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ABSTRACT

Prevalence of subcontracting in Japan has traditionally been ascribed to risk shifting behavior of manufacturers. But, Asanuma's field research has elicited the following. First, in transactions with those suppliers with which it maintains longstanding relations, each typical manufacturer absorbs risks to a nonnegligible degree. Second, the degree tends to be higher (1) the larger the share occupied by the manufacturer in the total sales of the supplier; and (2) the more rudimentary the category of the item transacted viewed from evolutionary paths of suppliers. We adapt the principal–agent model derived by Kawasaki and McMillan based on a fundamental result acquired by Holmstrom and Milgrom on linearity of the optimal conpensation scheme, construct a set of data on individual suppliers to each of four major automobile manufacturers, and quantitatively verify the above propositions.

Journal of Economic Literature Classification Numbers: D82, L14, L23, L62, M11.

1. Introduction

The Risk Shifting Hypothesis

It has been been widely perceived that major Japanese manufacturing firms tend to use subcontracting to a larger extent than their counterparts in other industrialized countries. In other words, large firms in Japan have been noticed to procure a relatively greater portion of the parts and processing services necessary to manufacture their final products from outside firms, relying less on in–house plants.[1)] Since information on the outside purchasing ratio is currently hard to obtain systematically, it is difficult to examine validity of this perception rigourously for each individual product. But, fragmental pieces of evidence do suggest that the characterization is roughly correct, at least in U.S.–Japan comparisons.[2)]

Until fairly recently, researchers and policy makers tended to regard the perceived tendency as a resultant of late development of Japan and as a weak point of her economy. As the 1970s evolved into the 1980s, however, this evaluation began to be reversed. The same tendency has come to be thought consonant with contemporary technologies and tastes, and adding quick adaptability to Japanese manufacturing industries.[3)]

But, what are the incentives for major Japanese manufacturers that have made them use outside suppliers to such an extent? Concerning this question, there has been a conventional view. The view has its origin in the pre–war views on the Japanese subcontracting system held by Japanese social scientists, and has been diffused worldwide since the 1950s with the literature that spotlights the "dual structure" of the Japanese economy.[4)]

This conventional view emphasizes the following as the major factor: exploiting their monopsonistic position, large manufacturers can utilize their outside suppliers as a buffer against business fluctuations. More precisely, the assertion is as follows. During business upswings, buying a relatively higher proportion of parts from outside, large manufacturers save investments in fixed assets. When demand for the final products slackens, they quickly withdraw the supply contracts from outside firms. Thus, large firms can enjoy relatively stable utilization rate of their capacities and work forces, and hence less fluctuation of their operating profit, at the expense of their subcontractors. In short, the conventional view has characterized subcontracting mainly as a device through which large manufacturers can shift the risk involved in their business income onto their subcontractors. Let us therefore name this view the Risk Shifting Hypothesis (RSH, hereafter).

Emergence of Another Strand of View

While RSH became an integral part of a widely held picture of the Japanese economy, a different view came to be voiced as Japan experienced years of high econimic growth. Based on a questionnaire survey and field research conducted in Kansai area, Tasugi (1961) has noted that, in the machinery industry, core firms have come to take a long run view in their use of subcontractors; at least for major core firms, development of the skills of their subcontractors by maintaining ongoing relationship and providing technological guidance has become their major concern, so that utilization as a capacity buffer does not constitute their primary motive any more.[5)] Tasugi's observation went unnoticed or neglected by most of his contemporary scholars. A similar view has been asserted by Kiyonari (1970) based on his research on the small and medium sized firms in Japan during the latter half of the 1960s. This again remained the minority opinion and had to await the 1980s to get appreciation from wider audience including some of those who had once been in the opponents' camp. [6)]

Reflections on the measures taken by large firms in Japan for adjustment during the years that ensued the first oil shock, and a survey released by MITI on subcontracting , led Aoki (1984) to a view which can be regarded as a developed version of the view taken by Tasugi in 1961 and by Kiyonari in 1970. Aoki's distinct contribution is that he has connected the issue with the economic theory of risk bearing. He has interpreted the observed behavior of Japanese firms in the hard time as risk sharing between large firms and their subcontractors. Further, he has noted that large core firms may possibly be absorbing relatively more risk and performing an insurance function in exchange for premiums payable in the form of monopolistic (and/or monopsonic) gains. [7)]

The Risk Absorption Hypothesis

Based on field research, Asanuma (1984a,1984b) has given a systematic description of the contractual practices developed in the Japanese automobile industry regarding parts transaction. This work has shown, among others, the following: such a set of practices that works, viewed as a whole, as had been expected by Aoki in fact exists and is prevalent. Asanuma (1989) has complemented this work based on additional field research on the Japanese automobile and electric machinery industries. From what have been reported in these articles, we extract below three points which seem to have crucial importance in assessing validity of RSH. Since RSH is concerned primarily with "subcontractors" in the sense of suppliers of "Ordered Goods," or customized parts or processing services, as opposed to "Marketed Goods" type parts, we hereafter focus on suppliers that fall under this category.[8)]

(A1). It is certainly true that, frequently, the first tier suppliers to a given core firm include such firms that can receive orders from this core firm only intermittently, being used by this core firm as a capacity buffer. But, this kind of firms comprise only a subset of the entire body of the first tier suppliers. Moreover, the subset occupies only the peripheral portion of the entire set, since it consists of marginal suppliers viewed from the ranking system which this core firm applies to its suppliers. The nucleus portion of the same set consists of suppliers ranked higher. For later reference, we name members of this portion "satellites."[9)] The core firm typically seeks to develop close and longstanding relations with each "satellite," placing orders as continuously as possible.

(A2). If we focus on the relations between a given core firm and its "satellites," contractual practices observable therein typically contain mechanisms through which the core firm absorbs risks involved in the transaction to a nonnegligible degree.

(A3). Concerning this risk absorption, the following two tendencies are observable. (1) The more concentrated the business of this supplier to the supply to this particular core firm, the more risk this core firm will be willing to absorb. (2) The more rudimentary, from an evolutionary viewpoint, the present position of the supplier in terms of the nature of the item being supplied, the more risk the core firm will be willing to absorb.

Two remarks are in order here. First, (A1) implies the following. RSH fails to capture the fact that the core firm treats its suppliers differently depending on the rank it has given each supplier, arguing as if the situation which is actually observable only for marginal suppliers were applicable to "satellites" as well. It makes an oversimplification in this regard. Second, both (A2) and (A3) imply that, for "satellites," RSH gives wrong predictions. Note especially the following. Upon the condition in (1) or (2) in (A3), RSH would predict that the core firm will treat the subcontractor in question all the more relentlessly as its buffer, since both conditions imply that the purchaser's position is enhanced toward monopsonicity. But (A3) gives an exactly opposite prediction.

In sum, taken as a bundle, (A2) and (A3) provides a counter hypothesis to RSH. We therefore combine (A2) and (A3) together and name it the Risk Absorption Hypothesis (RAH, hereafter).

