DETERMINANTS OF FIRM BOUNDARIES:
EMPIRICAL ANALYSIS OF THE JAPANESE AUTO INDUSTRY FROM 1984 TO 2002

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I. Introduction

This paper empirically examines the boundaries of the firm, focusing on the Japanese auto industry. We analyze make-or-buy decisions by Japanese OEMs on a variety of components to estimate what influenced their choices of vertical integration.

Since Coase's (1937) seminal work, the boundaries of the firm have long been one of most important issues for researchers, and the auto industry has been one of the most investigated industries.[1] One example is Monteberde and Teece (1982), which demonstrated transaction cost, which was measured by engineering efforts and firm-specificity to design components, indeed did matter for the vertical integration decision by OEMs (GM and Ford). This paper extends their analysis in three directions. First, for the dependent variable, in addition to the two choices (make internally or buy from the market), we put the third choice, "buy from affiliated ("keiretsu") suppliers." Second, for independent variables, we examine a set of new variables to measure multiple dimensions of contractibility. Third, we use a set of panel data of the Japanese auto industry, which we have built up to cover the make-or-buy decisions of 7 OEMs on 54 types of components for almost two decades from 1984 to 2002.[2]

II. Theoretical Framework

In this section we present a (reduced form) theoretical framework for the organizational and contract choice for efficient supply of a component in the automobile industry, drawing on the insights from the transaction cost economics (see Williamson (1975)) and the property rights theory (see Grossman and Hart (1986)), so as to derive testable propositions.

Efficient coordination of design and manufacturing, quality assurance, and low cost

[1] For example, GM's acquisition of Fisher Body was analyzed by Klein, Crawford and Alchian (1978), Hart (1978), and Langlois and Robertson (1995).

[2] We would like to thank the respondents to our questionnaire survey used in this research, Kentaro Nobeoka and Seiji Manabe, who jointly designed and carried out the survey, and our research assistants, Yangjoong Yun and Chikako Takanashi, who helped us build up the dataset.

are important determinants for the efficiency of component production. In the case of automobile industry, efficient coordination with an OEM in design and manufacturing is a particularly important factor, since an automobile is a system product, the performance of which depends critically on how much each key component is designed and manufactured in an integrative manner for a particular vehicle model. On the same ground, quality assurance is critical, since a failure of one key component can make the entire automobile non-functional.

To achieve efficiency in these terms, an OEM has the choice between integration and non-integration as well as the choice between the non-keiretsu (short-term[3]) contracting and keiretsu (relational or long-term) contracting. More specifically, we discuss how three alternatives, non-keiretsu outsourcing, keiretsu outsourcing, and vertical integration (Figure 1)[4], are chosen, taking into account of the transaction cost advantage of vertical integration for accommodating un-contractible design changes (see Bajari and Tadelis (2001) and Tadelis (2002)), the incentive effect of relational contracting for quality assurance (See Baker, Gibbons and Murphy (2002) for a recent contribution), and the ownership interest of the suppliers for cost reduction. We focus three key variables that would address these considerations: interdependency, specificity, and testability of a component.

Higher specificity of a component as well as higher interdependency between a component and the other components of an automobile would increase the value of vertical integration of that component production. High specificity would increase the hold-up risk for the OEM and high interdependency would require more frequent and extensive negotiations with an (internal or external) supplier when an OEM wishes to change the design of its

[3] Most of contracts with non-keiretsu suppliers are long-term (continues for more than 10 years), but could be regarded as shorter-term (higher probability of discontinuity of transaction) in comparison with those with keiretsu suppliers.
[4] There is a potential choice of non-keiretsu employment, in which an employee who is hired on a non-keiretsu basis performs a task. Although such possibility may also be important, we do not consider this choice in this paper.

components, which would not be easily contractible ex-ante. In the case of vertical integration the OEM has the control right to force such necessary changes at its will. On the other hand, if an independent supplier is involved, such design change initiated by the OEM would be costly, especially if it is made late in the process of automobile design or production. Such supplier can potentially hold-up the OEM by refusing the cooperation for such change. Such threat would be larger when the component is highly specific so that the ex-post lock-in is significant. Thus, the vertical integration would enable more frequent changes of the design of an automobile, including ex-post adjustments, so that it can economize the transaction cost in the sense of preventing the opportunity loss of design change or adaptation. Among outsourcing decisions, the long-term contracting or keiretsu outsourcing would have smaller transaction cost, since the keiretsu firm would have a smaller incentive to hold-up the OEM, given that such opportunistic behavior would result in the loss of the keiretsu relationship or in the removal of management of the keiretsu firm when the OEM has a significant ownership stake.

Let us turn to the determinants of production cost, which consists of the manufacturing cost for a given quality and the cost of quality assurance. If the quality of the component is easily testable, a contract conditional on the level of quality could be developed so that the switch from internal production to outsourcing from an external non-keiretsu supplier would not increase the quality assurance cost[5]. In addition, outsourcing to such external supplier would give a strong incentive for such firm to reduce the design and production cost, since it would often involve price-based (not cost-based) contracting. Thus, non-keiretsu market contracting would result in strong manufacturing cost reduction, without compromising the quality. On the other hand, if it is internalized, the incentive for cost reduction would be weak. Keirestu

[5] Here we assume that the testability of a component matters mainly in manufacturing stage, although it might affect the design stage as well by increasing the ex-post information available for implementation of the design.

contracting would also provide smaller incentive for cost-reduction, compared to non-keiretsu-market contracting, due to more limited competition.

