable automakers tend to purchase one kind of part from more than one supplier and do not concentrate on transactions with a specific supplier. Nobeoka's empirical analysis also shows that more profitable auto parts suppliers enjoy economies of scope by expanding their transaction relationships to several automakers. Therefore, it is hypothesized that suppliers who have a larger number of transaction relationships and do not concentrate on a relationship with a specific automaker will achieve higher productivity growth (Hypothesis II).

In order to test the two hypotheses above, we estimate the following regression model which explains the determinants of auto parts suppliers' TFP growth.

$$\ln TFP_f - \ln TFP_{f,-1} = \alpha + \beta \ln TFP_{f,-1} + \gamma \ln Y_{f,-1} + \phi D_f + \delta W_f + \varepsilon_f \qquad (3)$$

The left-hand side of Equation (4) represents the TFP growth rate of plant *f*. On the right-hand side, α is the constant term and $\ln TFP_{f,-1}$ is the logarithm of the initial TFP level of plant *f*. As Dowrick and Nguyen (1989) discuss, a plant with a low initial TFP level may achieve higher TFP growth because of the catch-up effect. Taking this effect into account, we add the initial TFP level as an explanatory variable.[15]

[15] When a temporary shock affects TFP, the coefficient of the initial TFP level may possibly take a negative value even though there are no catch-up effects. This is known as "Galton's fallacy". For a discussion of economic convergence and "Galton's fallacy", see, for example, Friedman (1992) and Quah (1993).

The third term of the right hand side $(\ln Y_{f,-1})$ is the logarithm of the initial output of plant *f* and this controls the scale effect. D_f is a dummy variable for plant *f*'s products. W_f is a vector of plant *f*'s various characteristics, and ε_f is the error term. We take each plant's TFP growth rate from 1981 to 1996 as the dependent variable and the year 1981 is the initial year of our analysis. Samples used in our regression analysis are plants of primary auto parts suppliers for which firm information and data on the sales ratio to each automaker are available in Auto Trade Journal (1997).

In order to examine the above two hypotheses, we consider the following factors as the determinants of auto parts suppliers' TFP growth:

(i) *Keiretsu*: A *keiretsu* supplier of a specific automaker, or an independent supplier and the strength of the keiretsu relationships. We use dummy variables to control for the *keiretsu* factor.

(ii) Range of Customers: Economies of scope generated by expanding the range of customers and by not being concentrated on a specific transaction with a specific automaker. As a variable representing the customer concentration ratio, we use a Herfindahl index which is constructed from the sales ratio to each automaker. In addition, as a variable representing diversified business, we use a non-automobile customer ratio (1- sum of shares of sales to automakers). According to Hypothesis II, we would expect a negative coefficient for the former variable and a positive coefficient for the latter.

(iii) R&D Spillovers from Automakers: R&D spillover effects generated through the transaction relationship with an automaker. We use the R&D intensity of automakers and we expect a positive coefficient.

(iv) Agglomeration Effect: Positive effects generated by being located near the R&D center or the assembly plant of an automaker. When the suppliers are located near the automaker, it should be easier to promote face-to-face contacts or information exchange among engineers and to efficiently carry out the Just-In-Time production system. We use the distance between the supplier's plant and the R&D center or the assembly plant of the automaker. We would expect a negative coefficient.

We estimate the following six regression models in order to identify the determinants of suppliers' TFP growth.[16]

Model 1: Comparison between *Keiretsu* Suppliers and Independent Suppliers

In order to test whether there is a significant difference in TFP growth rates between *keiretsu* suppliers and independent suppliers, we include a dummy variable which takes the value one for independent suppliers.

Model 2: Range of Customers and R&D Spillover Effect from Automakers

According to Hypothesis I, auto parts suppliers will receive positive R&D spillovers from the automakers with whom they have transaction relationships, and therefore the supplier's TFP will be increased by the R&D spillover effect. In contrast, according to Hypothesis II, TFP of the suppliers who have a wide range of customers will increase faster as a result of the scope economies effect. Therefore, we introduce two variables which represent the automaker's R&D intensity and the range of customers, respectively. As Griliches (1995) argues, R&D spillovers are ideas borrowed by research teams of industry (or firm) i from the research results of industry (or firm) j.[17] It is considered that the extent of borrowed knowledge from other

[16] For detailed definitions and sources of the variables, see Appendix 1.

[17] Total factor productivity in industry i is affected by productivity improvements in industry j to the extent of its purchases from that industry and to the extent that the improvements in j have not been appropriated by its producers and/or have not been incorporated in the official price indices of that industry by the relevant statistical agencies. This kind of effect, however, is not real knowledge spillover but just a consequence of conventional measurement problem.

industries or firms depends on the technological "distance." Although the relevant concept of "distance" is very hard to define empirically, we use the purchase share or sales share as a proxy for the technological distance. Therefore, in our calculation, automaker's R&D intensity for a supplier is a weighted average of the R&D intensity of all the automakers with whom the supplier has a transaction relationship.

Models 3, 4: Distance between automakers and suppliers

According to Hypothesis I, when automakers and suppliers are located close to each other, their face-to-face contacts will become much easier, generating larger R&D spillover effects. Therefore, we include the following two explanatory variables in the model.

(i) The automaker's R&D intensity divided by the distance between the R&D center of the automaker and the supplier's plant.

(ii) The average distance between the automaker's assembly plant and the supplier's plant.

Models 5, 6: Automaker-Specific Effects

Although there should be many factors specific to an automaker, we only control the R&D intensity in Models 2, 3, and 4. As a result, the estimated coefficients of other explanatory variables may contain some biases. For example, in some *keiretsu*, when the assembly plant of the automaker and its *keiretsu* suppliers are located closely together and when overall performances are not good for some reasons other than R&D, the coefficient of the distance variable will be biased in a positive direction. In order to solve this kind of problem, in Models 5 and 6, we control the automaker-specific effects using *keiretsu* dummy variables.

4.2 Estimation Results

Table 4 reports the results of the estimates of Models 1 to 6. Both the coefficients on initial TFP level (*lnTFP(-1)*) and on initial output (*lnY(-1)*) were found to be negative and significant. That is, the lower the initial TFP level and the smaller the initial output of a plant, the higher is the rate of TFP growth achieved. In addition, the estimated coefficient on the independent supplier dummy is not significant in Model 1, suggesting that there is no significant difference in TFP growth between *keiretsu* suppliers and independent suppliers. This suggests that we should take account not only of the existence of *keiretsu* relationships but also of the strength of such relationships, which differs for the various *keiretsu* groups.

Irrespective of the specification, the R&D intensity of automakers (*RDINT1*, *RDINT2*) has a significantly positive coefficient, suggesting the existence of R&D spillover effects from the automakers. We should note that many primary auto parts suppliers also conduct R&D activities by themselves and that we should include parts suppliers' own R&D intensity in the regression models. For most auto parts suppliers, however, R&D data are not available and we gave up on including suppliers' R&D intensity in our regression. As for the R&D intensity divided by the distance between automakers' R&D center and the supplier's plant (*RDINT1/DISTRD*, *RDINT2/DISTRD*), the coefficient has a positive sign but was not statistically significant.