Toward Quantitative Establishment of RAH

The purpose of this paper is to present the results of our research aimed at giving a quantitative test to RAH. Looking from the aim of this work, a seminal step has been taken by Kawasaki and McMillan (1987). Stimulated by the findings reported by Asanuma, they derived a principal–agent model based on a fundamental result acquired by Holmstrom and Milgrom (1987) which guarantees that, in a fairly broad range of situations, the optimal scheme for a principal to compensate his or her agent can be given by a linear function of end–of–period results. They then estimated the parameters from Japanese industrial data, and tested a hypothesis very close to our RAH. According to their own summary, their work has shown the following. First, the subcontractors are risk averse. Second, the contracts have the principal absorbing some of the risk on behalf of the subcontractors. Third, the price adjusts more to changes in the subcontractor's production costs (1) the more risk averse the subcontractor; (2) the bigger the fluctuation in costs; and (3) the less severe the moral hazard.

Our work extends this accomplishment by Kawasaki and McMillan in the following way. Regarding the model, we basically follow them. More specifically, we adopt estimation equations that have the same basic structure as those used by them. To the interface between the model and computational work, however, we introduce following two inventions. The first is that, mobilizing three data sources the combined use of which in academic research is attempted here fore the first time, we construct a data set which enables to conduct analysis at a more micro level. Kawasaki and McMillan had to rely on two data sources compiled and published by MITI. These sources, though dependable, only provide classified aggregate data. This imposes following two constraints on analyzers, which is frustrating for the type of analysis we aim at. One of the constraints is that the data do not permit discriminating the "satellites" to large manufacturing firms from other firms subsumed in the same class. Another is that the data do not allow regrouping of suppliers by their core firms. Our data set enables surpassing these constraints. The second of our inventions is that we contrive new proxies which enables the test of RAH as represented by (A2) and (A3), for this form reflects practices of Japanese core firms more directly, and perhaps a little more fully, than the version used by Kawasaki and McMillan.

Our main results are twofold. First, for each of the four major automobile manufacturers in Japan, Toyota, Nissan, Mazda, and Mitsubishi Motor Corporation (MMC, hereafter), as much as 90 percent of unpredicted cost overrun or underrun incurred by its satellites is shown to have been absorbed in the course of their transaction. Second, again for each of the core firms named above, both (1) and (2) in (A3) is confirmed. Though there are substantial differences among these core firms in their respective historical paths for development and current shares in the automobile market, our analysis illuminates that these firms have taken surprisingly similar attitudes toward their respective suppliers.

The rest of the paper is organized as follows. Section 2 sets out the model used for estimation. Section 3 expounds the data set we constructed. Section 4 explains the proxies we contrived. Section 5 presents the results of estimations and interpretes them. Section 6 concludes the paper.

2. The Model

In this section we give a brief account of the model used for our estimation. This is repetitive of Kawasaki and McMillan, but is included here to make the paper self-contained. For further details, the readers are referred to their article.

In this model, the principal corresponds to a core firm and the agent to a subcontractor. The core firm is assumed to behave as if it is risk neutral toward a particular contract, while the subcontractor is assumed to behave toward the same contract reflecting a utility function with constant absolute risk aversion.

The subcontractor's production activities take place throughout a period, but the core firm pays the subcontractor only at the end of the period. The payment p is based on the accumulated production cost c. This cost fluctuates randomly, but the subcontractor can, with costly effort, achieve cost reduction.

The core firm's optimal payment function is represented by

$$p = b + \alpha(c - b), \tag{1}$$

where p is the price paid, b is the target price set in advance by the core firm, and α is the sharing parameter chosen ex ante by the core firm. If $\alpha = 0$, the contract is fixed price; all of the risk of cost fluctuations is borne by the subcontractor. If $\alpha = 1$, the contract is cost plus; the core firm bears the entire risk. If $0 < \alpha < 1$, the risk is shared. The quantity ordered from the subcontractor for the period concerned is taken to be exogenous and, by appropriate choice of units, is normalized to one. Thus the price p can be regarded as equivalent to the sales from the subcontractor to the core firm for the entire period.

The realized production cost c is supposed to be decomposable into three components:

$$c = c^* + w - \xi \tag{2}$$

where c^* represents the ex ante expected cost including normal profit margin; w is a random variable representing unpredictable cost fluctuations observed only by the subcontractor in the course of doing the work; ξ denotes the reduction in cost due to the subcontractor's effort. The effort can be measured in monetary terms as $h(\xi)$, is financed from the gross profit of the subcontractor, and exhibits the following kind of diminishing returns property:

$$h(\xi) = \xi^2 / 2\delta \tag{3}$$

for some $\delta > 0$.

The value of c^* is known to both party. While the core firm cannot observe the realization of w, it does know its distribution, which is assumed to be normal with mean zero and variance σ^2. The core firm also cannot directly observe the level of the cost reducing effort by the subcontractor and, because the core firm cannot observe the realization of w, it cannot deduce the subcontractor's effort from its observation of the total cost c. Thus there is asymmetry of information between the parties, and hence the problem of moral hazard.

Maximizing expected utility of profit, the subcontractor will choose a level of effort:

$$\xi = \delta(1 - \alpha). \tag{4}$$

Denote the variance of the subcontractor's profits by s^2. Then, we have:

$$s^2 = (1 - \alpha)^2 \sigma^2. \tag{5}$$

If the value of the sharing parameter, α, is set high, then, a large proportion of the effect of possible cost overruns beyond the control of the subcontractor will be shifted to the core firm, and a large proportion of windfall gains from cost underruns has to be yielded to the core firm, both through ex post price adjustments. This is the insurance effect of the contract formula of price revision expressed by (1). But, when α is set high, the cost reduction achieved by the subcontractor's innovation effort has also shared by the core firm to a great extent. This consideration may attenuate the subcontractor's innovation effort. This is the incentive (or moral hazard) effect that the same formula bears.[10)]

Anticipating that the subcontractor will respond to any choice of the value of α by choosing his cost reducing effort $h(\xi)$ so that (4) is satisfied, the core firm will choose the value of α so as to satisfy:

$$\alpha = \lambda \sigma^2/(\delta + \lambda \sigma^2), \tag{6}$$

where λ is the Arrow–Pratt measures of absolute risk aversion, and δ is a measure of effectiveness of the cost reducing effort, which is also interpreted as a measure of moral hazard.

Taking logarithms of both sides of (6) and rearranging, we have:

$$\ln (1/\alpha - 1) = \ln (1/ \sigma^2) + \ln (1/ \lambda) + \ln \delta. \tag{7}$$

This is the basic equation used by Kawasaki and McMillan for their regressions. We follow them in adopting this equation as the basis for our empirical analysis.