On the other hand, in the case where the quality of the component is not easily testable by the OEM, the contract with respect to quality becomes significantly incomplete (see Barzel (1982) and Baker and Hubbard (2003) for the effects of information availability on the choice of organizational or contractual choice). Then, a non-keiretsu supplier would have the motivation to reduce the quality of the component to be supplied when it is effective for saving cost. Thus, the quality assurance cost would be high. On the other hand, a relational contracting could constrain the incentive for such quality-degradation, since once such conduct would be uncovered, the supplier would lose the keiretsu relationship. Rent from such relationship would motivate the firm to assure quality (Shapiro (1983)). In vertical integration, the provision of a strong cost-reducing incentive to an employee would not be used, so that such incentive for compromising quality due to multitasking is weak (Holmstrom and Milgrom (1991) for a theory and Slade (1996) for an empirical analysis). Thus, if the quality of the component is not easily testable, the relational contracting or vertical integration could be preferred for total cost reduction, including the cost of quality assurance. The potential room for quality-degradation would be high when the specificity of the component is high, since each such product requires new skills or investment in quality evaluation.

More formally, let us denote *integration* or *make* choice by the combination of $y=1$ and $z=0$, *keiretsu or relational contracting* choice by $z=1$ and $y=0$, and the *non-keiretsu* contracting choice by $z=0$ *and* $y=0$. Based on the above consideration, we can hypothesize that stronger ownership control by an OEM would enhance the value of the component in terms of its contribution of the total value of an automobile by enhancing design flexibility. Such effect increases with the specificity(s), interdependency (θ) and the interaction between the two of the component, considering the fact that the holdup problem would increase multiplicatively with interaction and specificity of the component. Keiretsu outsourcing would have a similar but attenuated effect on the value of the component, since design change, for an example, will involve negotiations between two firms. Thus, the value from the component is given by

$$v(y,z;s,\theta,t) = v_0 + a(1+\beta_1 s + \beta_2\theta + \beta_3 s\theta)(y+\mu z) + \varepsilon \tag{1}$$

, where $v_0 > 0, a > 0, \beta_1 > 0, \beta_2 > 0, \beta_3 > 0$ and $0 < \mu < 1$, reflecting higher transaction cost of keiretsu outsourcing than that of vertical integration. The marginal effect of higher specificity (or higher interdependency) on the value of the component increases with vertical integration or keiretsu outsourcing:

$$\partial^2 v(y,z;s,\theta,t)/\partial(\beta_1 s + \beta_2\theta + \beta_3 s\theta)\partial(y+\mu z) = a > 0 \tag{2}$$

The total cost function for the component supply consists of the manufacturing cost and the quality insurance cost. The manufacturing cost is the highest when integration is chosen, reflecting the effect of the loss of ownership interests in cost reduction. On the other hand, the cost of quality assurance matters when testability *t* is low and such cost is lower when integration is chosen or keiretsu sourcing is chosen. Thus, we have

$$\begin{aligned} &c(y,z;s,\theta,t) = \\ &c_0 + c_1(y+\kappa z) + c_2(1+\lambda_1 s)\{1-\delta(y+\rho z)\}/t + \eta \end{aligned} \tag{3}$$

We expect that $c_0 > 0, c_1 > 0, 0 < \kappa < 1$, $c_2 > 0, \lambda_1 > 0, \delta > 0, 0 < \rho < 1$, and η is a stochastic term. The second term is the manufacturing cost and the third term is the cost of quality assurance which declines with testability *t*. We have

$$\partial^2 c(y,z;\theta,s,t)/\partial(1+\lambda_1 s)\partial(y+\rho z) = -c_2\delta/t < 0 \tag{4}$$

Higher specificity (*s*) would result in higher cost under non-keiretsu contracting, when testability is low.

The efficient organizational and contractual choice is given by

$$\text{Max}_{y,z} \quad w = v(y,z;s,\theta,t) - c(y,z;s,\theta,t)$$

$$= v_0 + a(1+\beta_1 s + \beta_2\theta + \beta_3\theta s)(y+\mu z) + \varepsilon$$

$$- [c_0 + c_1(y+\kappa z) + c_2(1+\lambda_1 s)\{1-\delta(y+\rho z)\}/t + \eta] \qquad (5)$$

The choices are over vertical integration, keiretsu and non-keiretsu market: *(y,z)*={(1,0),(0,1),(0,0)}.

Given the above analytical framework, we can derive the following three propositions. The specificity (*s*) of a component only increases the value of the vertical integration and the relational contracting (the value of design flexibility and the value of quality assurance) and such effect becomes smaller when testability is high, since high testability reduces the cost of quality assurance, as shown below.

$$\partial^2 w / \partial s \partial y = a(\beta_2 + \beta_3\theta) + c_2\lambda_1\delta / t > 0 \qquad (6)$$

In addition, we have

$$\partial^2 w / \partial s \partial y > \partial^2 w / \partial s \partial z \, . \qquad (7)$$

given that $0 < \mu < 1$ and $0 < \rho < 1$. Thus, we have

Proposition 1 *(Transaction cost (specificity) as a determinant of organizational and contractual choice): We would observe more vertical integration relative to keiretsu outsourcing and less non-keiretsu outsourcing relative to keiretsu contracting for a component with more specificity (s). Such effect is weaker for a component with low testability and stronger with high* interdependency (θ).

We have a very similar result for the effect of interdependency (θ).

$$\partial^2 w / \partial \theta \partial y = a(\beta_2 + \beta_3 s) > 0 \qquad (8)$$

$$\partial^2 w / \partial\theta\partial y > \partial^2 w / \partial\theta\partial z \,. \qquad (9)$$

Thus

Proposition 2 *(Transaction cost (interdependency) as a determinant of organizational and contractual choice): We would observe more vertical integration relative to keiretsu outsourcing and less non-keiretsu outsourcing relative to keiretsu contracting for a component with higher* interdependency (θ). *Such effect is weaker for a component with high specificity.*

Finally, let us turn to the effect of testability of a component, which would increase the value of integration and keiretsu outsourcing, which in turn depends on the specificity of the component as well as on the level of testability.

$$\partial^2 w / \partial t\partial y = -c_2 (1 + \lambda_1 s)\delta / t^2 < 0 \qquad (10)$$

$$\partial^2 w / \partial t\partial z = \rho\partial^2 w / \partial t\partial y < 0 \qquad (11)$$

Thus, we have

Proposition 3 (Measurement cost as a determinant of organizational and contractual choice): *We would observe less vertical integration relative to keiretsu outsourcing and more non-keiretsu outsourcing relative to keiretsu outsourcing for a component that is easily testable when specificity is high.*

III. Econometric Model and Data

We evaluate the above three propositions based on the dataset of component transactions between 7 Japanese OEMs and their suppliers (including in-house divisions) of 54 major components for 7 every-three years from 1984 to 2002. A more detailed description and sources of the data are provided in Appendix.