Turning to the distance between assembly plant and supplier plant (*lnDIST*), the estimated coefficient is not significant in Models 3 and 4. However, when we control for the automaker-specific factors by including *keiretsu* dummy variables, the coefficient of the distance is negative and significant as reported in Models 5 and 6. Thus, if a supplier's plant is located far from the assembly plant, its TFP growth rate tends to be low, which suggests there is a positive effect from the agglomeration of suppliers near the assembly plant.

The non-automobile customer ratio (*NONAUTO*), which represents a diversified business or a wide range of customers, has a significantly positive coefficient, irrespective of specification. The more diversified the supplier is and the more its products are sold to non-automobile customers, the higher the TFP growth that was achieved. The estimated coefficient on the customer concentration ratio (*HI*), however, has a negative sign but was not significant in any of the models.

[INSERT TABLE 4]

Thus, our estimation results support Hypothesis I, suggesting that the parts suppliers who are located near the assembly plant and keep a close relationships with the automaker realize higher TFP growth through the joint-use of technological knowledge with the automaker. On the other hand, we did not obtain clear evidence which supports Hypothesis II. Both the independent suppliers dummy (*DINDEP*) and the customer concentration ratio do not have significant coefficients. However, we obtain a significantly positive coefficient for the non-automobile customer ratio. This suggests that suppliers who sell a larger share of their products to non-automobile customers show a higher TFP growth rate.

Now let us examine the reason for performance differentials among *keiretsu*. Figure 4 shows the relationship between an automaker's R&D intensity and the average distance between the automaker and its *keiretsu* primary suppliers.[18] In Figure 4, we find that the three better-performing automakers (Group A) tend to display a higher R&D intensity, while the three worse-performing automakers (Group B) tend to have a relatively lower R&D intensity. As for the distance between an automaker's R&D center and its *keiretsu* suppliers, we cannot see any clear tendency for the above two groups (Panel (a) of Figure 5). However, as for the distance between an automaker's assembly plant and its keiretsu suppliers, we can see that the distance tends to be shorter in Group A and to be longer in Group B (Panel (b) of Figure 4). Our results in Table 4 and the relationship in Panel (b) of Figure 4

[18] Average distance between an automaker and its *keiretsu* primary suppliers is calculated as follows. The automaker *i*'s purchase from plants *j* of keiretsu suppliers is $z_{i1}, z_{i2}, \ldots, z_{ij}$. The distance between automaker *i*'s R&D center or assembly plant and plants *j* of *keiretsu* suppliers is $d_{i1}, d_{i2}, \ldots, d_{ij}$. Then, the average distance between automaker *i* and its *keiretsu* suppliers is calculated using the following equation:

$$\text{Average Distance} = \sum_{n=1}^{j} z_{in} d_{in} \Big/ \sum_{n=1}^{j} z_{in}$$

imply that geographical proximity is an important factor for productivity growth both at the automaker's plants and its *keiretsu* suppliers' plants. If the keiretsu suppliers are located near the automaker's assembly plant, face-to-face contacts among engineers of both the automaker and the suppliers can be much more easily arranged, shortening the lead time in product development. Moreover, other aspects of the production system, such as Just-in-Time delivery, will be much more efficient. As mentioned in Section 3, Dyer (1996) conducts a comparative study on Japanese and U.S. automakers and concludes that the important characteristics of Japanese automakers are the geographical proximity with parts suppliers and the frequent communication among engineers. The results of our analysis imply that the geographical factor is also an important determinant of the difference in Japanese automaker's performance. The better-performing automakers have an agglomeration of parts suppliers near the assembly plants and utilize the technological knowledge jointly with their suppliers. This may possibly generate synergies leading to productivity growth at both the automakers and the suppliers.

5. Concluding Remarks

In this paper, we analyzed productivity growth and its determinants in the Japanese automobile industry since the 1980s, focusing on R&D spillover effects and agglomeration effects in transaction relationships between automakers and auto parts suppliers.

According to our measurement, the annual TFP growth rate from 1981 to 1996 was at low level, i.e., about 0.6 percent in the automobile manufacturing industry and about 1.3 percent in the auto parts manufacturing industry. Given that the annual TFP growth rate for the Japanese automobile industry until the early 1980s was estimated at approximately around 4 percent in previous studies, our estimates of 0.6 to1.3 percent are very low.

During the period of stagnating productivity since the 1980s, the performance differentials among automakers have magnified. We found differences among automakers in inventory ratios, price-cost margins, TFP, and so on. As for the automakers that achieved relatively high TFP growth (we called them Group A), their *keiretsu* suppliers also tend to show a higher TFP growth rate. Moreover, our regression results imply that Group A automakers tend to have many *keiretsu* suppliers near the assembly plants and to share technological knowledge with their suppliers, and that, therefore, both the automakers and the suppliers could attain higher productivity growth. Although previous case studies have often pointed out the importance of “relation-specific skills” and knowledge-sharing networks, these had so far not been empirically and statistically investigated using measurements of plant productivity. Using plant-level data, our study for the first time empirically demonstrated significant R&D spillover effects and agglomeration effects on parts suppliers’ TFP growth.

In our comparison of independent suppliers and *keiretsu* suppliers, we did not obtain significant evidence that the former tend to show higher TFP growth rates than the latter. We found, however, that parts suppliers who have a wider range of customers such as non-automakers tend to show higher TFP growth.

Several points remain to be further investigated. Although we found that geographical proximity with automakers had significantly positive effects on parts suppliers’ TFP growth, many other locational factors such as the agglomeration of related supporting industries and various types of infrastructure probably also affect productivity. In addition, the *keiretsu* relationships are said to be changing along with automakers’ business re-structuring and with the shift toward overseas production. It is possible that this would also affect productivity. These points are to be investigated in future.

APPENDIX 1. Data Sources and Methods of Data Construction

1.1 Measures of Capital Input and Capital Cost

Using plant-level data on the book value of tangible fixed assets, we constructed an index of the real value of net stock of buildings and structures, machinery and equipment, and others[19], for each plant. The net capital stock of plant *f* in the initial year *b* in constant 1990 yen, RK_{fb} is calculated as follows:

$$RK_{fb} = BV_{fb} * \left(HCK_b / BV_b \right) \tag{A1}$$

where BV_{fb} is the initial net book value of plant *f*, HCK_b represents the initial net capital stock of the whole industry in constant 1990 yen, and BV_b is the initial net book value of the whole industry. That is, (HCK_b/BV_b) stands for the ratio of real value in constant 1990 yen to book value of capital stock of the whole industry in year *b*. As an appropriate industry-level capital stock deflator is not available in Japan, we constructed this ratio ourselves. HCK_b, the initial net capital stock of the whole industry in constant 1990 yen, is calculated as follows:

(i) We take the data on the book value of tangible fixed assets from the *Census of Manufactures 1970* published by MITI. We converted the book value into the real value in constant 1990 yen using the net fixed assets deflator in the *Annual Report on National Accounts* published by the Economic Planning Agency.