3. The Data Set

We have mentioned in Section 1 that the data sources used by Kawasaki and McMillan impose two constraints on analyzers. In addition to these two, the sources actually involve one more constraint. Of the two data sources used by them, *Census of Manufactures (The Firm Series)*, and *Surveys of Industries*, it is the latter that provides data more or less related to subcontracting. But, for those data items that are especially important for the analysis of subcontracting, *Surveys of Industries* limits its samples to the firms with less than 300 employees. This practice may be traced back to the legal definition of "subcontracting small and medium sized firms" adopted in the *Law on the Promotion of Subcontracting Small and Medium Sized Firms* enacted in 1970, and can be justified for the purpose of this law. When one's purpose is to conduct analysis on the suppliers that surround a given core firm, however, there is no reason to confine attention to the firms with less than 300 emplyees, since subcontractors per se do not necessarily fall under the small and medium sized firm category. To assess validity of RSH, it becomes particularly important to examine how risk shifting (or absorbing) behavior of the core firm toward relatively developed suppliers differs from that shown to less developed supplier. To surpass the three constraints including this last imposed by the official statistics used by Kawasaki and McMillan, we constructed our data set mobilizing following three data sources.

Cosmos 1 Data File

For each of the firms in Japan whose stocks are either listed at the stock exchanges or registered for over–the–counter trading, *Yuka Shoken Hokokusho Soran* (The Financial Report of the Companies filed to the Ministry of Finance in compliance with the Law on Securities Transaction) published by the Ministry of Finance, the American counterpart of which is the 10–K Report, provides fairly detailed information. Unfortunately, there are a large number of suppliers whose stocks are neither listed nor registered. Some of them are not even a joint–stock corporation. *Yuka Shoken Hokokusho Soran* is not suited therefore to the analysis of subcontracting. This must be the basic reason why Kawasaki and McMillan were compelled to turn to the aggregate data.

But, there exists a data source that furnishes micro financial data akin to the items in *Yuka Shoken Hokokusho Soran* even for those companies which do not have to report to the Ministry of Finance. This is *Cosmos 1 Data File* compiled by Teikoku Data Bank, a credit information service company, as the basis for its information service. Since collection of individual firm data for this file depends solely on cooperative attitude of the firms, some companies refuse to supply data when they come to feel unhappy with their performance at the end of a particular period; some other firms do not want to disclose their data from the beginning. For this reason, coverage of firms is not 100 percent and time series data of the firms in this file are at times incomplete. Still, the feature noted at the outset of this paragraph suggests that development of academic use of this data source is worth attempting. As will be seen shortly, the source does provide a considerably good coverage of the "satellite" type suppliers to major Japanese automobile manufacturers.

Member Lists of Cooperative Associations

As has been mentioned in Asanuma (1989), the "satellite" type suppliers to a given core firm in the Japanese automobile industry typically organize themselves into *Kyoryokukai* (Cooperative Association). Member lists of these associations are available either from reports of industrial research companies like IRC or IRS published mainly for business use, or from annual editions of *Nippon no Jidosha Buhin Kogyo* (The Automobile Parts Industry in Japan) edited by Nippon Jidosha Buhin Kogyokai (The Japanese Association of Parts Manufacturers) jointly with Auto Trade Journal, Inc.

Reflecting individual historical situations, satellites of a given core firm have organized themselves along various principles. For instance, the "satellite" type parts suppliers to Toyota type have formed three associations named Tokai Kyohokai, Kanto Kyohokai, and Kansai Kyohokai on regional basis. Some suppliers that have their offices and/or plants in two different regions may possibly be joining two of the three regional associations at a time. On the other hand, the "satellite" type parts suppliers to Nissan have formed two associations named Takarakai and Shohokai. The former consists of subsidiaries and related companies of Nissan in addition to the suppliers that have been relatively more dependent on Nissan; the latter is constituted by other firms which have been relatively more independent but still kept close and longstanding relations with Nissan.[11)] Thus there is not necessarily one single association corresponding to each core firm. This makes determination of the number of "satellites" a little troublesome.

As of 1987, the number of the "satellite" type parts suppliers to each of major automobile manufacturers that we were able to determine from member lists of cooperative associations is: 181 for Toyota, 166 for Nissan, 188 for Mazda, and 329 for MMC.

Micro Data in Industrial Research Reports

For each of the "satellite" type suppliers thus determined, we investigated availability of its balance sheets and profit and loss statements from *Cosmos 1 Data File* for 11 consecutive fiscal years from 1977 to 1987. These time series data are required to compute the value of α for each company using Equation (5).

To conduct regressions, we need another kind of micro data in addition to the financial data of the sort explained above. They are required to determine the values of three variables which will be explained later: SPEC, IMP1, and IMP2. The reports made by and published from IRC, one of the industrial research firms mentioned before, contain for some suppliers sufficient information to enable this determination, but not for others.

The number of the "satellite" type parts suppliers for which both kinds of micro data are available is: 96 for Toyota, 75 for Nissan, 87 for Mazda, and 97 for MMC. These suppliers comprise our sample.[12)]

4. The Proxies

In carrying out regression analysis, Kawasaki and McMillan have derived two variants of the equation (7), named Model I and Model II respectively, and obtained estimates for each of the two. In dealing with Model II, they first got estimates of λ separately, and then, using these values, estimated the coefficient of $\ln(1/\lambda)$, one of the independent variables in (7). For δ, on the other hand, they used a pair of proxies instead of trying to get its estimates directly. In dealing with Model I, they used proxies for both λ and δ. In this section, focusing on their Model I, we describe what kind of proxies we have introduced instead of those used by Kawasaki and McMillan, and explain why. How we estimated our values of λ and conducted regressions for an equation which corresponds to their Model II will be explained later in Section 5.

The basic form of their Model I is given by the following equation.

$$\ln(1/\alpha - 1) = a_0 + a_1\ln(1/\sigma^2) + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + \varepsilon. \qquad (8)$$

Here x_2 and x_3 are proxies for the inverse of the degree of risk aversion, and x_4 and x_5 are ptoxies for the extent of moral hazard. All of the coefficients a_i are predicted to take strictly positive values, except a_0, which is predicted to be zero.

We take up the proxies for moral hazard first, and then proceed to those for risk aversion.

Proxies for Moral Hazard

Table III in Kawasaki and McMillan (1987) shows that the estimated coefficient of x_5 gives the wrong sign, and is statistically insignificant. This indicates that the choice of the variable may have been inappropriate. Kawasaki and McMillan used the wage/material costs ratio as x_5, citing a couple of findings reported by Asanuma as the basis for this choice. But, as has been discussed in detail in Asanuma and Kikutani (1990), the Asanuma's report in fact does not necessarily lead to this choice; nor does the variable seem to suit their intention very well. On the other hand, their choice of x_4, the proportion of inputs secured by the subcontractor himself, has produced far better results. But, here, we come across the following problem. Dependence of materials procurement on the core firms is a phenomenon typical to smaller subcontractors engaged primarily in processing services, and quickly disappears as suppliers grow. Since we want to encompass in the analysis the whole body of "satellites," including firms with more than 299 employees and with own proprietary technology, we need a proxy that can reflect relative capabilities of suppliers over a more extended continuum.