The basic econometric model we employ is the following multinomial logistic model.

Firm i chooses one of the three organizational or contract choices for each component j for year t, according to the following probability function:

$$\begin{aligned} \Pr(choice_{i,j,t}) = f\,(&specificity_j, \text{int}erdependency_j, testatibility_j, crossterms_i, \\ &controls_{i,t}, firmdummies_i, yeardummies_t, \varepsilon_{i,j,t}) \end{aligned} \tag{12}$$

Since our data of the component characteristics are available for only one year (in any case these characteristics change only gradually over time), the estimation is essentially cross-section, although we do have variation of the production volume over time.

The dependent variable is the choice over the three alternative transaction modes (vertical integration, keiretsu outsourcing, non-keiretsu outsourcing[6]). In reality, a firm may use vertical integration, keiretsu outsourcing, and non-keiretsu outsourcing in combination for a component, but we have specified only one of them as the primary choice by choosing the transaction mode that supplies most. We use the choice of keiretsu outsourcing as the base and evaluate non-keiretsu outsourcing and vertical integration relative to keiretsu outsourcing in our multinomial estimation, to be consistent with the above propositions.

Our primary explanatory variables are *specificity*, *interdependency*, and *testability*, which are constructed from a questionnaire survey of automobile engineers at Japanese OEMs on the detailed characteristics of the components[7]. The variable *specificity* indicates how the interfaces and main part design of the component is specific to the firm[8]. The variable *interdependency* indicates the degree of relatedness with the other components in terms of design, structure, function, and manufacturing. The variable *testability* represents how easily the component can be tested as a stand-alone object, and whether it can be developed and experimented on the stand-alone basis as the performance target of the component can be easily

[6] See Appendix for the operational definition of keiretsu suppliers.
[7] See Appendix for the description of the survey and how these variables were measured.
[8] As shown in Appendix *specificity* is given by (6 - the degree of *industry-wide standardization*), which indicates how the interface of the component is clearly specified and how design specifications are standardized in the industry as a whole.

specified by numbers. We also use the interaction terms of these variables in order to assess their complementarities, as implied by the above theoretical framework.

Let us move on to control variables, which may affect the contractual or organizational choice. We introduce four additional variables indicating the characteristics of components as well as two variables indicating the scale and stability of OEMs' production.

The variable *complexity* indicates the level of technology used for the component, the speed of relevant technological changes, and the level of professional knowledge used for the design, and the complexity of the component itself. The technologically sophisticated complex component may be still outsourced if the OEM does not have the technological capability to design and manufacture it (an example is car audio equipment). This variable controls such correlation between the complexity and outsourcing of a component, based on a division of labor. The variable *safety* indicates how important the component is for the safety of the car, the variable *customer-value* indicates the value of the component (price cost margin) and its contribution to the marketability of the automobile. The variable *firm-standard* indicates the level of standardization of the interface, technology, manufacturing method, and design standards within a firm.

In addition, we use the level as well as the change of the total volume of vehicle production of the OEM. The former is included to examine how the degree of scale economy (manufacturing cost efficiency) of the OEM would affect the choice. The latter (annual change (%) in production volume on the average over the previous three years) is included to examine how the OEM used the choice to adjust for the change of production volume. Finally, we use 6 firm dummies and 6 year dummies to control firm level and year level fixed effects. We also introduce firm by year dummies for robustness check.

We also conduct supplementary estimation with the share of vertical integration and that of quasi-vertical integration (vertical integration plus keiretsu outsourcing) of the total purchase of a component as the dependent variable with the random effects assigned to each component.

Table 1 provides descriptive statistics for these variables. Figure 2 depicts how the choice changed over time in the industry as a whole in terms of simple arithmetic average of the choice over the entire sample components. The share of the choice for vertical integration was around 8.7% in 1984 and gradually declined to 5.6% in 2002. Keiretsu outsourcing accounted for around one third of the total procurement volume, and non-keiretsu outsourcing accounted for 55 to 60%. Figure 3 shows the relations between the choice and the three primary independent variables. It shows that the share of both vertical integration and keirestu outsourcing increases with interdependency and specificity, as we have expected, but not with testability. Figure 4 shows the variation of the choice among 7 sample OEM firms. It is clear that the share of keiretsu outsourcing increases with the production volume of the OEM, while such relationship is not clear for the share of vertical integration.

IV. Estimation Results

Table 2 presents two basic estimations. Model 1 does not use the interaction term, while Model 2 uses the interaction terms between *specificity* and *testability* and between *specificity* and *interdependency*. As shown in Model 1, the coefficients of both *specificity* and *interdependency* have expected signs, consistent with Proposition 1 and 2. Non-keiretsu outsourcing is significantly less preferred to keiretsu outsourcing for a component with high specificity *(s)* or high interdependency (θ). In addition, vertical integration is preferred to keiretsu outsourcing when interdependency or specificity is important (although only the former effect is significant). On the other hand, the variable *testability* has a wrong sign, indicating that testability favors keiretsu outsourcing over non-keiretsu market outsourcing, inconsistent with Proposition 3. We will inquire into this puzzle later.