(ii) Using the perpetual inventory method, we added the new investment in constant 1990 yen to the real value of 1970 fixed assets and then subtracted the value of depreciation. We repeated this calculation for succeeding years. We used the capital formation deflator in the *Annual Report on National Accounts.*

[19] In the Japanese Industrial Statistics Survey, transportation equipment and tools are classified as other tangible fixed assets.

Starting from the initial net capital stock of plant *f* calculated by Equation (A1), the following perpetual inventory formula was applied separately for buildings and structures, equipment, machinery and equipment, and others:

$$RK_{ft} = RK_{ft-1} * (1-\delta) + I_{ft} \tag{A2}$$

Using results obtained by Dean et al. (1990), the depreciation rates (δ) for buildings and structures, machinery and equipment, and others are assumed to be 0.062, 0.173, and 0.281 respectively. I_{ft} represents the value of newly acquired tangible fixed assets, deflated by the capital formation deflator in the *Annual Report on National Accounts.*

Following Fuss and Waverman (1992) and Tajika and Yui (2000), the rental rate of capital (p_k) is estimated for buildings and structures, equipment, machinery and equipment, and others, separately as follows:

$$p_k = q_k \cdot \left(\frac{1-\tau z}{1-\tau}\right)\left[r + \delta_k - \frac{dq_k}{q_k}\right] \tag{A3}$$

where q_k is the price of the *k*-th investment good, τ is the corporate tax rate, *z* is present value of the depreciation allowances on an investment of one unit of currency, *r* is the *ex ante* rate of return, δ_k is the rate of depreciation of the *k*-th investment good, and dq_k/q_k is the rate of capital gain on that good. We used the capital formation deflator in the *Annual Report on National Accounts* for $q_{k,}$ and the average long-term loan contract rate (city banks and regional banks) published by the Bank of Japan for *r*. Data on corporate tax rates were taken from the *Ministry of Finance Statistics Monthly*. To obtain the implicit cost of capital, the real capital stock estimated as above was multiplied by the rental rates per yen of capital.

1.2 Costs of other factor inputs

For labor costs, we use the “total cash wages and salaries paid” deflated by the general consumer price index (whole country, 1990 base) in the *Price Indexes Annual* published by the Bank of Japan.

The cost of intermediate goods (raw materials) is the “cost of raw materials and subcontracting orders” deflated by the overall wholesale price index for intermediate materials (semi-finished goods, 1990 base) in the *Price Indexes Annual* published by the Bank of Japan. The cost of intermediate goods (fuels and electricity) is the “cost of fuels and electricity consumed” deflated by the overall wholesale price index for intermediate materials (fuel & energy, 1990 base) in the *Price Indexes Annual*. For labor input, we use the “total number of workers” multiplied by the hours worked index. The hours worked index is calculated using data on the number of monthly hours worked per regular employee (total hours worked; motor vehicles, parts, and accessories)” in the *Monthly Labour Survey* published by the Ministry of Labour.

1.3 Productivity Measures

Output per worker (unit: 10,000 yen per person):

Output / (“monthly average number of regular employees” + “private entrepreneurs and unpaid family workers”) * hours worked index / 100

Output = “value of shipments” + “value of inventories of finished goods, semi-manufactured products, and unfinished products at end of the year” – “value of finished goods, semi-manufactured products, and unfinished products at beginning of the year”

- Output is deflated by the domestic wholesale price index (automobiles or automobile parts, 1990 base) in the *Price Index Annual*.

Value added per worker (unit: 10,000 yen per person):

Value added / (“monthly average number of regular employees” + “private entrepreneurs and unpaid family workers”) * hours worked index / 100

Value added = output – (“cost of raw materials, fuels and electricity consumed, and subcontracting orders” + “value of depreciation”)

Average Inventory Ratio:

0.5*("value of inventories at beginning of the year" + "value of inventories at end of the year") / output

Average monthly wages:

('Total cash wages and salaries paid to regular employee" / 12) / "monthly average number of regular employee" * hours worked index / 100

Capital-labor ratio:

Real value of net capital stock / ("monthly average number of regular employees" + "private entrepreneurs and unpaid family workers")

Outsourcing ratio:

"Cost of raw materials, fuels and electricity consumed, and subcontracting orders" / ("total cash wages and salaries paid" + "cost of raw materials, fuels and electricity consumed, and subcontracting orders" + implicit total cost of capital)

Price-cost margin:

(Output – "cost of raw materials, fuels and electricity consumed, and subcontracting orders") / output

Output-cost ratio:

Output / ("total cash wages and salaries paid" + "cost of raw materials, fuels and electricity consumed, and subcontracting orders" + implicit total cost of capital)

1.4 Description of Variables Used in the Regression Analysis

Share of purchases from a supplier's plant in an automaker's total value of purchases (*P*):

For each automaker (Toyota, Nissan, Mitsubishi, Mazda, Honda, Isuzu, Suzuki, Daihatsu, Subaru, and Hino), we first calculated the value of purchases from each plant of auto parts suppliers using our plant-level data and the data in the Auto Trade Journal (1997). Then, for each automaker, we divide the value of purchases from the supplier's plant by the total value of the automaker's purchases.

Share of sales to an automaker in a supplier's total value of sales (*S*):

The data is taken from the Auto Trade Journal (1997). Although most suppliers also sell their products to customers other than the ten major Japanese automakers, we calculated the share in order that the sum of the shares for the ten major automakers should become unity.

Non-automobile customers ratio (*NONAUTO*):

We define the non-automobile customer ratio as (1 – sum of shares of sales to the ten major Japanese automakers).

Customer concentration ratio (*HI*):

The Herfindahl index representing the customer concentration ratio is defined as follows:

$$HI_k = \sum_{i=1}^{10} S_{ik}^2 \tag{A4}$$

where S_{ik} $(i=1,2,\ldots,10)$ is the share of sales to automaker *i* in supplier *k*'s total value of sales.

Automaker's R&D intensity (*RDINT1*, *RDINT2*):

We first calculate the R&D stock for the ten major automakers. Following Griliches (1980), Nadiri (1980), and Goto and Suzuki (1989), we calculate the R&D stock using the perpetual inventory formula. We employ 10.5 percent as the rate of obsolescence of the R&D stock. In order to estimate the rate of obsolescence of R&D stock, we used the Science and Technology Agency's survey of the "life span" of technology (Science and Technology Agency, *White Papers on Science and Technology 1986*). This "life span" is the length of time patents generated royalty revenues, and/or the average length of time products embodying the patented technologies generated profits. Assuming that R&D stock depreciates and becomes obsolete over time, we obtain the rate of obsolescence by simply taking the inverse of the average "life span" of patents in automobile industry.

Assuming that the growth rate of R&D expenditure, RF_{it}, is the same as the growth rate of R&D stock, R_{it}, the initial amount of R&D stock, R_{itb}, is obtained as follows:

$$R_{itb} = \frac{RF_{itb+1}}{g+\theta} \tag{A5}$$

where g is the growth rate of RF_{it} and θ is the rate of obsolescence of R&D stock. In this paper, the initial year t_b is 1981, and g is the average growth rate from 1982 to 1987. Our R&D expenditure data are taken from *Kaisha Shiki Ho [Japan Company Handbooks]* published by Toyo Keizai Shimpo-sha. To obtain the real value of R&D expenditure, we used the R&D expenditure deflator (natural science, corporations, 1990 base) in the *White Papers on Science and Technology 2000*.