Our contrivance here is as follows. Based on the observed tendency given by (2) of (A3) in Section 1, we introduce just one variable, instead of two, as our proxy for the moral hazard/incentive effect. This variable measures the degree of evolution achieved to date by the supplier concerned. The current position of any supplier in the whole conceivable evolutionary loci is, in turn, determined by the properties of the main product offered by this supplier to its customers.

We use a three dimensional space, the basic idea of which has been laid out by Asanuma (1989), to plot the position of each supplier determined by the method described above. The first coordinate axis of this space coincides with the horizontal axis of TABLE 2 in Asanuma (1989), which measures the degree of technological initiative that a supplier can exert vis–a–vis a given core firm in the development and manufacturing stages of its main product. Seven subcategories of parts are discriminated along this axis. The first three subcategories comprise the DS(Drawings Supplied) parts category, the next three constitutes the DA(Drawings Approved) parts category, the last corresponding to the "Marketed Goods" type parts category. As has been stated in Propositions 4 and 6 in Asanuma (1989), the more rightward we go along this axis, the more the processes of development and manufacturing become black–box seen from the core firm, and, other things being equal, the profit margin can increase.

The direction of development that a supplier seeks in its pursuit of growth is not limited to the rightward movement along the first axis, however. For some "Marketed Goods" type parts, the number of suppliers may be large, making any of them easily substitutable. On the other hand, when a supplier gets a contract to supply transmissions to a core firm based on the drawings supplied from this core firm, this supplier cannot be switched so easily in comparison to the suppliers of simpler DS parts, even if both this transmission and the simpler parts concerned fall under the same subcategory II regarding the first axis. Further, as it becomes more difficult for a given core firm to find alternative sources of supply of a given item, it becomes harder for the same core firm to keep the profit margin of this item low utilizing competition among the potential suppliers. Taking these into consideration, we introduce a second axis which measures the degree of difficulty faced by a given core firm to find alternative sources of supply for a given part in question. The more northward we go along this axis, the situation approaches that of monopoly.

The third axis measures the share of the part in question in the total amount of relational quasi-rent attributable to the final product manufactured by the core firm concerned. The amount of relational quasi-rent is approximated by the value added in the empirical work to follow.

Suppose that the positions of a supplier A and another supplier B are given by (x_a, y_a, z_a) and (x_b, y_b, z_b). If the former is greater than the latter in the sense of ordering of vectors, then we call that A has achieved a higher degree of evolution than B. Or alternatively, we say that the product of A bears a higher degree of importance than that of B.

Obviously, it is difficult to treat the degree of importance as a continuous variable in the empirical work. We therefore trichotomize the whole space into the high, middle, and low grade regions. Correspondingly, we introduce three dummy variables: IMP1, IMP2, and IMP3. If a supplier and its main product falls under the high (middle, low) grade region, we assign 1 as the value of IMP1 (IMP2, IMP3) and 0 as the value of other two dummy variables. Since IMP1 + IMP2 + IMP3 = 1 for each supplier, the following two alternatives are available in carrying out regressions. One is to explicitly deal with only two of the three dummy variables and, at the same time, to include the constant term in the estimation equation; the other is to explicitly deal with all of the three dummy variables and drop the constant term. Our choice is to take the former course and to estimate how IMP1 and IMP2 give respectively an additional effect in comparison to the state, which is taken as a floor, that would be achieved if the supplier belonged to the IMP3 category.

How we classified several parts and suppliers into different grade regions is illustrated by FIGURE 1.

< FIGURE 1 about here>

Proxies for Risk Aversion

As the first proxy for the inverse of the degree of risk aversion, x_2 in Equation (8), Kawasaki and McMillan used "the size of overall operation of the subcontractor represented by the total sales of the firm." We share their reasoning that the size of the firm must be inversely related to the degree of risk aversion, but prefer "the number of employees of the firm," denoted by NUM hereafter, to the "total sales of the firm" as the size variable. The reason is as follows. From the assumption of the theoretical model, the degree of risk aversion λ should be a constant, independent from the profit π which is a stochastic variable. However, since the quantity ordered from the subcontractor is normalized to one in this model, as has been noted in Section 2, the sales is equal to the price paid p and hence satisfies the following equation.

$$\begin{aligned} \text{sales} &= p = \pi + c + h(\xi) \\ &= \{\alpha/(1-\alpha)\}\pi + \mathrm{b} + \{\alpha/(1-\alpha)\}h(\xi). \end{aligned} \tag{9}$$

Thus the sales is linearly related to the profit. If we take the sales as the proxy for $1/\lambda$, therefore, it contradicts the initial assumption. The number of employees is, on the other hand, directly related to the quantity produced which is assumed to be nonstochastic. Therefore it seems more compatible with the theoretical model to use the number of employees as the size variable. In addition, observers on employment practice of Japanese firms have reported that adjustment of the number of employees is made relatively more slowly than fluctuation of sales and profit.[13)]

As the second proxy for the inverse of the degree of risk aversion, x_3 in Equation (8), Kawasaki and McMillan used "the proportion of materials secured by the subcontractor himself." However, once we hypothesize (A2) and (A3), we come across the following problem. Suppose that two suppliers X and Y have an identical number of customers but are in different situations in the following sense. X has already become a satellite to a large and growing firm and, further, has been securing this firm as its main customer in terms of the share in the total sales of X. Starting from this foothold, it has recently acquired additional customers. On the other hand, Y has never become a satellite to any firm that can offer a large and growing market, so that Y has been compelled to diversify its customers from an early stage of development. Then, (A2) and (A3) imply: the main customer of X will endeavor to absorb risks involved in its transaction with X to a greater extent than any customer of Y will do in its transaction with Y. For this reason, we use a different variable as the second proxy for risk aversion.

The new variable, denoted by SPEC, represents the degree of concentration of the business of the supplier in question to a specific core firm. To determine the value of SPEC for each supplier, we use the reports by IRC as the data source. If the share occupied by a specific core firm, say Nissan, in the total sales of a particular supplier, say Aichi Kikai, is found to be equal to or more than 33 percent, we assign 1 as the value of SPEC of this supplier in its relation to that core firm. If the ratio is below 33 percent, we assign 0. Thus we treat SPEC as a dummy variable.[14)] We predict that the coefficient of SPEC will take a strictly negative value. Thus, SPEC is introduced directly based on (1) of (A3) stated in Section 1. The threshhold value of 33 percent used in determination of the value of SPEC is based on a piece of information acquired in the process of field research.

5. The Results and Interpretations

The Sharing Parameter

As has been noted by Kawasaki and McMillan, Equation (5) in Section 2 can be rearranged into

$$\alpha = 1 - s/\sigma, \tag{10}$$

where s and σ represent the standard deviations of profit and cost. We start our estimations from computing the value of the sharing parameter α using Equation (10), for each of the suppliers that comprise our sample.

