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EMPIRICAL ANALYSIS OF THE JAPANESE AUTO INDUSTRY FROM 1984 TO 2002

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ABSTRACT

We have assessed the determinants of the choice of integration, relational contracting (keiretsu sourcing) and market sourcing by seven Japanese automobile manufacturers (OEMs) with respect to 54 components in light of contract economics. Our major findings are the following. First, the specificity and interdependency of a component significantly promotes vertical integration over keiretsu and keiretsu over market, consistent with transaction cost economics. Second, interdependency is a more important consideration for the former choice than for the latter choice, and the reverse is the case for specificity. This suggests that the hold-up risk due to specific investment can be often effectively controlled by a relational contracting based on keiretsu sourcing, while accommodating non-contractible design changes may often require vertical integration. Third, while higher testability of a component makes the effects of specificity significantly smaller, it also promotes the choice of keiretsu sourcing over market sourcing. One interpretation of this last result is that while higher testability improves the contractibility of the component with high specificity, it simultaneously enhances the advantage of keiretsu sourcing since it provides more opportunities for the supplier to explore new information for a collaborative exploitation with an OEM.

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1. Introduction

This paper empirically examines the determinants of the boundaries of the firm, focusing on the Japanese auto industry. Since Coase's (1937) seminal work, the boundaries of the firm have long been one of most challenging issues for researchers, and the auto industry has been one of the most investigated industries.[1] A seminal paper based on a transaction cost view of the firm boundary is Monteverde and Teece (1982), which demonstrated transaction cost, which was measured by engineering efforts and firm-specificity to design components, mattered for the vertical integration decision by OEMs (GM and Ford)[2]. 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 introduce the third choice, "buy from affiliated ("keiretsu") suppliers." This sourcing from keiretsu seems to be a good example of relational contracting, which earlier literature on transaction cost economics does not pay much attention (see Williamson (1975)), but the importance of which is now well recognized (see Williamson (1985) and Baker, Gibbons and Murphy (2002)). Since keiretsu sourcing accounts for a major part of the component procurements by Japanese auto industry (more than 50% of the procurements of the components under this study for Toyota, Nissan and Honda), the dataset of the Japanese auto industry provide unique opportunities for us to examine the choice of integration and relational contracting simultaneously.

Second, for independent variables, we introduce a set of new variables on component characteristics based on their detailed survey[3], to measure multiple dimensions of contracting

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[1] For example, GM's acquisition of Fisher Body was analyzed by Klein, Crawford and Alchian (1978), Hart (1989), and Langlois and Robertson (1995).

[2] See also Masten (1984) for the study of the Aerospace Industry and Masten, Meehan and Snyder (1989) for the study distinguishing physical and human capital investment on the U.S. auto industry.

[3] 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.

environment (the *specificity*, *interdependency* and *testability* of a component) and to strengthen controls on missing variables (the *complexity*, *safety*, *customer-value*, and *firm-standard of* a component). The availability of these new variables allows us to inquire new questions, for an example, as to whether higher *testability* of a component enables more contracting choice for supplying a component with high *specificity*. Third, we use a set of time series 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.

The organization of this paper is the following. Section 2 provides theoretical framework for the organizational and contract choice for the efficient supply of a component in the automobile industry. Section 3 describes econometric model and data, and section 4 presents estimation results. Section 5 concludes.

2. 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, 1985)) and the property rights theory(see Grossman and Hart (1986)), so as to derive testable propositions. Efficient coordination of design activities between an OEM and a component supplier, the quality assurance of the components manufactured, and their low cost are the important determinants for the efficiency of component supply. In the case of automobile industry, efficient coordination with an OEM in design 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 in an integrative manner for a particular vehicle model. On the same ground, the quality assurance in manufacturing 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 organizational choice between integration and non-integration as well as the contract choice between non-keiretsu (short-term[4]) contracting and keiretsu (relational or long-term) contracting (see Figure 1, which is based on Baker, Gibbons and Murphy (2002))[5].