Then, we calculated the R&D intensity by dividing the annual average increase of the automaker's R&D stock by the annual average of its sales. Our sales data are taken from *Yuka Shoken Hokokusho [Financial Report of Listed Companies]*.

For each auto parts supplier k, the automaker's R&D intensity (Definition 1) for plant j of supplier k, $RDINT1_{kj}$, is obtained as follows:

$$RDINT1_{kj} = \sum_{i=1}^{10} P_{ikj} RDINT_i \qquad (i=1,2,\ldots,10) \tag{A6}$$

where P_{ikj} is the share of purchases from plant j of supplier k in automaker i's total value of purchases. Therefore, $RDINT1_{kj}$ is the weighted average of the R&D intensities of all ten automakers.

Moreover, the automaker's R&D intensity (Definition 2) for supplier k, $RDINT2_k$, is obtained as follows:

$$RDINT2_k = \sum_{i=1}^{10} S_{ik} RDINT_i \qquad (i=1,2,\ldots,10) \tag{A7}$$

where S_{ik} is the share of sales to automaker i in supplier k's total value of sales. We should note that S_{ik} is assumed to be same for all the plants owned by supplier k.

Distance from the automaker's R&D center (*DISTRD*):

The distance between the supplier's plant and the automaker's main R&D center is calculated by the spherical distance formula using data on latitude and longitude of the city, town, or village.

Distance from automaker's assembly plant (*DIST*):

The distance between supplier's plant and automaker's assembly plant is calculated by the spherical distance formula using data on latitude and longitude of the city, town, or village. Although each of the ten major Japanese automakers has more than one assembly plants, we calculate the distance from the nearest assembly plant of each automaker. The distance between plant j of supplier k and automaker i's assembly plant, $DIST_{kj}$ is obtained as follows:

$$DIST_{kj} = \sum_{i=1}^{10} S_{ik} DIST_{ikj} \qquad (i=1,2,\ldots,10) \qquad \text{(A8)}$$

R&D intensity (Definition 1) divided by distance from R&D center (*RDINT1/DISTRD*):

$$\sum_{i=1}^{10} P_{ikj} \frac{RDINT_i}{DISTRD_{ikj}} \qquad (i=1,2,\ldots,10) \qquad \text{(A9)}$$

where $DISTRD_{ikj}$ is the distance between plant j of supplier k and automaker i's R&D center.

R&D intensity (Definition 2) divided by distance from R&D center (RDINT2/DISTRD):

$$\sum_{i=1}^{10} S_{ik} \frac{RDINT_i}{DISTRD_{ikj}} \qquad (i=1,2,\ldots,10) \qquad \text{(A10)}$$

Keiretsu dummies:

We classify primary auto parts suppliers into *keiretsu* suppliers of the ten major automakers or non-*keiretsu* independent suppliers, using the information in the Auto Trade Journal (1997). We employ the following variables representing *keiretsu* relationships:

(i) *DMAKER*: A dummy which takes one for plants directly owned by the automakers and zero for other plants.

(ii) Cross term of sales share and *keiretsu* dummy:

$$S_i \times DKRETS_i \qquad (i=1,2,\ldots,9)$$

where S_i is the share of sales to automaker i in a supplier's total value of sales, and $DKRETS_i$ is a dummy which takes one for plants belonging to automaker i's *keiretsu*.

(iii) *DINDEP*: A dummy which takes one for independent plants that do not belong to any *keiretsu*.

Product dummies:

Using the item code of the major product of each plant, we compile the product dummies identifying engine parts (*DENGINE*), accelerators (*DACCEL*), brakes (*DBRAKE*), and body parts (*DBODY*).

APPENDIX 2. Estimation of Plants' Capital Utilization Ratio

To estimate the capital utilization ratio, we use data on intermediate inputs or electricity consumed which are considered to be correlated with the level of capital utilization.[20] We estimate the capital utilization ratio in the following way:

(i) First of all, we estimate the following equation which represents capital utilization, using aggregated data for the motor vehicle industry.

$$u_t = \alpha + \beta\left(\frac{M_t}{K_t}\right) + \sum_{s=0}^{2}\gamma_s\left(\frac{P_{mt-s}}{P_{kt-s}}\right) \qquad \text{(A11)}$$

where u_t is the capital utilization ratio, M_t is the cost of raw materials, K_t is the real value of net capital stock, P_{mt} is the price of raw materials, and P_{kt} is the price of capital in year t. For u_t , we use the capital utilization index (1990 base) for the transportation equipment industry as reported by MITI and for M_t, the cost of raw materials for the manufacture of motor vehicles and motor vehicle parts (industry code: 311) in the *Census of Manufactures* published by MITI. K_t is the real value of net capital stock calculated in the same way as

[20] For example, Jorgenson and Griliches (1995), Burnside et al. (1995), Basu (1996), and Fukao and Murakami (2000) estimate capital utilization ratio using data on energy or intermediate inputs consumed.

explained in Appendix 1.1, using the data on the book value of tangible fixed assets reported in the *Census of Manufactures*. For P_{mt}, we use the overall wholesale price index for intermediate materials (semi-finished goods, 1990 base) in the *Price Indexes Annual* published by the Bank of Japan. P_{kt} is the price of capital calculated in the same way as explained in Appendix 1.1. Taking the difference of the logarithm of each variable, we conducted an ordinary least squares estimation for Equation (A11) using annual data from 1973 to 1998. The estimated equation is as follows:

$$\Delta \ln u_t = -0.006 + 0.370 \Delta \ln \left(M_t / K_t \right) \tag{A12}$$

(-0.624) (2.607)**

No. of observations: 25

F-value: 6.8**

Adjusted R-squared: 0.195

Note that the t-values are in parentheses and that two asterisks (**) indicate a significance level of 5 percent.

(ii) Using the above Equation (A12), the theoretical value of the change in capital utilization ratio is calculated for each plant. Then, we obtain the trend of the capital utilization ratio for each plant. Assuming that the capital utilization ratio should be 100 percent at the peak of the trend, the level of capital utilization at each year can be calculated one after another. However, it is not realistic that exiting plants are operating at full capacity, even though the trend is at its peak. Therefore, for exiting plants, we assume that the capital utilization ratio at the peak of the trend is the average capital utilization ratio of all the plants operating throughout.

(iii) We multiply the three kinds of capital inputs (buildings and structures, machinery and equipment, and others) with the estimated capital utilization ratio for each plant.