Let us turn to the coefficients of control variables. *Complexity* and *firm-standard* favor keiretsu outsourcing over integration, while *customer-value* favors integration over keiretsu outsourcing. *Safety* and the level of production volume favors keiretsu outsourcing over non-keiretsu outsourcing, while customer value favors the reverse. Standardization within a firm promotes keiretsu outsourcing, consistent with our expectation. Finally, the production volume favors keiretsu outsourcing over the non-keiretsu outsourcing, which indicates the importance of the economy of scale for keiretsu production.

As for firm dummies, more variation across firms seems to exist for the choice over non-keiretsu outsourcing versus keiretsu outsourcing than that over integration versus keiretsu outsourcing. A larger automobile manufacturer (Toyota, Nissan and Honda) prefers keiretsu outsourcing, even though the production volume is controlled. This may indicate a non-linearity or other firm-specific issues. As for the choice between vertical integration and keiretsu outsourcing, Honda exceptionally disfavors integration. As for time dummies, we observe moves favoring keiretsu outsourcing: increasing choice of keiretsu outsourcing both over vertical integration and over non-keiretsu market outsourcing (except for year 2002[9]).

Let us turn to Model 2 with interaction terms. Let us start with the interaction between *specificity* and *testability.* What the coefficient of the interaction term suggests is that the specificity of the component favors vertical integration over keiretsu outsourcing and keiretsu outsourcing over non-keiretsu market outsourcing when testability is low, but the degree declines as the testability increases even though the relationship is not reversed. These results are consistent with Proposition 2. As for the interaction between *interdependency* and *specificity*,

[9] In the late 1990s some OEMs, such as Nissan and Mazda, discontinued their keiretsu relations with some suppliers by selling their stocks.

it is significant for the choice between vertical integration and keiretsu outsourcing, and *interdependency* favors non-keiretsu outsourcing even though higher specificity reduces such tendency. The latter result is not consistent with Proposition 1, which may reflect non-linearity of these effects. The interaction term for the choice between keiretsu outsourcing and non-keiretsu outsourcing is not significant. As for the control variables and the other variables, the estimation results are very similar to those for Model 1.

Models 3 and 4 of Table 3 inquire the source of the "wrong" sign of the testability variable, by estimating its firm-specific effects. Model 3 allows the coefficient of *testability* to vary by firms. Model 4 does the same for the GLS regression with the share of vertical integration and that of quasi-vertical integration (vertical integration plus keiretsu outsourcing) of the total purchase of a component as the dependent variable with the random effects assigned to each component. Both models suggest that Toyota significantly favors keiretsu outsourcing over non-keiretsu outsourcing when the testability of a component is high, in contrast with Proposition 3. In contrast, a smaller firm, Mazda, favors significantly keiretsu outsourcing over vertical integration and non-keiretsu outsourcing over keiretsu outsourcing when the testability of a component is high, which is consistent with Proposition 3.

V. Discussion and Conclusion

Our major findings are the following. Keiretsu outsourcing is preferred to non-keiretsu outsourcing for a component with high specificity *(s)* and high interdependency (θ). Vertical integration is preferred to keiretsu outsourcing when interdependency or specificity is high. These results provide strong evidence for the transaction cost advantage of vertical integration for accommodating un-contractible design changes.

In addition, we have found that the testability of a component significantly affects such choice. In particular, high testability reduces significantly the preference by the OEM to vertical integration over keiretsu outsourcing and that to keiretsu outsourcing over non-keiretsu outsourcing in the case of high specificity. This result seems to indicate the importance of the incentive effect of relational contracting for quality assurance. Thus, the organizational and contractual choice by the Japanese automobile firms with respect to component production is significantly consistent with the insights from the transaction cost economics and property right theory.

Our empirical analysis also indicates several interesting observations. Larger volume production by an OEM and more standardization within the firm promote keiretsu outsourcing both over non-keiretsu market outsourcing and over vertical integration, which may indicate the importance of the economy of scale base for the development of keiretsu network. Also, the observation that OEMs adjusted for changes in production volume by non-keiretsu suppliers (ordered more when the production volume expanded, and less when declined) may indicate some evidence to support the dualist theory (OEMs use non-keiretsu suppliers as a buffer for fluctuation in production volume)

There are, however, several puzzles. We have found that testability per se significantly makes the OEM to favor keiretsu outsourcing over non-keiretsu outsourcing. This result seems to be driven by the behavior of Toyota. In addition, the interaction between interdependency and specificity favors keiretsu-sourcing over vertical integration, which may reflect non-linearity of these effects.

References

Baker, George P., and Thomas Hubbard, 2003, “Make or Buy in Trucking: Asset Ownership, Job Design, and Information,” *American Economic Review*, 93, 551-572.

Baker, George, Robert Gibbons and Kevin J. Murphy. 2002. “Relational Contracts and the Theory of the Firm.” *Quarterly Journal of Economics* 117: 39-83.

Bajari, Patrick and Steven Tadelis, 2001, “Incentives versus Transaction Costs: A Theory of Procurement Contracts: A Theory of Procurement Contracts,” *Rand Journal of Economics*, Autumn, 32(3), pp. 387-407

Barzel, Yoram, 1982, “Measurement cost and the organization of markets,” *Journal of Law and Economics*, April, 25(1), pp. 27-48

Holmstrom, Bengt and Paul Milgrom, 1991, “Multitask Principal-agent Analyses: Incentive Contracts, Asset Ownership and Job Design,” *Journal of Law, Economics and Organization*, Spring, 7, pp.24-52.

Klein, B., R. G. Crawford, and A. Alchian, 1978, “Vertical Integration, Appropriable Rents, and the Competitive Contracting Process.” *Journal of Law and Economics*, 21 (2): 297-326.

Grossman, Sanford and Oliver Hart, 1986. “The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Ownership.” *Journal of Political Economy,* 94: 691-719.