(Figure 1)

Formally, let us denote *integration* or *make* choice by the combination of *y=1* and *z=0, keiretsu or relational contracting* choice by *y=0* and *z=1*, and the *market (*or *non-keiretsu*) contracting choice by *y=0 and z=0*. We hypothesize that higher design specificity (*s*) of a component as well as higher interdependency (θ) between the component and the other components in design would increase the value of vertical integration of that component production. High design specificity would involve the tangible or intangible investment specific to the OEM by the supplier, which is subject to hold-up risk. High interdependency in design would require frequent and extensive negotiations with a supplier when an OEM wishes to change the design of its components, which would not be contractible ex-ante. Vertical integration has advantages in promoting relation-specific investment and for accommodating non-contractible design changes (see Bajari and Tadelis (2001) and Tadelis (2002)). Sourcing from keiretsu would have a similar but attenuated effect on the value of the component, since design change, for an example, will still involve negotiations between two firms. Thus, we hypothesize that the value of a component net of design cost is enhanced by vertical integration or keiretsu sourcing, the degree of which increases with the *specificity* and *interdependency* of the component:

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

[4] Most 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.
[5] There is a potential choice of spot employment. Although such possibility may also be important, we do not consider this choice in this paper.

, where $v_0 > 0, a > 0, \beta_1 > 0, \beta_2 > 0$, $0 < \mu < 1$ and ε is a random variable. We may expect $\beta_3 > 0$, given that the marginal effect of *interdependency* is likely to be larger, the higher the *specificity* of the component is.

The cost function for the component supply consists of the manufacturing cost and the quality assurance cost net of the value from quality improvement. The manufacturing cost is given by

$$c_0 + c_1(y + \kappa z) \qquad (2)$$

, which is the highest when integration is chosen ($c_0 + c_1$), reflecting the effect of the loss of ownership interest in cost reduction (internal procurement is cost-based). Sourcing from a keiretsu supplier would also provide smaller incentive for cost-reduction, compared to sourcing from the market, due to limited competition ($o < \kappa < 1$).

The cost of quality assurance would matter especially when the testability of the component is low and the component is specific to the OEM. We assume that as *testability* improves (the cost of testing becomes lower), the cost of quality assurance declines to zero. For a given level of *testability,* the cost of quality assurance would be higher for a spot supplier which would have the motivation to reduce the quality of the component to be supplied when it is effective for saving cost. A relational contracting could constrain the incentive for such quality-degradation, since once such conduct would be uncovered, the rent from long-term relationship would be lost (Shapiro (1983)). In vertical integration, the provision of a strong incentive to an employee for cost-reduction would not be used, so as to avoid creating an incentive for compromising quality due to multitasking (Holmstrom and Milgrom (1991) for a theory and Slade (1996) for an empirical analysis). Given these considerations, we can hypothesize that the cost of quality assurance increases with specificity, declines with testability and is reduced by vertical integration or relational contracting:

$$c_2(1+\lambda s)\{1-\delta(y+\rho z)\}/t \quad (3)$$

with $\delta, \rho > 0$, with ρ indicating the efficiency of keiretsu relative to vertical integration for quality assurance.

Finally, we take into account the quality improvement based on the collaboration between a supplier (gathering information useful for quality improvement) and an OEM (its implementation) [6]. We assume that a vertically integrated supplier does not engage in voluntary efforts for gathering information for quality improvement, due to its weak incentive for such information exploration (the assignment of the patent right of an employee inventor to a firm in Agion and Tirole (1994) and the absence of recourse when the upstream party reneges in Baker, Gibbons and Murphy (2002)). A supplier external to the OEM would have an incentive to do such information exploration. In addition, such information can be more easily shared with the OEM when it is a keiretsu supplier than when it is an independent supplier, since relational contracting enables non-contractible efforts being rewarded ex-post. In addition, we assume that high *testability* of the component would create more opportunities for a supplier to discover information useful for improving the quality of the component. Given these considerations, the value of quality improvement enabled by the information discovered by a supplier is given by

$$bt(1-y+\phi z), \quad (4)$$

with $b, \phi > 0$.

The efficient organizational and contractual choice is given by

$$\text{Max}_{y,z} \quad w = v(y,z;s,\theta,t) - c(y,z;s,\theta,t)$$
$$= v_0 + a(1+\beta_1 s+\beta_2\theta+\beta_3\theta s)(y+\mu z)+\varepsilon$$
$$-[c_0+c_1(y+\kappa z)+c_2(1+\lambda s)\{1-\delta(y+\rho z)\}/t]+bt(1-y+\phi z)+\eta \quad (5)$$

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6 See Barzel (1982) for the effects of measurement cost on the choice of organizational or contractual choice. Also see Baker and Hubbard (2003) for the effects of information availability on the choice of organizational or contractual choice.