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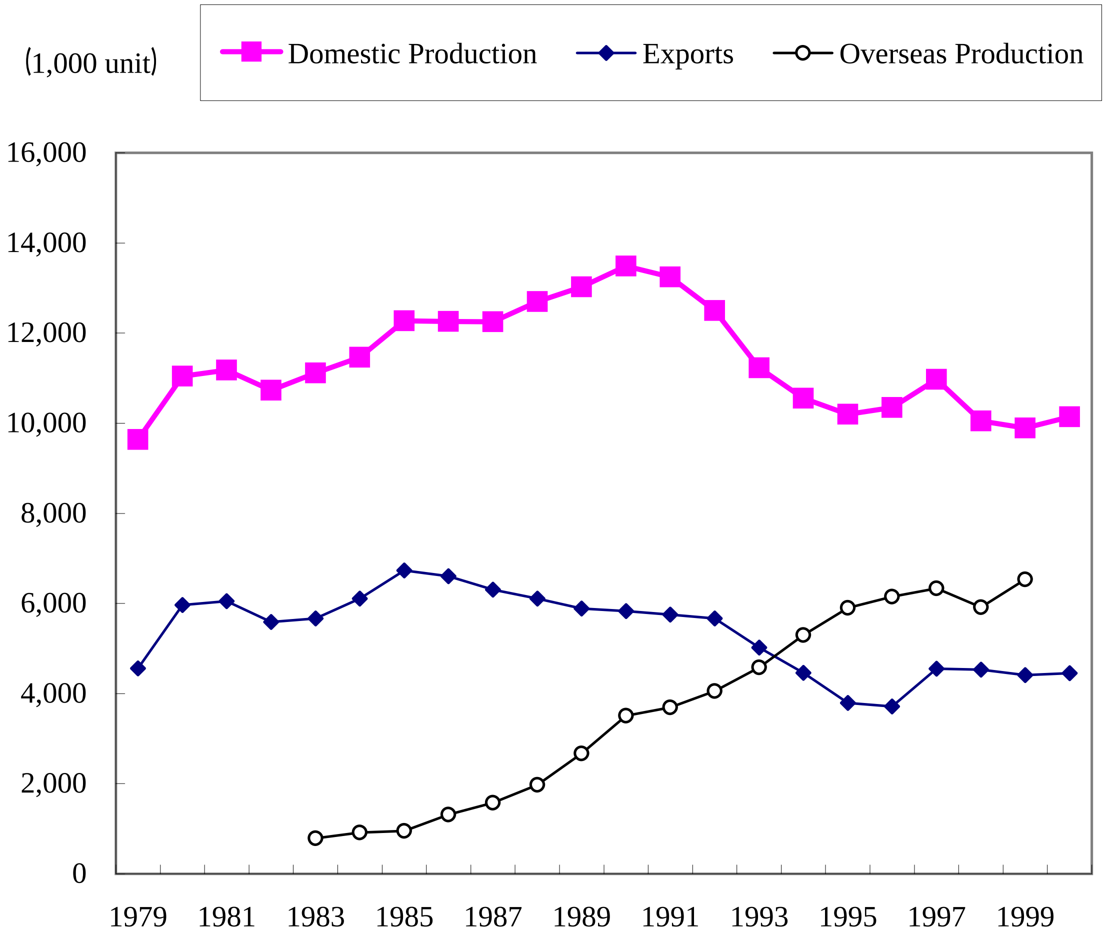
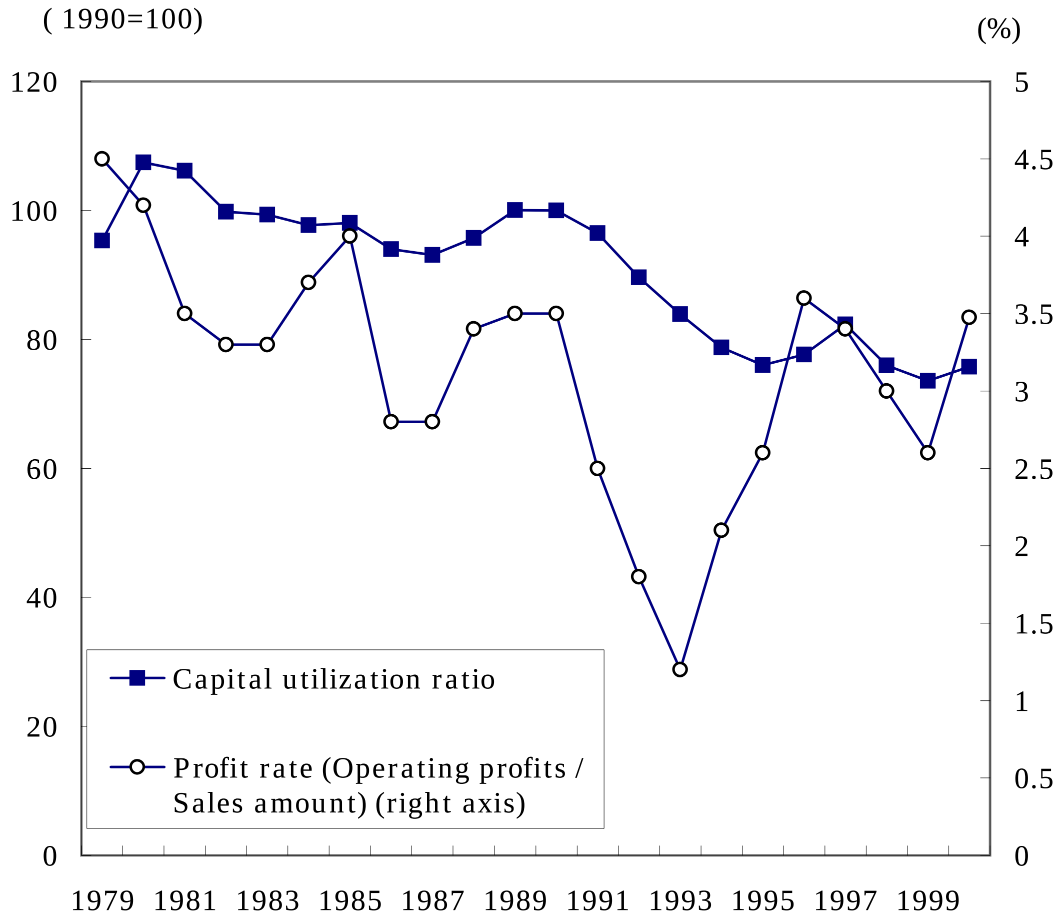
Figure 1: Production and Export Units of Four-Wheelers by the Japanese Automakers



Source: Nikkan Jidosha Shinbun-sha / Nihon Jidousha Kaigisho, *Jidousha Nenkan* (various years) [Automotive Yearbook].