Hart, Oliver, 1989, “An Economist’s Perspective on the Theory of the Firm.” *Columbia Law Review*, 89 (7): 1757-1774.

Langlois, R. and P. Robertson, 1995, *Firms, Markets and Economic Change*. Routledge: New York.

Lincoln, J., M. Gerlach, and P. Takahashi, 1992. “Keiretsu Networks in the Japanese Economy: A Dyad Analysis of Intercorporate Ties,” *American Sociological Review*, 57: 561-585.

Monteverde, K. and D. Teece, 1982. “Supplier Switching Costs and Vertical Integration.” *Bell Journal of Economics*, 13 (1): 206-213.

Slade, Margaret E., 1996, “Multitask Agency and Contract Choice: An Empirical Exploration,” *International Economic Review*, Vol. 37, No.2 pp. 465-486

Shapiro, C., 1983, “Premiums for High Quality Products as Rents to Reputation,” *Quarterly Journal of Economics* 98: 659-80.

Tadelis, Steven, 2002, “Complexity, Flexibility, and the Make-or-Buy Decision,” *American Economic Review*, Vol. 92, No.2 pp. 433-437

Williamson, Oliver, 1975, *Markets and Hierarchies: Analysis and Antitrust Implications.* Free Press: New York.

Appendix: Description of the Data

1. Sources

The data on component transactions between Japanese OEMs and suppliers were compiled from "Jidosha Buhin 200 Hinmoku Seisan-Ryutsu Chosa [Report on Production and Transactions of 200 Auto Components]", published every three years by IRC, a Japanese market research company. The report provides the information on which OEMs purchased how much (in volume) of each component from which suppliers, including in-house divisions, for their domestic operation for the year (see Table A1 for an example), covering approximately 200 types of components. We analyze seven OEMs (Toyota, Nissan, Honda, Mazda, Suzuki, Daihatsu, and Fuji Heavy Industry), all of which manufactured mainly passenger cars and light trucks. Other Japanese OEMs that manufactured heavy trucks are not included in our analysis.

Among about 200 components, we picked up 54 components that were covered by the report throughout the period we analyzed (from 1984 to 200). Table A2 lists the components included in the dataset.

To measure the nature of these components, a questionnaire survey was carried out with four Japanese OEMs (anonymous due to our confidential agreement). The survey was conducted between winter 2003 and summer 2004 jointly by Kentaro Nobeoka (Kobe University), Seiji Manabe (Yokohama National University), and Akira Takeishi. Engineers from these firms answered for each of the 54 components the questions about various dimensions of component characteristics mostly based on 5-point Likert-scale (See Table A3 for the questions to measure each variable of component charcteristics).

2. Definition of Keiretsu Suppliers

As for the definition of keiretsu suppliers, we use the definition by IRC, whose report shows if a particular supplier is a keiretsu supplier of a particular OEM. According to IRC, while the financial tie (stock ownership) is the most important factor to define keiretsu relationships, other factors such as sales dependency, director dispatch, and historical relationships, are also taken into consideration. For example, even without financial tie, a supplier is heavily dependent in sales for a long period upon a particular OEM and the industry generally sees the supplier as a keiretsu supplier of the OEM, it is a keiretsu supplier of the OEM in IRC's definition. Although IRC does not have an objective, well-defined definition of keiretsu suppliers, we think their definition captures well the actual perceptions shared by practitioners in the industry, which should be relevant in the make-or-buy decisions by OEMs. To define and use alternative, more objective definition is one of the next steps we would like to take in the future (see, for example, Lincoln, Gerlach, and Takahashi 1992 for discussion of Japanese keiretsu networks).

Figure 1 Organizational and Contractual Choice

		Organizational choice	
		Non-integration	Integration
Contractual choice	"spot"	non-keiretsu outsourcing	
	relational	keiretsu outsourcing	vertical integration

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Choice	2603	2.49	0.63	1	3
VI	2603	0.07	0.23	0	1
QVI	2603	0.42	0.45	0	1
interdependency	2603	3.89	0.54	2.34	4.84
intdpnttest	2603	13.41	2.32	8.65	18.05
specificity	2603	3.90	0.96	1.50	5.00
spectest	2603	13.39	3.55	5.06	19.41
intdpntspec	2603	15.30	4.71	4.73	24.22
testability	2603	3.48	0.56	2.25	4.44
complexity	2603	2.88	0.74	1.36	4.82
safety	2603	3.71	1.04	1	5
customer-value	2603	3.55	0.86	1.88	5.88
firm-standard	2603	3.63	0.53	2.35	4.60
production volume	2603	1.38	1.03	0.42	4.22
prod. vol. change	2603	1.44	8.58	-21.34	20.73
TYT	2603	0.15	0.35	0	1
NSN	2603	0.14	0.35	0	1
MZD	2603	0.14	0.35	0	1
HND	2603	0.14	0.35	0	1
SZK	2603	0.14	0.35	0	1
DHT	2603	0.14	0.35	0	1
YR87	2603	0.14	0.35	0	1
YR90	2603	0.14	0.35	0	1
YR93	2603	0.15	0.35	0	1
YR96	2603	0.14	0.35	0	1
YR99	2603	0.15	0.35	0	1
YR02	2603	0.14	0.35	0	1