, where η is a random variable. The choices are over vertical integration, keiretsu and market: *(y,z)*={(1,0),(0,1), (0,0)}. Given the above analytical framework, we can derive the following three propositions on the effects of component characteristics on organizational and contractual choice, using sourcing from keiretsu as the base.

Proposition 1 *(Effect of Specificity)*

We would observe more vertical integration relative to keiretsu sourcing and more keiretsu sourcing relative to market sourcing for a component with higher specificity (s). These effects decline with testability.

(Proof) We have

$$\partial^2 w / \partial s \partial y = a(\beta_1 + \beta_3 \theta) + c_2 \lambda \delta / t > 0 \quad (6.1)$$

$$\partial^2 w / \partial s \partial z = a(\beta_1 + \beta_3 \theta)\mu + c_2 \lambda \delta \rho / t > 0 \quad (6.2)$$

Subtracting, we have

$$\partial^2 w / \partial s \partial y - \partial^2 w / \partial s \partial z = a(\beta_1 + \beta_3 \theta)(1-\mu) + c_2 \lambda \delta (1-\rho) / t > 0 \quad (6.3).$$

Proposition 2 *(Effect of interdependency)*

We would observe more vertical integration relative to keiretsu and more keiretsu sourcing relative to market sourcing for a component with higher interdependency (θ *).These effects of interdependency would increase with specificity (s).*

(Proof) We have the following results for the effect of interdependency (θ).

$$\partial^2 w / \partial \theta \partial y = a(\beta_2 + \beta_3 s) > 0 \quad (7.1)$$

$$\partial^2 w / \partial \theta \partial z = a(\beta_2 + \beta_3 s)\mu > 0 \quad (7.2)$$

Proposition 3 (*Effect of Testability)*

We would observe less vertical integration relative to keiretsu as the testability of the component increases. We can observe more keiretsu sourcing relative to market sourcing as the testability of the component increases if the quality improvement based on information sharing effect is important.

(Proof) $\partial^2 w / \partial t \partial y = -c_2(1+\lambda s)\delta / t^2 - b < 0$ (8.1)

$\partial^2 w / \partial t \partial z = -c_2(1+\lambda s)\delta\rho / t^2 + b\phi$ (8.2)

$\partial^2 w / \partial t \partial y - \partial^2 w / \partial t \partial z = -c_2(1+\lambda s)(1-\rho)\delta / t^2 - b(1+\phi) < 0$ (8.3)

We can depict the choice for each combination of the component characteristics in the parameter space. The dividing lines for choices are characterized in the following manner, assuming their existence.

The dividing line between vertical integration and keiretsu (*V-K line*):

$a(1+\beta_1 s+\beta_2\theta+\beta_3\theta s)(1-\mu)+c_2(1+\lambda s)\{\delta(1-\rho)/t\}-bt(1+\phi)=c_1(1-\kappa)$ (9.1),

The dividing line between keiretsu and market (*K-M line*):

$a(1+\beta_1 s+\beta_2\theta+\beta_3\theta s)\mu+c_2(1+\lambda s)(\delta\rho/t)+bt\phi=c_1\kappa$ (9.2),

The dividing line between market and vertical integration (*M-V line*):

$a(1+\beta_1 s+\beta_2\theta+\beta_3\theta s)+c_2(1+\lambda s)\delta/t-bt=c_1$ (9.3)

Figure 2 and 3 provide two examples of the patterns of choices with *specificity* and *interdependency* represented by horizontal and vertical axes (assuming a given *testability*). Since the *specificity* and *interdependency* of a component enhance the value of vertical integration more than that of keiretsu over market sourcing (that is, $0<\mu<1$), we may expect a monotonic change of the choices from market to keiretsu, and then to vertical integration as the *specificity* and *interdependency* of a component increases. This would be indeed the case when keiretsu's relative advantage in enhancing the value of design is larger than its relative manufacturing cost disadvantage ($\mu > \kappa$) and the effects of organizational choice on quality assurance and on sharing new information on quality improvement are negligible ($\delta = b = 0$). In such case, the choices over three organizational choices are monotonically sorted by either *specificity* or *interdependency*, as in Figure 2, since the two lines (*V-K line* and *K-B line*) are parallel to each other.