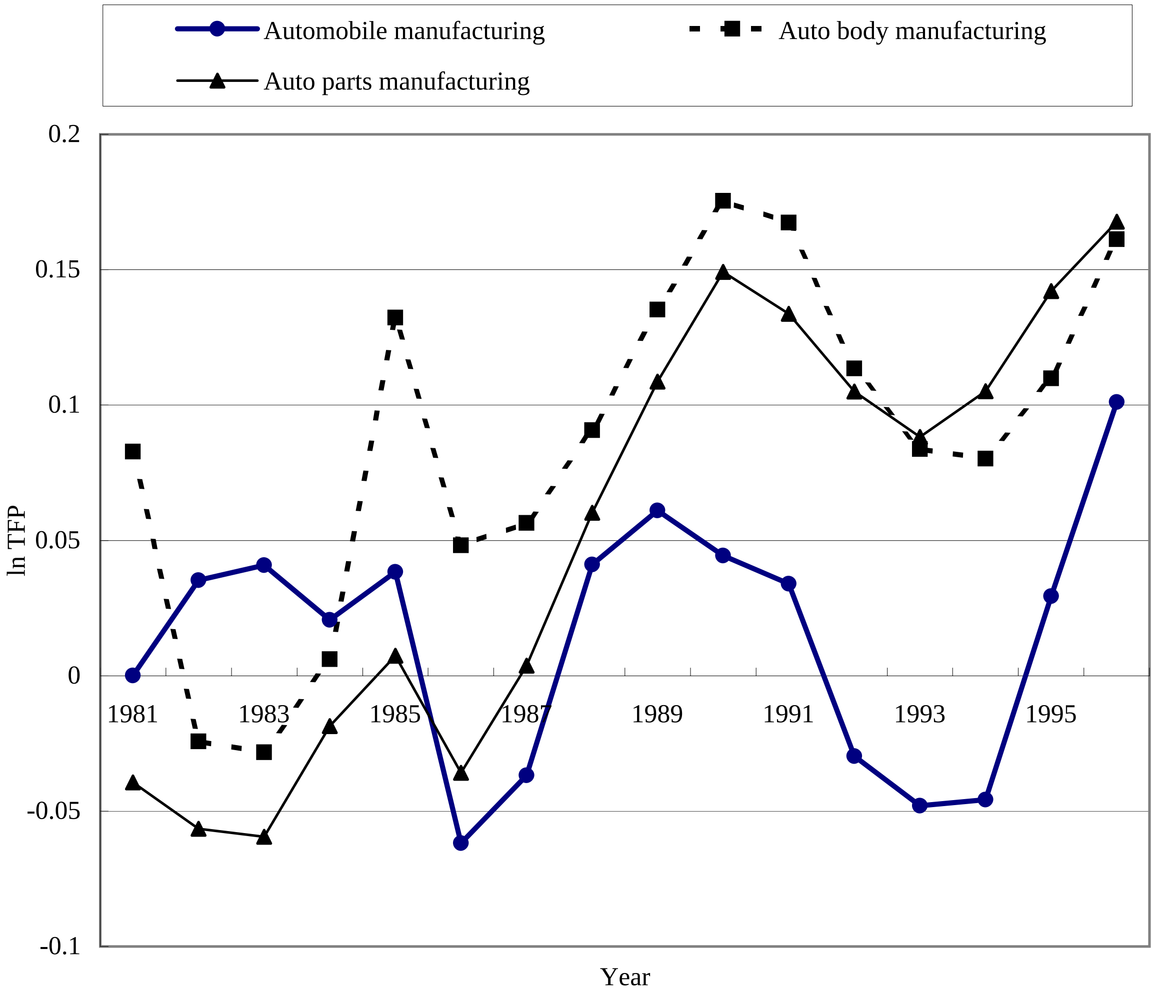
Figure 2: Capital Utilization Ratio and Profit Rates in the Japanese Automobile Industry



Sources: METI (former MITI), *Tsusan Handbook* (various years) [Handbook of International Trade and Industry].

Ministry of Finance, *Zaisei Kinyu Tokei Geppo* (various issues) [Ministry of Finance Statistics Monthly].

Figure 3: TFP Levels in the Japanese Automobile Industry Since 1980s



Source: Author's calculations.

Table 1: Differences among Automobile Assembly Plants (Average in Period): Group A vs. Others

	1981–1986			1986–1991			1991–1996		
	Group A	Others	t-test	Group A	Others	t-test	Group A	Others	t-test
No. of plants	72	162		73	165		78	180	
Output per worker	8472.28	6068.02	***	12171.84	8608.62	***	13850.27	10215.02	***
Value-added per worker	1857.83	1276.36	***	2879.09	1678.43	***	3650.68	1812.39	***
Average inventory ratio	0.03	0.05	***	0.03	0.05	**	0.03	0.06	***
Average monthly wage	41.12	40.44		46.50	45.12		54.39	49.62	***
Capital-labor ratio	1492.90	1088.56	***	1844.25	1399.21	***	2271.73	1920.55	**
Outsourcing ratio	0.84	0.82	***	0.88	0.85	***	0.85	0.83	
Price-cost margin	0.16	0.13	*	0.18	0.13	**	0.23	0.15	***
Output-cost ratio	1.17	1.11	**	1.24	1.12	***	1.31	1.14	***
Capital utilization ratio (%)	85.92	83.12		88.17	84.06	**	80.89	78.29	
TFP level (in logarithm)	0.02	-0.05	***	0.06	-0.04	***	0.10	-0.03	***

Notes: 1. All figures are the simple mean of the values of all the samples in each period.
2. Group A refers to plants owned by the three Japanese automakers which increased their market shares during the period from 1981 to 1996.
3. *significant at the 10% level, **significant at the 5% level, ***significant at 1% level. (two-tailed test)
4. For the definitions of the indices, see Appendix.

Source: Author's calculations.

Table 2: Differences among Auto Parts Manufacturing Plants (Average in Period): Group A *Keiretsu* vs. Other *Keiretsu*

	1981			1986			1991			1996		
	Goup A *Keiretsu*	Other *Keiretsu*	t-test	Goup A *Keiretsu*	Other *Keiretsu*	t-test	Goup A *Keiretsu*	Other *Keiretsu*	t-test	Goup A *Keiretsu*	Other *Keiretsu*	t-test
No. of plants	121	120		134	134		159	144		178	160	
Output per worker	2527.44	2314.97		3433.20	2976.28		4956.56	4250.43	*	5111.07	4592.78	
Value-added per worker	560.87	594.82		681.35	566.62		1363.76	1082.87	**	1404.46	1213.95	
Average inventory ratio	0.04	0.05	***	0.03	0.07		0.03	0.04	**	0.04	0.04	
Average monthly wage	32.16	31.71		35.61	34.26		39.72	39.45		46.10	41.95	***
Capital-labor ratio	762.18	606.63		920.19	860.17		1308.79	1090.00	**	1515.71	1432.19	
Outsourcing ratio	0.69	0.67		0.71	0.70		0.72	0.73		0.70	0.71	
Price-cost margin	0.09	0.13	*	0.10	0.06		0.19	0.20		0.20	0.18	
Output-cost ratio	1.04	1.09		1.06	1.03		1.19	1.17		1.19	1.18	
Capital utilization ratio (%)	89.10	88.44		84.36	84.75		81.36	81.82		77.15	74.92	
TFP level (in logarithm)	-0.09	-0.05		-0.05	-0.09		0.08	0.07		0.11	0.08	
TFP growth rate	-	-		0.03	-0.05	***	0.15	0.17		0.04	0.01	
TFP growth rate (1981−96)	-	-		-	-		-	-		0.22	0.14	**

Notes: 1. All figures are the simple mean of the values of all the samples in each period.
2. *significant at the 10% level, **significant at the 5% level, ***significant at 1% level. (two-tailed test)
3. For the definitions of the indices, see Appendix.

Source: Author's calculations.