For profit, we used the value of *eigyo rieki* (operating income) in the profit and loss statement available from the Cosmos 1 Data File. For cost, we used the value of *uriage genka* (cost of sales) available from the same source. By construction of our data set, values of these items are available for 11 consecutive fiscal years backward from the fiscal year of 1987. From these values, we first computed s and σ, and then α.

To show the values of α for all of the supplier in the sample would consume too much space. We therefore show in TABLE 2, as the summarized result, only the mean and variance taken over all of the satellites to each of the four core firms.

< TABLE 2 about here >

Testing of Risk Aversion

Before we proceed to testing the principal–agent model, we estimate the degree of risk aversion, λ, as Kawasaki and McMillan did in Section 5 of their article. Estimation of λ can be done in two different ways. The first is to apply the same method that Kawasaki and McMillan used in reaching the results shown in their TABLE 2. The method consists of two steps. The first step is to derive the following equation, using the assumptions of constant risk aversion and normality of cost and profit disturbances, from the expression for the subcontractor's expected utility of profit:

$$\mu = (\lambda/2)s^2 + k, \tag{11}$$

where μ is the mean of profit and k corresponds to the profit after risk premium. The second step is to estimate $\lambda/2$ and k for each group of satellites sorrounding a core firm by a regression using the values of μ and s^2 computed from the time series data on profit from Cosmos 1 Data File. The result acquired by this method is shown by our TABLE 3.

< TABLE 3 about here >

Another way of estimating λ is as follows. Note first that, for Kawasaki and McMillan, it was impossible to go beyond computing just one value of λ for all of the firms subsumed in a class, since only classified aggregate data were available to them. But, since data on individual suppliers are available to us, we can go beyond computing just one value of λ for all of the satellites surrounding a core firm, which we have done right now by the first method. As the initial step, let us note the following two points. First, on the purely theoretical ground, λ should most plausibly decrease as the size of the firm increases. Second, TABLE II by Kawasaki and McMillan clearly shows that the result of their empirical testing indeed supports this theoretical reasoning. Taking note of these two points, let us presume a function $\lambda = \lambda(z)$, where z represents the size of the firm. Within the family of functions which have the property that the value of the function λ decreases as z increases, we choose the following two functions and try to estimate the parameters of the functions.

(Case 1) $$\lambda = c_0\exp(-c_1 z) \qquad (12)$$

(Case 2) $$\lambda = d_0 + d_1/z \qquad (13)$$

Inserting (12) or (13) into (11), we eliminated λ. Then, using the data on μ and s^2, and the number of employees as the value of z, we estimated (c_0,c_1,k) or (d_0,d_1,k) by the maximum likelihood method. The acquired results are shown in TABLE 4 and TABLE 5 respectively. Note that the estimates of c_0, c_1, d_0, and d_1 take positive values for all of the satellite groups. This corroborates our prediction that all of the sattelites are risk averse and their degree of absolute risk aversion decreases as the size of the firm increases, which also reinforces one of the main results acquired by Kawasaki and McMillan.

< TABLE 4 about here >

< TABLE 5 about here >

Test of the Principal–Agent Model

To test the principal–agent model given by Equation (7), we used, just as Kawasaki and McMillan did, two kinds of estimation equations both of which are derived from Equation (7). The first one corresponds to their Model 1. As has been explained in Section 4, we replaced their two proxies for risk aversion by NUM and SPEC. Further, we introduced IMP1 and

IMP2 in place of their two proxies for moral hazard. Thus our first estimation equation is:

$$\ln(1/\alpha - 1) = a_0 + a_1\ln(1/\sigma^2) + a_2\text{NUM} + a_3\text{SPEC} + a_4\text{IMP1} + a_5\text{IMP2} + \varepsilon, \quad (14)$$

where a_3 is predicted to take a negative value, while a_1, a_2, a_4, and a_5 are predicted to be positive, and a_4 is predicted to be larger than a_5.

Our second estimation equation, which corresponds to Model 2 of Kawasaki and McMillan, is:

$$\ln(1/\alpha - 1) = b_0 + b_1\ln(1/\sigma^2) + b_2\ln(1/\lambda) + b_4\text{IMP1} + b_5\text{IMP2} + \varepsilon, \quad (15)$$

where b_1, b_2, b_4, and b_5 are predicted to be positive, and b_4 is predicted to take a larger value than b_5.

Using the results given in the previous subsection, we estimated the coefficients of (15) by two methods. In the first method, we assumed that λ can be expressed as an exponential function of the size of the firm, z, as is in (12); then, using the values of parameters of the function, c_0 and c_1, given in TABLE 4, and the values of z given by *Cosmos 1 Data File*, we computed λ for each of the suppliers. Using the values of λ thus acquired, the coefficients were estimated. In the second method, we adopted hyperbolic function as the functional form of $\lambda = \lambda\ (z)$, as is in (13); then, using the values of d_0 and d_1 given in TABLE 5 and those of z, we computed the values of λ , using which the coefficients were estimated.

The results of the estimation of Equation (14) are shown in TABLE 6. The estimates of the coefficients of Equation (15) acquired by the first method explained above are shown in TABLE 7 under the name of (15a), those acquired by the second method being given in TABLE 8 under the name of (15b). For all of the estimations of the coefficients of these equations, OLS was used.

< TABLE 6 about here >

<TABLE 7 about here>

<TABLE 8 about here>

Interpretation of the results

In the first place, the results acquired for α shown in TABLE 2 are striking. From the very definition of α given by Equation (10) and the mothod we adopted for estimation, what TABLE 2 is exactly telling us is as follows. Take any of the four groups of satellites that surround the four major Japanese automobile manufacturers respectively. Then, the suppliers in the group have shown, on average, the following sort of financial performance: in comparison to the fluctuation of cost of sales that the average supplier experienced over the past eleven fiscal years, the fluctuation of operating income that the same supplier had over the same period was only 10 percent in magnitude. What factors have worked as shock absorbers ? We cannot entirely deny the possibility that some accounting practices or financial operations meant for leveling the reported income figures over time may have exerted influence. But, since we are working on operating income here, not dealing with ordinary income nor net income, it is not very likely that such practices or operations could become the dominant factor. Thus we can regard that the phenomenon we observe here as being caused by, for the most part, the nature of business transactions which these suppliers have been engaged in. Here again, we cannot entirely deny the possibility that the transactions with firms other than the specific core firm in question may have exerted influence. That such effect should be taken into account must be especially true for those suppliers for which the SPEC variable takes the value of zero. Yet, the most natural way to interprete the results in TABLE 2 seems to be to presume that the core firms have significantly absorbed external shocks incurred by their suppliers, mainly through ex post price adjustments conducted at each period in a manner that can be approximated by the model we are using. As will be discussed shortly, the SPEC variable is shown to affect the value of α in the positive direction as has been predicted. This reinforces the interpretation of TABLE 2 we have just given.