(Figure 2)

More generally, however, such monotonic relationship does not hold. We may observe a jump from market sourcing to vertical integration as *specificity* or *interdependency* increases. For simplicity, let us assume that quality assurance is important ($\delta > 0$) and keiretsu and vertical integration can equally achieve the efficiency of quality assurance ($\rho = 1$) and there is no effect of information sharing ($b = 0$). In this case the dividing line between vertical integration and keiretsu *(V-K line*) does not shift as δ increases. However, the dividing line between market and keiretsu *(K-M line*) rotates in the clock-wise in Figure 3. As a result, the choice can make a "jump" from market sourcing to vertical integration in the region where specificity is low and interdependency is high as either variable has a higher value. As *testability* increases, the keiretsu region may expand in both upward and downward directions, due to increasing contractibility and increasing value of information sharing (see (8.3) and (8.2)).

(Figure 3)

3. Econometric Model and Data

In light of the above three propositions, we evaluate the choice of the three modes of component transactions between 7 Japanese OEMs and their suppliers (including in-house divisions) with respect to 54 major components (see Table A2 in the Appendix) for 7 every-three years from 1984 to 2002. The independent variables on the engineering characteristics of the components are constructed from a questionnaire survey of the automobile engineers at four Japanese OEMs on the detailed characteristics of the components (see Table A3 in the Appendix).A detailed description and the sources of the data are provided in Appendix 1, including how these variables were measured.

The basic econometric model we employ is the multinomial logistic model with the dominant choice of each OEM firm *i* in procuring a component *j* in time *t* among the three alternative transaction modes (vertical integration, keiretsu sourcing, market sourcing[7]) as the dependent variable. We also report the results based on the ordinary least squares focusing on the choice of two alternatives in terms of the difference of procurement shares (vertical integration vs. keiretsu sourcing, and keiretsu sourcing vs. market sourcing) in Appendix 2. As shown in Figure 4, a firm often combines two or even three modes in procuring a component. For an example, 22% of the procurements involve both keiretsu sourcing and market sourcing, and 3% of the contracts involve all three modes. However, we have specified only one of them as the primary choice which is the transaction mode that supplies most, following Monteverde and Teece (1982). We use the choice of keiretsu sourcing as the base and evaluate the determinants of the choices of market sourcing and vertical integration relative to keiretsu sourcing in our multinomial estimation, to be consistent with the above propositions.

(Figure 4)

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

$$\Pr(choice_{i,j,t}) = f(specificity_j, \text{int}erdependency_{j,} testability_j, crossterms_i, \\ controls_{i,t}, firmdummies_i, yeardummies_t, \varepsilon_{i,j,t}) \quad (10)$$

Since our data of the component characteristics are available for only recent years (survey was

[7] See Appendix 1 for the operational definition of keiretsu suppliers.

conducted in 2003 and 2004. Note, however, that these characteristics change only gradually over time), the estimation is essentially cross-section, although we do have the variations of the organizational or contract choices of each component and that of production volume of the OEMs over time.

Our primary explanatory variables are *specificity*, *interdependency*, and *testability*. The variable *specificity* constructed from the questionnaire survey indicates how the design criteria and the interfaces 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.

Let us move on to control variables, which may affect the contractual or organizational choice and have correlation with the above independent variables. We introduce four variables indicating the characteristics of components as well as two variables indicating the scale and stability of OEMs' production, in addition to firm and year fixed effects (dummies). The variable *complexity* indicates the level of technology used for the component, the speed of the 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 negative correlation between the complexity and sourcing 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

[8] The variable *specificity* is defined by (6 - the degree of *industry-wide standardization*). The latter variable indicates how the interface of the component is clearly specified and how design specifications are standardized in the industry as a whole, as shown in Appendix Table A3.

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 of an OEM might 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 may use 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.