Table 3: Differences among Auto Parts Manufacturing Plants (Average in Period): Independent Suppliers vs. *Keiretsu Suppliers*

	1981			1986			1991			1996		
	Indep.	*Keiretsu*	t-test	Indep.	*Keiretsu*	t-test	Indep.	*Keiretsu*	t-test	Indep.	*Keiretsu*	t-test
No. of plants	40	241		45	268		50	303		57	338	
Output per worker	2953.08	2421.65		3426.39	3204.74		6807.49	4620.97	**	5990.53	4865.73	
Value-added per worker	832.01	577.77	**	857.76	623.99	**	2508.37	1230.27	***	2021.08	1314.28	**
Average inventory ratio	0.05	0.04		0.04	0.05		0.05	0.04	**	0.05	0.04	
Average monthly wage	32.26	31.94		35.02	34.94		39.61	39.59		43.59	44.13	
Capital-labor ratio	707.53	684.73		731.93	890.18		946.44	1204.81	**	1383.52	1476.18	
Outsourcing ratio	0.69	0.68		0.69	0.71		0.72	0.73		0.68	0.71	
Price-cost margin	0.15	0.11		0.14	0.08		0.24	0.19	*	0.25	0.19	
Output-cost ratio	1.12	1.06		1.12	1.04	**	1.27	1.18	**	1.26	1.18	*
Capital utilization ratio (%)	88.21	88.77		84.80	84.56		82.77	81.58		73.90	76.09	
TFP level (in logarithm)	-0.03	-0.07		-0.01	-0.07	*	0.16	0.07	**	0.17	0.10	*
TFP growth rate	-	-		0.02	-0.01		0.14	0.16		0.02	0.02	
TFP growth rate (1981–96)	-	-		-	-		-	-		0.19	0.18	

Notes: 1. All figures are the simple mean of the values of all the samples in each period.
2. *significant at the 10% level, **significant at the 5% level, ***significant at 1% level. (two-tailed test)
3. For the definitions of the indices, see Appendix.

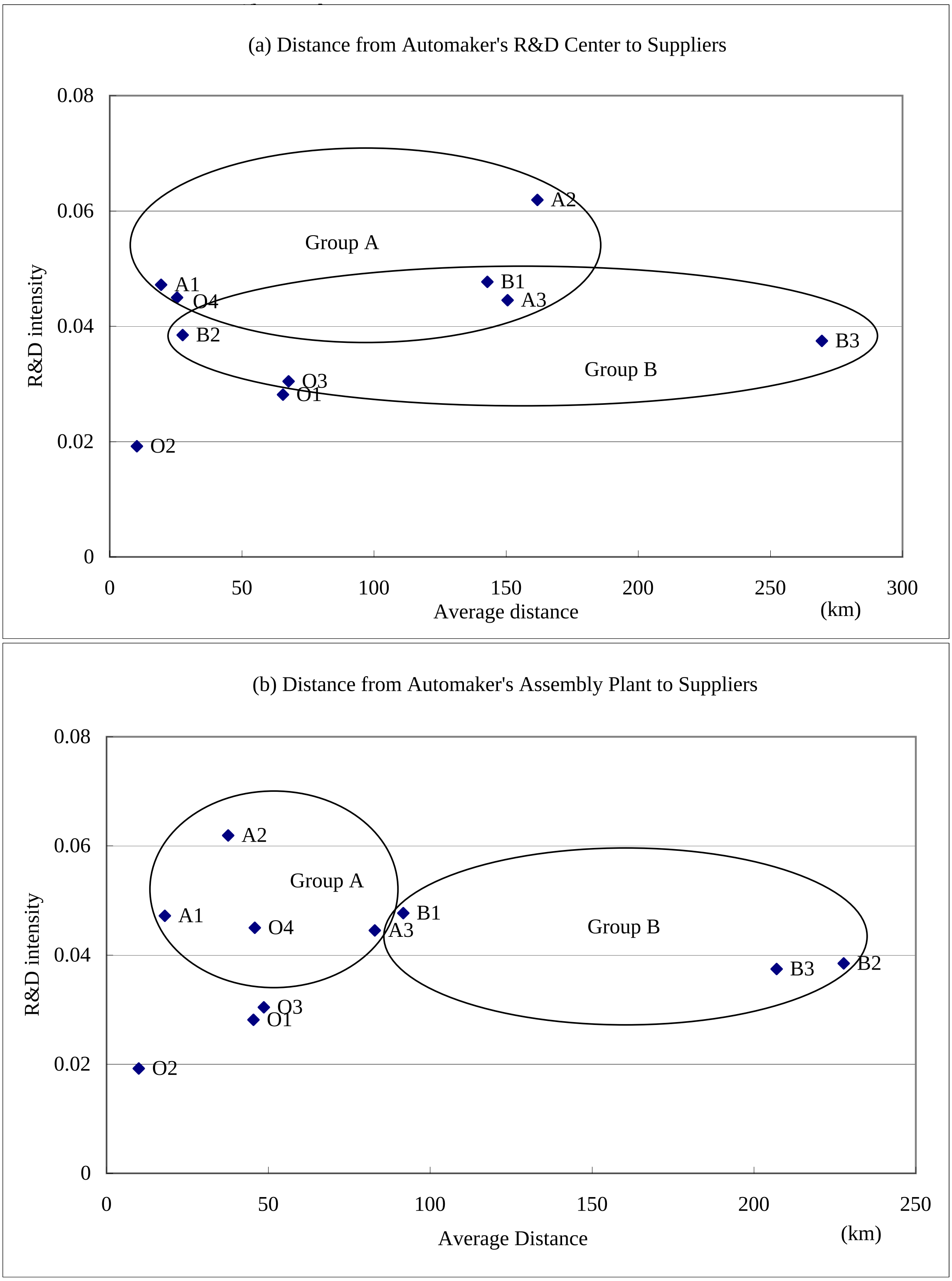
Source: Author's calculations.

Table 4: Determinants of TFP Growth Rate for the Japanese Auto Parts Manufacturing Plants (OLS Estimation)