Comparison of our TABLE 2 with TABLE I in Kawasaki and McMillan (1987) reveals one interesting point. The values we acquired for α are, on the whole, much larger than those estimated by Kawasaki and McMillan, except that their estimate for one class of firms which belong to the transportation equipment industry and have 50 to 99 employees comes very close to our estimates. This difference between our estimates and theirs seems to reflect the following observed phenomenon which has been subsumed by (A1) and (A2) in Section 1. The phenomenon is that, among the transactions that core firms have with all of their suppliers, only in those which they have with their "satellites," core firms seriously think about absorbing risks based on long-term considerations.

A caveat becomes necessary in making inferences from the results shown in TABLEs 3, 6, 7, and 8. Since we are making cross-sectional analyses of firms here, homoscedasticity of the error terms is unlikely to hold, meaning that t-statistics from OLS will not be consistent.[15)] We therefore computed White-adjusted t-statistics, the values of which are shown in the parentheses under the estimates in these TABLEs. It has turned out that, notwithstanding this adjustment, a considerable number of the estimates remain significant; at some places, White-adjusted t-statistics takes even more favorable values in comparison to the values taken by ordinary t-statistics that are shown in the corresponding TABLEs in Asanuma and Kikutani (1990).

Let us look at the test of the principal-agent model, starting from TABLE 6. As to the effect of the degree of cost fluctuations, the coefficient takes positive values for all of the satellite groups as has been predicted, and the estimates are significant all over. This reinforces one of the main results reported by Kawasaki and McMillan. Concerning the effect of the firm size measured by the number of employees, the coefficient takes uniformly positive values here again as has been predicted. The estimates are not only significant, but also taking larger values for the satellites of Toyota and those of MMC than other satellite groups. This parallels a result seen in TABLEs 4 and 5 that for the satellites of Toyota and those of MMC the degree of risk aversion decreases with the increase of the size of the supplier more sharply in comparison to other satellite groups.

Regarding the effect of SPEC, the coefficient takes negative values and the estimates are significant all over, which supports our prediction. In comparison with the result of the test of a similar hypothesis exercised by Kawasaki and McMillan using the number of parent firms as the proxy, our SPEC has brought a more satisfactory result. A second caveat should be mentioned in this connection, however. We cannot deny the possibility that SPEC may represent aspects of both risk aversion and moral hazard. If SPEC is large because the supplier has been supplying a number of different items in parallel to the core firm in question, then the core firm may be able to assume that the moral hazard associated with a particular contract for a particular item is relatively small, for the supplier knows that poor performance on this contract can be punished by the core firm's refusing to renew its other contracts. Thus SPEC's being large could mean that the supplier is very risk averse and that moral hazard is small. Both effects work in the same direction in the regression equation, which might explain the fact that the estimation results show the SPEC coefficient to be significant.[16)]

Concerning the effect of the degree of evolution, the coefficient of IMP1 is larger than that of IMP2 and both are positive for all of the satellite groups. Again, this is consonant with our prediction. Although only half of the estimates are significant, the result has been improved in comparison to the estimated coefficient acquired by Kawasaki and McMillan for the wage/material cost variable. One might guess, however, that the degree of evolution achieved by the supplier would tend to be related to the size of the firm. If this is in fact true, then the multicollinearity problem arises. To investigate the extent of correlation between the degree of evolution variable and the size variable, we classified all of the satellites to each of the four automobile manufacturers into the following six classes and computed the average number of employees for the firms in each of the classes: (SPEC, IMP1), (SPEC, IMP2), (SPEC, IMP3), (NONSPEC, IMP1), (NONSPEC, IMP2), and (NONSPEC, IMP3). For the suppliers in the NONSPEC category, the following is indeed true for all of the four core firm groups: as we proceed from IMP3 suppliers to IMP2 suppliers and then to IMP1 suppliers, the average number of suppliers increases stepwise. On the other hand, however, for the suppliers in the SPEC category, the same does not hold all over. For Mazda and Mitsubishi, IMP2 suppliers have, on average, a greater number of employees than IMP1 suppliers. But, we should admit that this result may in turn have been subject to sampling bias. This is because, as we have mentioned before, necessary data were not available for all of firms in each of the satellite groups, and hence, when we divide our sample satellites into six classes, the number of firms in a class sometimes becomes very small. We therefore cannot dismiss the correlation issue as the result of this investigation of our sample. However, at the level of theoretical conception with a limited number of concrete examples, we do not think that the degree of evolution must proceed with the size of firm hand in hand. For instance, a supplier named Usui Kokusai Sangyo, Inc. has expertise in producing fine tubes including fuel and brake tubes and should be classified into IMP1. It nevertheless has kept to be a moderate sized firm, which had only 720 employees as of 1986. On the other hand, we have classified several large chemical firms into IMP2, as long as they are supplying not so high value added items as just one component of their much diversified product portfolio. In sum, the result we acquired for the degree of evolution variable cannot be taken as final and decisive, which is our third caveat. We nevertheless believe that the result is providing a useful foothold for further progress.

Let us turn to TABLE 7 and TABLE 8. These are meant to provide a pair of results both of which correspond to the result shown by Kawasaki and McMillan in their TABLE III for their Model II. As has been mentioned before, to get estimates shown in TABLE 7(8), we used the values of λ acquired utilizing the results shown in TABLE 4(5). Since nonlinear estimations were done to get the results shown in TABLEs 4 and 5, inferences on significance of the estimated coefficients based on t–statistics should be made with caution. Bearing this caveat in mind, we see in TABLEs 7 and 8, most of the coefficients have the predicted signs and are significant. The results shown in TABLEs 7 and 8 are, on the whole, comparable to those shown in TABLE 6. In comparing the two, TABLE 8 gives somewhat better results than TABLE 7 on the whole, except that in TABLE 8 the coefficient of IMP2 takes a negative but insignificant value for the satellites of Toyota.

6. Concluding Remarks

In this paper we presented the results of our attempt to proceed one step further in the analysis of Japanese manufacturer–supplier relationships using a seminal accomplishment by Kawasaki and McMillan as an important foothold. Though a number of caveats mentioned in Section 5 should be borne in mind in interpreting the results of our estimation, the results presented in this paper provide interesting evidence on the nature of relations between Japanese major core firms and their suppliers. Not only it reinforces the three major findings reported by Kawasaki and McMillan, it illuminates a couple of important aspects anew by virtue of the newly constructed data set. For one thing, the values of sharing parameter are found to be higher than those reported by Kawasaki and McMillan, when we focus on the relations between major core firms and their "satellite" type suppliers. For another, the attitudes taken by the four major core firms toward their respective satellites on risk absorption are found to be surprisingly similar; the empirical laws summarized as (1) and (2) of (A3) in Section 1 that Asanuma has elicited through his field research seem to be supportable in light of the quantitative data that we have mobilized in this research.