Figure 2 Make-or-Buy Choices over Time

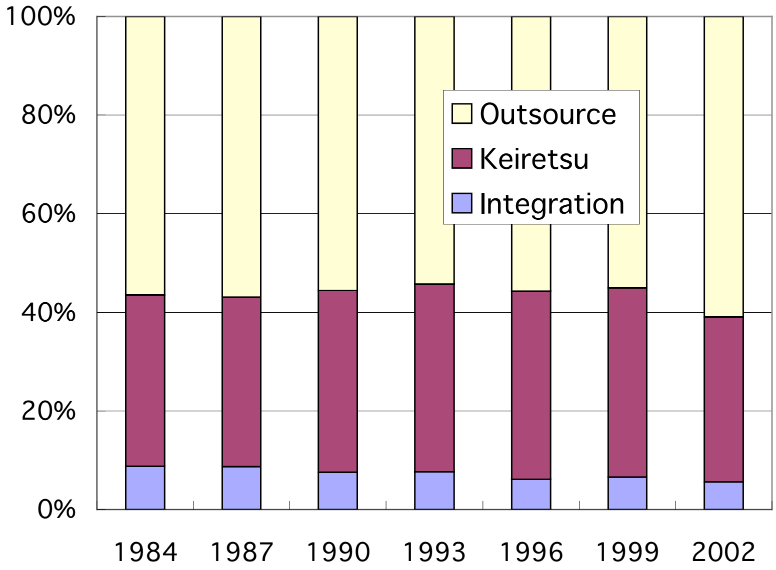

Figure 3 Frequency of Make-or-Buy Choices over Component Characteristics

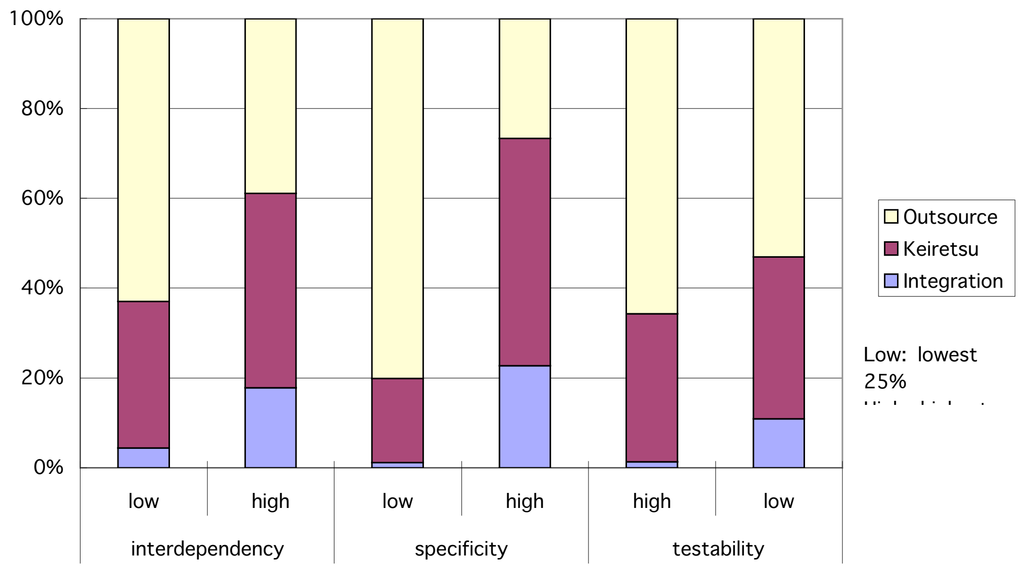

Figure 4 Make-or-Buy Choices by OEMs

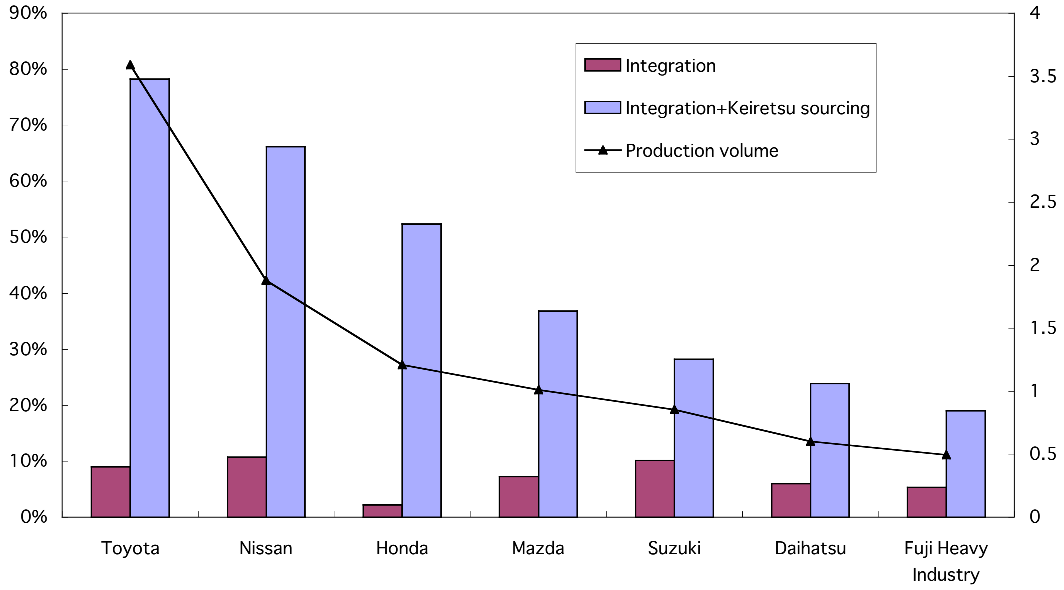

Table 2 Basic Estimation Results (Multinominal Logistic Regression)