	Dependent variable: TFP growth rate from 1981 to 1996					
	(1)	(2)	(3)	(4)	(5)	(6)
lnTFP(-1)	-0.787 (-8.72) ***	-0.866 (-6.80) ***	-0.865 (-6.79) ***	-0.832 (-6.84) ***	-0.910 (-7.19) ***	-0.881 (-6.84) ***
lnY(-1)	-0.032 (-1.94) *	-0.031 (-1.76) *	-0.034 (-1.92) *	-0.028 (-1.68) *	-0.057 (-3.62) ***	-0.043 (-2.62) ***
NONAUTO		0.216 (2.71) ***	0.224 (2.70) ***	0.216 (2.58) **	0.257 (2.73) ***	0.229 (2.45) **
HI		-0.018 (-0.35)	-0.054 (-0.80)	-0.075 (-1.08)	-0.025 (-0.15)	-0.069 (-0.40)
RDINT1		24.722 (2.53) **	24.602 (2.70) ***		31.950 (3.47) ***	
RDINT1/DISTRD			26.489 (0.48)			
RDINT2				5.262 (2.16) **		
RDINT2/DISTRD				0.110 (0.07)		
lnDIST			-0.015 (-1.02)	-0.014 (-0.87)	-0.035 (-2.09) **	-0.033 (-1.98) **
DENGINE	0.073 (1.37)	0.062 (1.03)	0.068 (1.12)	0.081 (1.36)	0.062 (1.10)	0.076 (1.35)
DACCEL	0.032 (0.86)	0.041 (0.97)	0.050 (1.15)	0.045 (1.06)	0.026 (0.62)	0.022 (0.52)
DBRAKE	0.025 (0.54)	0.015 (0.31)	0.024 (0.47)	0.024 (0.48)	0.052 (0.97)	0.044 (0.81)
DBODY	0.055 (1.22)	0.074 (1.47)	0.072 (1.43)	0.079 (1.54)	0.060 (1.27)	0.054 (1.12)
DMAKER		-0.098 (-0.69)	-0.107 (-0.71)	0.003 (0.02)	-0.026 (-0.20)	0.036 (0.28)
S_1 **KRETS* $_1$					0.008 (0.06)	0.020 (0.15)
S_2 **KRETS* $_2$					-0.054 (-0.40)	-0.021 (-0.16)
S_3 **KRETS* $_3$					-0.017 (-0.11)	0.022 (0.14)
S_4 **KRETS* $_4$					0.101 (0.76)	0.114 (0.85)
S_5 **KRETS* $_5$					-0.218 (-1.32)	-0.189 (-1.12)
S_6 **KRETS* $_6$					-0.059 (-0.41)	-0.023 (-0.16)
S_7 **KRETS* $_7$					-0.428 (-1.82) *	-0.412 (-1.61)
S_8 **KRETS* $_8$					-0.175 (-1.13)	-0.144 (-0.95)
S_9 **KRETS* $_9$					-0.191 (-1.07)	0.109 (0.50)
DINDEP	0.035 (0.80)					
const.	0.522 (2.31) **	0.463 (1.89) *	0.572 (2.40) **	0.282 (1.14)	0.948 (4.06) ***	0.793 (3.31) ***
No. of obs.	281	210	210	210	210	210
F-value	13.62 ***	8.87 ***	7.25 ***	7.89 ***	5.57 ***	4.83 ***
Adj. R-squared	0.306	0.264	0.269	0.257	0.371	0.336
Root MSE	0.254	0.262	0.262	0.264	0.249	0.255

Notes: 1. The figures in parentheses are t-statistics based on White's robust standard errors.
2. *significant at the 10% level, **significant at the 5% level, ***significant at 1% level. (two-tailed test

Figure 4: Japanese Automakers' R&D Intensity and the Average Distance to Primary *Keiretsu* Suppliers



Sources: Toyo Keizai Shimpo-sha, *Kaisha Shiki Ho* (various issues) [Japan Company Handbooks].
Nikkei QUICK Information, *Nikkei Kigyo Data: Nikkei NEEDS-MT* [Nikkei Company Data].
Auto Trade Journal (1997).

Appendix Table 1:
Number of Establishments and Number of Workers Used in Our Analysis

3111：Automobile manufacturing

	Establishments used in our analysis				All establishments with 30 or more workers	
	No. of est.	(%)	No. of workers	(%)	No. of est.	No. of workers
1981	39	(83.0%)	178,553	(95.5%)	47	186,902
1982	39	(79.6%)	181,129	(94.4%)	49	191,793
1983	39	(83.0%)	181,547	(94.8%)	47	191,480
1984	39	(73.6%)	184,204	(94.8%)	53	194,343
1985	39	(83.0%)	193,054	(96.0%)	47	201,084
1986	39	(78.0%)	184,304	(95.6%)	50	192,750
1987	40	(80.0%)	179,121	(94.4%)	50	189,747
1988	39	(83.0%)	178,358	(94.7%)	47	188,311
1989	39	(86.7%)	180,810	(94.9%)	45	190,546
1990	39	(83.0%)	183,236	(97.0%)	47	188,861
1991	42	(85.7%)	188,856	(96.8%)	49	195,046
1992	42	(89.4%)	185,916	(96.1%)	47	193,504
1993	43	(89.6%)	185,863	(96.0%)	48	193,633
1994	43	(87.8%)	182,850	(99.2%)	49	184,390
1995	44	(88.0%)	177,877	(97.0%)	50	183,298
1996	44	(89.8%)	176,625	(97.4%)	49	181,396

3112：Auto body manufacturing

	Establishments used in our analysis				All establishments with 30 or more workers	
	No. of est.	(%)	No. of workers	(%)	No. of est.	No. of workers
1981	79	(51.3%)	38,593	(78.4%)	154	49,240
1982	79	(55.6%)	38,704	(83.1%)	142	46,586
1983	81	(57.9%)	39,208	(79.2%)	140	49,536
1984	83	(63.8%)	40,436	(82.1%)	130	49,223
1985	83	(52.5%)	42,000	(78.4%)	158	53,549
1986	85	(50.6%)	43,381	(79.7%)	168	54,407
1987	87	(55.4%)	43,186	(86.0%)	157	50,222
1988	88	(56.4%)	43,753	(85.5%)	156	51,152
1989	88	(53.3%)	45,836	(84.9%)	165	53,990
1990	92	(57.1%)	46,994	(85.3%)	161	55,106
1991	94	(55.0%)	50,629	(83.5%)	171	60,668
1992	98	(59.0%)	51,232	(85.3%)	166	60,027
1993	100	(60.6%)	46,917	(83.2%)	165	56,400
1994	106	(61.3%)	48,367	(85.9%)	173	56,290
1995	108	(63.9%)	47,028	(87.2%)	169	53,957
1996	108	(62.1%)	45,836	(86.9%)	174	52,727

3113：Auto parts manufacturing

	Establishments used in our analysis				All establishments with 30 or more workers	
	No. of est.	(%)	No. of workers	(%)	No. of est.	No. of workers
1981	963	(47.1%)	243,696	(63.9%)	2044	381,608
1982	963	(48.0%)	244,028	(65.4%)	2005	373,226
1983	994	(49.2%)	248,575	(67.1%)	2021	370,704
1984	1017	(47.8%)	258,030	(65.8%)	2129	391,964
1985	1043	(45.2%)	269,637	(63.9%)	2305	421,727
1986	1062	(45.0%)	272,295	(64.9%)	2361	419,835
1987	1074	(46.4%)	273,760	(65.4%)	2317	418,410
1988	1082	(46.0%)	280,152	(67.4%)	2353	415,682
1989	1091	(45.4%)	290,409	(67.5%)	2402	429,979
1990	1122	(45.5%)	303,288	(66.9%)	2467	453,384
1991	1164	(45.4%)	311,794	(64.8%)	2564	480,961
1992	1224	(47.8%)	320,176	(68.4%)	2560	468,381
1993	1267	(51.0%)	320,476	(69.6%)	2486	460,646
1994	1299	(52.4%)	319,434	(68.9%)	2480	463,499
1995	1344	(54.9%)	315,352	(70.5%)	2448	447,294
1996	1377	(56.6%)	315,091	(69.3%)	2435	454,408

Source: Compilations from plant-level data underlying METI's *Census of Manufactures*.