Concerning RSH, there seems to be little room that this can survive rigorous testing. As Asanuma recognized in (A1), there do exist some suppliers that are used by some core firm as capacity buffer. But, to explain such use of some firm, the economic theory of risk bearing is neither suited nor necessary. As Kawasaki and McMillan (1987) asserted in the second paragraph of p. 345, it can be explained simply by downward (upward) movement of opportunity cost of internal production perceived by core firms in business downswings (upswings).

The empirical laws summarized as (1) and (2) of (A3) may seem paradoxical to those who have been accustomed to RSH, but are not difficult to explain if we put things in an evolutionary perspective as follows. As Tasugi (1961) rightly perceived thirty years ago, the primary motive for a major core firm to employ the firms in the nucleus part of its suppliers is not to make a buffer against business fluctuations, but to tap specialized abilities accumulated by these firms making it thereby possible to use its own human resources in a more concentrated way. But, to secure sufficient adaptability of the production network thus spanned, these suppliers are required to develop a certain kind of skill named "relation–specific skill" by Asanuma (1989). Development of this skill, in turn, requires continuity of the relation. Further, the core firm has to care about the health of each supplier, as far as it has cleared initial screening for admission to the nucleus group and continues to pass experience ratings, to promote development of this skill. The more underdeveloped the supplier, the more concerned the core firm has to be about the health of this supplier; as the supplier grows up, the core firm can gradually decrease its attention.

Several problems remain to be further illuminated. First, in the theoretical model used in this paper, the quantity ordered from the subcontractor for each period is normalized to one. Hence the effect of quantity fluctuation experienced over time cannot be analyzed. Though it seems difficult to obtain relevant data for this type of analysis, the task of developing a suitable theoretical model nonetheless remains. Second, extending the type of analysis that we have done in this paper toward the manufacturer–dealer interface seems to be a very interesting task. Such work is expected to contribute to illuminate more fully aspects of the risk sharing mechanism developed in the Japanese society.

Footnotes

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1. The term subcontracting has been used in several meanings both in practice and in the literature. In its broadest meaning, it is used as synonymous with purchasing of any sort of the part or processing service necessary to manufacture a final product. This coincides with the use of the term in the first paragraph of the text. In another usage, purchasing of noncustomized parts or processing services is excluded from the meaning of the term. In a still narrower usage, only purchasing of DS parts in Asanuma's terminology is contained in the meaning of the term. In the main body of this paper, the term is used in its second meaning for the reason that will be given in the text.

2. *Yuka Shoken Hokokusho Soran* of each Japanese automobile manufacturer contains a brief description of the outside purchasing of the company. The term outside purchasing ratio is defined in this source as the proportion of the payment to outside firms for the parts and processing services purchased therefrom in the total manufacturing costs incurred by the automobile manufacturer to build one unit of vehicle. The ratio typically ranges from 70 to 75 percent. By comparing this information with TABLE 1 in Page 30 of Cole and Yakushiji (1984), it can be inferred that GM and Ford have been buying less portion from outside in comparison to any Japanese automobile manufacturers. Further, in MITI (1984), the result of a field research has been reported to illuminate that, in TV set production, typical Japanese

firms have tended to buy more portion from outside in comparison to their American counterpart.

3. MITI(1984) has manifested the view that the social division of labor achieved by subcontracting has significantly contributed to the postwar development of Japanese manufacturing industryand the importance of the role played by subcontractors is foreseen to grow, rather than decline, as products of the high value-added types come to occupy greater portions of national products. Both Altshuler et.al.(1984) and Cole and Yakushiji (1984) have noted that one of the competitive edges shared by major Japanese automobile manufacturers vis-a-vis their foreign competitors must reside in manufacturer-supplier relationships and that that a currently discernible trend in the U.S. and Western Europe is a movement toward more vertical disintegration with closer manufacturer-supplier interface. More recently, The MIT Commission on Industrial Productivity (1989) has stressed that the component supply system developed in Japan contains elements worth emulation by American automobile manufacturers. In a more general context, Milgrom and Roberts (1990) have clarified that an integral aspect of modern manufacturing is to increase reliance on outside suppliers which, although keep independence in terms of ownership, are linked with the firm on the purchasing side by closer communication than in the traditional arms-length exchange relations.

4. For a description of the typical characterization of Japanese subcontracting system in the context of the "dual structure," see Chapter 5 of Nakamura (1981), especially p.175. Chapter 4 of Friedman (1988) contains a useful historical overview of the "dual structure" view, as well as the result of his empirical study that has led him to the conclusion that, in actuality, applicability of the characterization of the Japanese Economy put forth by the "dual structure" view is limited to the period from the late 1930s to the late 1960s. Nakamura himself seems to hold the view that the "dual structure" began to emerge in the 1920s, was a real problem in the 1950s, and then became insignificant during the 1960s. But, the momentum of the "dual structure" view remained quite strong long after the beginning of the 1970s. See also footnote 6 for a related point.

5. In a pioneering study of subcontracting relationships in the Japanese machinery industry, the same author had already noted that there was a possibile line of development toward such

a direction. See Tasugi (1941), especially pp.253–254.

6. See Sato (1989) for a historical survey of the research on the Japanese small and medium sized firms.

7. See also Aoki (1984b) for further remarks on this point. For his more recent remarks on manufacturer–supplier relationships in Japan, see Aoki (1988, 1990).

8. For the terminology of the "Ordered Goods," "Marketed Goods," and so on, see Asanuma (1989).

9. Our definition of the term "satellite" allows that s supplier can be a satellite of more than one core firms simulataneously. In fact, a number of such cases can be found. In other words, the groups of satellites surrounding major core firms are not disjoint.

10. For this exposition of the incentive effect, see Aoki (1988), p.213.

11. According to a press release made by Nissan in April 1991, reorganization of the two cooperative associations of parts suppliers to Nissan will take place in June 1991. Takarakai and Shohokai will be dissoluted to form a single association named Nisshokai. The principal motive is to respond to criticism of the closed nature of the traditional form of the two organizations. As far as Takarakai and Shohokai stood separately based on different principles for membership as is described in the text, it was inevitable for Nissan to face such criticism.

12. The reader may want to know here why the group of the "satellites" to Honda has been removed from the object of our analysis. The reason is that Honda's purchasing behavior has been somewhat anomalous in comparison to other Japanese automobile manufacturer, making it difficult to apply the same method that we use in this paper. The anomaly occurs in the following two respects. First, Honda has never had any cooperative association corresponding to its corporate headquarters level, while each of Honda's plants located in different places in Japan has had cooperative associations comprised by local and small sized suppliers. This makes it impossible to delineate the entire body of the satellites to Honda using the member

list of cooperative association as we did for other core firms. Second, from 1978 on, each annual edition of *Nippon no Jidosha Buhin Kogyo* does provide a name list of "main suppliers to Honda" as an appendix to the portion where member lists of the cooperative associations to other automobile manufacturers are given. However, as TABLE 1 shows, the composition of the "main suppliers to Honda" is significantly more fluid than that of the cooperative associations of other automobile manufacturers. Thus, it is questionable whether the list of "main suppliers of Honda" can be taken as equivalent to the list of the satellites to Honda. Further research is required to determine (a) how and to what extent Honda has made effort to build up its own satellites and (b) the names of the satellites, before extending our analysis to cover Honda.