		Model 1 with no interactions						Model2 with interactions					
		Vertical integration/ Keiretsu			Non-keiretsu/Keiretsu			Vertical integration/ Keiretsu			non-keiretsu/Keiretsu		
		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
transaction cost and measurement cost	specificity	0.19	0.18		-1.78	0.10	***	12.03	3.44	***	-4.70	0.88	***
	specificity ×testability							-1.92	0.42	***	0.82	0.15	***
	interdependency	2.11	0.28	***	-0.44	0.12	***	6.82	2.73	**	-0.45	0.58	
	interdependency×specificity							-1.03	0.57	*	0.06	0.14	
	testablity	-0.20	0.20		-0.57	0.11	***	8.82	1.94	***	-3.98	0.63	***
Control variables	complexity	-0.94	0.18	***	-0.17	0.11		-0.53	0.20	***	-0.24	0.11	**
	safety	-0.16	0.10		-0.14	0.06	***	-0.21	0.11	*	-0.19	0.06	***
	customer-value	1.18	0.18	***	0.24	0.10	**	0.80	0.20	***	0.25	0.10	**
	firm-standard	-0.59	0.21	***	-0.18	0.11	*	-0.42	0.24	*	-0.18	0.11	
	production volume	-0.23	0.48		-0.60	0.29	**	-0.20	0.48		-0.64	0.30	**
	production volume change	0.00	0.02		0.01	0.01		0.00	0.02		0.01	0.01	
Firm dummies	TYT	-0.19	1.52		-1.78	0.91	*	-0.10	1.52		-1.77	0.94	*
	NSN	-0.12	0.76		-1.95	0.45	***	-0.01	0.76		-1.92	0.45	***
	MZD	-0.21	0.45		-0.91	0.25	***	-0.16	0.45		-0.86	0.25	***
	HND	-2.11	0.58	***	-1.80	0.29	***	-2.03	0.58	***	-1.73	0.29	***
	SZK	-0.03	0.44		-0.25	0.25		-0.03	0.44		-0.22	0.25	
	DHT	0.55	0.37		-0.49	0.22	**	0.58	0.37		-0.48	0.22	**
Year Dummies	YR87	-0.01	0.32		0.07	0.20		-0.02	0.32		0.07	0.20	
	YR90	-0.23	0.34		-0.01	0.21		-0.24	0.35		-0.01	0.21	
	YR93	-0.28	0.39		-0.16	0.22		-0.28	0.40		-0.17	0.22	
	YR96	-0.66	0.35	*	-0.28	0.20		-0.66	0.36	*	-0.28	0.21	
	YR99	-0.55	0.36		-0.28	0.20		-0.56	0.36		-0.29	0.20	
	YR02	-0.61	0.36	*	0.10	0.20		-0.63	0.36	*	0.10	0.20	
	constant	-8.82	2.30	***	15.83	1.13	***	-63.93	16.41	***	25.69	3.71	***
		Number of obs = 2603						Number of obs = 2603					
		Log likelihood = -1581.7045			Pseudo R2 = 0.3105			Log likelihood = -1583.8695			Pseudo R2 = 0.3096		

Note: *** 1% significant, ** 5% significant and * 10% significant

Table 3 Extended Estimation Results

		Model 3 Multinomial logistic reegression with firm specific effects of testability				Model 4 GLS with the share of vertical integration and that of quasi-vertical integration as the dependent variable			
		Vertical integration/ Keiretsu		non-keiretsu/Keiretsu		Vertical integration		Quasi Vertical integration	
		Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Rob. Std. Err.	Coef.	Rob. Std. Err.
transaction cost and measurement cost	specificity	0.68	0.23 ***	-1.42	0.09 ***	0.036	0.027	0.192	0.038 ***
	specificity ×testability								
	interdependency	1.88	0.27 ***	-0.30	0.12 **	0.063	0.052	0.065	0.075
	interdependency×specificity								
	testablity	0.65	0.59	-0.44	0.30	0.031	0.048	0.073	0.070
	(additional effect) TYT	-0.28	0.69	-1.00	0.38 ***	-0.019	0.021	0.127	0.036 ***
	NSN	-0.94	0.68	-0.02	0.37	-0.056	0.021 ***	-0.031	0.036
	MZD	-1.71	0.76 **	0.28	0.38	-0.068	0.021 ***	-0.081	0.036 **
	HND	-0.88	0.97	-0.45	0.36	0.003	0.021	0.033	0.036
	SZK	-0.99	0.79	-0.29	0.40	-0.040	0.021 *	0.018	0.036
	DHT	0.16	0.72	0.22	0.39	-0.015	0.021	-0.012	0.036
Control variables	complexity	-0.70	0.19 ***	-0.16	0.11	-0.018	0.045	-0.006	0.064
	safety	-0.22	0.11 **	-0.20	0.06 ***	-0.002	0.024	0.029	0.034
	customer-value	1.00	0.20 ***	0.27	0.10 ***	0.049	0.041	-0.001	0.058
	firm-standard	-0.42	0.22 **	-0.14	0.11	-0.020	0.047	-0.006	0.068
	production volume	-0.21	0.48	-0.65	0.30 **	0.018	0.018	0.089	0.031 ***
	production volume change	0.00	0.02	0.01	0.01	0.000	0.001	-0.002	0.001 *
Firm dummies	TYT	0.84	2.80	1.72	1.61	0.066	0.092	-0.152	0.159
	NSN	3.07	2.42	-1.83	1.36	0.212	0.077 ***	0.439	0.135 ***
	MZD	5.33	2.53 **	-1.79	1.32	0.241	0.074 ***	0.384	0.129 ***
	HND	0.93	3.24	-0.15	1.29	-0.044	0.075	0.129	0.131
	SZK	3.30	2.69	0.78	1.41	0.153	0.074 **	-0.042	0.128
	DHT	-0.02	2.47	-1.23	1.37	0.100	0.073	0.116	0.127
Year Dummies	YR87	-0.01	0.32	0.07	0.20	-0.004	0.012	-0.014	0.021
	YR90	-0.23	0.35	-0.01	0.21	-0.011	0.013	-0.006	0.022
	YR93	-0.28	0.39	-0.17	0.22	-0.009	0.014	0.002	0.024
	YR96	-0.65	0.35 *	-0.29	0.21	-0.016	0.012	0.025	0.022
	YR99	-0.55	0.36	-0.29	0.20	-0.017	0.012	0.014	0.021
	YR02	-0.61	0.36 *	0.10	0.20	-0.028	0.012 **	-0.047	0.021 **
	constant	-13.26	2.96 ***	11.55	1.40 ***	-0.481	0.366	-1.169	0.527 **
		Number of obs = 2603				Number of obs = 2603, Number of groups = 54			
		Log likelihood = -1621.075		Pseudo R2 = 0.2933		R-sq: within = 0.0372		R-sq: within = 0.3634	
						between = 0.2437		between = 0.4274	
						overall = 0.1405		overall = 0.3903	