13. See, for instance, Chapter 7 of Muramatsu (1983).

14. Obviously it would be nicer if we could treat SPEC as a continuous variable. Due to lack of sufficient data, however, such treatment is impossible.

15. We thank an annonymous referee for pointing out this problem and suggesting the use of White–adjusted–t statistics which are consistent under heteroscedasticity.

16. We owe this point to John McMillan.

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TABLE 1

Stability of membership of satellites by core firm

	Name of the core firm				
	Toyota	Nissan	Mazda*	MMC	Honda
Average number of satellites (1978–1987)	180	161	176	338	331
Average number of yearly exit (1978–1987)	1.5	2.0	2.0	8.1	25.9
Average number of yearly entry (1978–1987)	1.3	2.3	3.0	7.6	20.3

* Mazda's averages are taken over the period of 1981–1987 since data on Yokokai, its recently organized nationwide cooperative organization of suppliers, is available only from 1981.

TABLE 2

The mean and variance of α of satellites by core firm

	Name of the core firm			
	Toyota	Nissan	Mazda	MMC
Number of satellites in the sample	96	75	87	97
Mean of α	0.9061	0.9133	0.9081	0.9031
Variance of α	0.0056	0.0043	0.0057	0.0052

TABLE 3

Estimates of risk aversion (unit of k: 10^5 yen)

Estimated coefficient	Name of the core firm: Toyota	Nissan	Mazda	MMC
$(\lambda/2) \times 10^3$	0.8229**	0.7302**	0.8124**	1.339**
	(6.913)	(10.05)	(8.268)	(9.539)
k	39689**	46104**	43794**	29121**
	(6.070)	(5.526)	(6.060)	(6.195)
Adj.R^2	0.8038	0.8478	0.8615	0.8569

** Significant at the 1 percent level.

TABLE 4

Estimates of risk aversion (unit of k: 10^5 yen)
[The case of exponential function: equation (12)]

Estimated coefficient	Name of the core firm			
	Toyota	Nissan	Mazda	MMC
$c_0 \times 10^3$	3.5283*	0.7975*	0.0287*	5.3460*
	(9.920)	(5.809)	(10.208)	(6.904)
$c_1 \times 10^5$	2.3498*	0.1369	1.7880*	3.3110*
	(13.077)	(0.0529)	(12.001)	(9.265)
k	27557*	45423*	31711*	21377*
	(5.090)	(4.035)	(5.186)	(4.234)
Adj.R^2	0.9092	0.8463	0.9370	0.8899

* Significant at the 5 percent level.

TABLE 5

Estimates of risk aversion (unit of k: 10^5 yen)
[The case of hyperbolic function: equation (13)]

Estimated coefficient	Name of the core firm			
	Toyota	Nissan	Mazda	MMC
$d_0 \times 10^3$	0.3639* (5.286)	0.5899* (6.432)	0.0019* (2.735)	0.6702* (5.456)
$d_1 \times 10^5$	28.222* (7.593)	8.3081* (1.659)	0.4323* (9.310)	28.152* (5.916)
k	19705* (2.967)	39765* (3.416)	14551* (2.080)	15627* (2.965)
Adj.R^2	0.8776	0.8514	0.9310	0.8946

* Significant at the 5 percent level.

TABLE 6

Test of the Principal–Agent Model
[Equation (14)]

Independent variable	Name of the core firm			
	Toyota	Nissan	Mazda	MMC
a_0	0.5485 (0.9422)	0.0741 (0.1059)	0.4837 (0.5374)	0.3226 (0.5306)
$\log(1/\sigma^2)$	0.1719** (4.723)	0.1522** (3.896)	0.1423** (3.515)	0.1791** (4.650)
NUM $\times 10^{-4}$	0.2568** (2.639)	0.1572* (2.207)	0.1203* (1.794)	0.2889** (2.647)
SPEC	–0.4245** (–2.797)	–0.4218** (–2.650)	–0.5602* (–2.198)	–0.5682* (–2.276)
IMP1	0.2486 (1.168)	0.5235* (2.065)	0.5456** (2.478)	0.4720** (2.425)
IMP2	0.0727 (0.3227)	0.2136 (0.7838)	0.2398 (1.201)	0.4102* (2.080)
Adj.R^2	0.2037	0.1477	0.1711	0.1705

* Significant at the 5 percent level.

** Significant at the 1 percent level.

TABLE 7

Test of the Principal–Agent Model
[The case of exponential function: equation (15a)]

Independent variable	Name of the core firm			
	Toyota	Nissan	Mazda	MMC
b_0	−5.173** (−3.372)	−95.97** (−2.747)	−6.282* (−1.989)	−3.628** (−3.337)
$\log(1/\sigma^2)$	0.1628** (4.556)	0.1457** (3.712)	0.1221** (2.989)	0.1502** (4.129)
$\log(1/\lambda)$	1.083** (2.854)	14.87** (2.700)	0.6925 (1.624)	0.7395* (2.283)
IMP1	0.3069 (1.319)	0.3748 (1.350)	0.6427** (3.013)	0.5218** (2.393)
IMP2	0.1243 (0.5338)	0.2803 (1.049)	0.3512* (1.643)	0.4247* (2.085)
Adj.R^2	0.1512	0.1006	0.1258	0.1167

* Significant at the 5 percent level.

** Significant at the 1 percent level.

TABLE 8

Table of the Principal–Agent Model
[The case of hyperbolic function: equation (15b)]

Independent variable	Name of the core firm: Toyota	Nissan	Mazda	MMC
b_0	2.107**	−0.5513	0.9319	1.267**
	(3.856)	(−1.155)	(1.511)	(2.488)
$\log(1/\sigma^2)$	0.3934**	0.2851**	0.4284**	0.3408**
	(8.733)	(5.123)	(6.751)	(7.541)
$\log(1/\lambda)$	0.7721**	0.6813**	0.8060**	0.6525**
	(7.569)	(4.140)	(5.863)	(5.581)
IMP1	0.0753	0.3986	0.4051*	0.4833*
	(0.3401)	(1.559)	(2.272)	(2.270)
IMP2	−0.1431	0.0604	0.1178	0.2273
	(−0.7551)	(0.2719)	(0.7470)	(1.338)
Adj.R^2	0.3995	0.1862	0.3981	0.2747

* Significant at the 5 percent level.

**Significant at the 1 percent level.

Figure 1. The scheme to classify parts and suppliers