Note: *** 1% significant, ** 5% significant and * 10% significant

Table A1 Example of IRC Data
(the case of "changeable-timing valve unit" in 2002)

OEM	Supplier	Procurement Volume
Toyota	In-house	140.0
	Denso*	70.0
Nissan	Unisia-Jecks*	77.0
	Nittan-Valve	3.7
Honda	Unisia-Jecks	40.0
	Kehin*	32.0
Mazda	Mitsubishi Electric	5.2
Suzuki	Mikuni	27.0
Daihatsu	Aishin Seiki	30.0
	Denso	7.4
Fuji Heavy Industry	Denso	8.0

*=keiretsu supplier of the OEM
procuremet volume=for 1000 vehicles/month

Table A2 Components Included in the Data

ENGINE (INDUCTION / EXHAUST COMPONENTS)	1	Exhaust Manifolds
	2	Mufflers
ENGINE (LUBRICATION / COOLING COMPONENTS)	3	Water Pumps
	4	Oil Pans
	5	Oil Filters
	6	Thermostats
	7	Radiators
	8	Oil Pumps
ENGINE (ELECTRONIC SUPPLY COMPONENTS)	9	Alternators
	10	Starters
	11	Spark Plugs
	12	Distributors
	13	Butteries
ENGINE (FUEL SYSTEM COMPONENTS)	14	Carburetors
	15	Fuel Tanks
	16	Fuel Tubes
ENGINE (MAIN BODY COMPONENTS)	17	Engine Bearings
	18	Crankshafts (Cast+ Forged)
	19	Connecting Rods
	20	Cylinder Head Gaskets
	21	Pistons
SUSPENSION COMPONENT	22	Suspension Ball Joints
	23	Shock Absorbers
	24	Stabilizers
STEERING COMPONENTS	25	Steering Wheels
	26	Power Steering Systems
POWERTRAIN COMPONEN	27	AT
	28	MT
	29	Clutches
	30	Gear-Sticks
	31	Torque Control Levers
	32	Propeller Shafts
WHEELS / TIRES	33	Aluminum Wheels
	34	Steel Wheels
	35	Tires
EXTERIOR TRIM COMPON	36	Windshield Washers
	37	Window Regulators
	38	Glass
	39	Door Weather Strips
	40	Door Handles
	41	Door Locks
	42	Radiator Grills
	43	Windshield Wiper Assy
BODY ELECTRONIC COMP	44	Power Relays
	45	Flashers
	46	Horns
	47	Meters
	48	Lever Combination Switches
	49	Wire Harnesses
INTERIOR TRIM COMPONI	50	Sun Visors
	51	Seat Belts
	52	Power Seats / Seats (for passenger and commercial vehicles)
OTHERS	53	Air Conditioning Systems
	54	Audio Systems

Table A3 Measurement (Questions) of Component Characteristics

Component nature (category I)		*Interdependency*	*Specificity*	*Testability*	*Complexity*	*Firm-standard*	*Safety component*	*Customer value*
II-1	The connections between this component and other components (the interfaces with other components) have been clearly standardized as a set of rules within your company.					●		
II-2	The connections between this component and other components (the interfaces with other components) have been standardized and shared across your company.					●		
II-3	The connections between this component and other components (the interfaces with other components) have been clearly standardized as a set of rules within the industry. (*reversed scale)		●					
II-4	Techniques and methods for manufacturing the main part of this component have been standardized within your company.					●		
II-5	Criteria for designing the main part of this component (such as its dimension, strength and the materials to be used) have been standardized within your company.					●		
II-6	The main part of this component has been standardized and shared across your company.					●		
II-7	Criteria for designing the main part of this component have been standardized within the industry. (*reversed scale)		●					
III-1	This component is designed to perform a particular function only when combined with other components.	●						
III-2	When designing this component, its connections with other components have to be considered and adjusted carefully.	●						
III-3	The function of this component is self-contained. (It has little interdependency with other components). (*reversed scale)	●						
III-4	This component is structurally connected and interdependent with other components.	●						
III-5	A high degree of accuracy and precision is needed for this component when combined with other components (at the design and manufacturing levels) in order to ensure best performance and quality.	●						
III-6	A high degree of accuracy and precision is needed for this component when combined with other components (at the design and manufacturing levels) in order to achieve a better layout.	●						
III-7	When mounting this component or combining it with other components, coordination with the body and other components is required.	●						
IV-1	Advanced technology is used in this component.				●			
IV-2	The technology used in this component is fast-changing.				●			
IV-3	Highly sophisticated expertise is needed for designing this component.				●			
IV-4	This is an important safety component which greatly affects the safety of the vehicle.						●	
IV-5	The quality of this component can be assured independently of other components.			●				
IV-6	Prototype testing can be conducted independently of other components.			●				
IV-7	It is not easy to achieve the function and performance required for this component.				●			
IV-8	This component is comprised of many subcomponents.				●			
IV-9	This component is structurally complex.				●			
IV-10	The function and performance required for this component are complex (multidimensional).				●			
IV-11	The function and performance required for this component are vague in nature and difficult to measure in numeric terms. (*reversed scale)			●				
IV-12	It is difficult to manufacture this component in terms of quality and yield. (*reversed scale)			●				
IV-13	When designing this component, manufacturing requirements have to be carefully taken into consideration.	●						
IV-14	This component offers relatively high value (selling price/manufacturing cost) compared to other auto components.							●
IV-15	The quality of this component greatly affects the marketability of the end product (vehicle).							●

Note: the questions in the survey to measure each variable are shown.