Table 1 provides descriptive statistics for these variables. Figure 5 depicts how the choice evolved over time in the industry as a whole in terms of simple arithmetic average of the choices over the entire sample components. The share of vertical integration as the dominant choice was around 8.8% in 1984 and gradually declined to 5.6% in 2002. Keiretsu sourcing accounted for around one third of the total procurements (35% in 1984 and 36% in 2002), and market sourcing accounted for 55 % to 61%. Figure 6 shows the relations between the choice and the three primary independent variables. It shows that the share of both vertical integration and keiretsu sourcing increases with *specificity* and *interdependency*. The share of market sourcing increases with *testability*, although this variable have significant negative correlations with *specificity* and *interdependency* (see Table A4)[9]. Figure 7 shows the variation of these choices among 7 sample OEM firms with the size of their production volumes. It is clear that

9 As will be later shown, the partial positive correlation between market sourcing and testability is reversed in the regression model with multiple independent variables.

the share of keiretsu sourcing increases with the production volume, while such relationship is not observed for the share of vertical integration.

(Table 1, Figure 5, Figure 6 and Figure 7)

4. Estimation Results

Table 2 presents two basic estimations, with or without the interaction terms between *specificity* and *testability* and between *specificity* and *interdependency*. We use robust standard errors, to address potential heteroskedasticity. As shown in Model 1, the coefficients of both *specificity* and *interdependency* have expected signs and significant coefficients, consistent with Proposition 1 and 2. Market sourcing is significantly less preferred to keiretsu sourcing for a component with high specificity *(s)* or high interdependency (θ). Simultaneously, vertical integration is preferred to keiretsu sourcing when *interdependency* or *specificity* is important (although the latter effect is significant only at 10% level). In addition, the coefficient of interdependency is more than five times larger for the choice between vertical integration and keiretsu sourcing than the choice between market and keiretsu sourcing, while the coefficient of *specificity* is more than two times larger for the choice between vertical integration and keiretsu sourcing than the choice between market and keiretsu sourcing. Thus, *specificity* is a more important consideration for the choice between market and keiretsu sourcing, while *interdependency* is more an important consideration for the choice between vertical integration and keiretsu sourcing. This suggests that the hold-up risk due to specific investment can be often effectively controlled by a relational contracting based on keiretsu sourcing, while accommodating non-contractible design changes may often require vertical integration.

As for the variable *testability*, it does not have a significant coefficient for the choice between vertical integration and keiretsu choice as implied by Proposition 3, but it has a significantly negative coefficient for the choice between market sourcing and keiretsu sourcing, implying that a firm prefers keiretsu sourcing to market sourcing significantly more, the higher the testability of the component. One interpretation for this result is that an OEM firm may prefer using keiretsu sourcing when the testability of the component is high, since the procurement of such component can provide large opportunities for a supplier to obtain useful information for promoting quality improvement and such information can be more easily shared with a keiretsu supplier than with a non-affiliated supplier. A keiretsu supplier may have both the incentive to gather information for quality improvement enabled by the high testability of the component and to share the information with the OEM for its implementation.

Let us turn to the coefficients of control variables. *Complexity* and *safety* promote the choice of keiretsu sourcing over both integration and market sourcing, although the effect of c*omplexity* on the choice between market and keiretsu is not significant. The quality of a component important for safety can generate significant externality for the other components, providing a reason for vertical integration. However, placing the supplier of such component within an OEM may dilute an incentive for safety due to multi-tasking. In this regard, the keiretsu supplier may have an advantage. On the other hand, *customer-value* promotes integration over keiretsu sourcing, and market sourcing over keiretsu. *Firm-standard* promote keiretsu sourcing over integration and over market sourcing, although the latter effect is not significant. Since standardization within a firm would facilitate the development of the documentations for specifications, it would enhance the contracting-out. Finally, the production volume favors keiretsu sourcing over market sourcing, which indicates the importance of the economy of scale for keiretsu production.

As for firm dummies, a larger automobile manufacturer (Toyota, Nissan and Honda) prefers keiretsu sourcing over market sourcing, even though the production volume is controlled. This may indicate a non-linearity of the effects of the production volume or other firm-specific effects. As for the choice between vertical integration and keiretsu sourcing, Honda exceptionally disfavors integration. As for time dummies, we observe tendency toward keiretsu sourcing: increasing choice of keiretsu sourcing over both vertical integration and market sourcing (except for the choice between market sourcing over keiretsu in year 2002[10]).

Let us turn to Model 2 with the interaction terms. Let us start with the interaction between *specificity* and *testability*. What the coefficient of the interaction term suggests is that while the specificity of a component favors vertical integration over keiretsu sourcing and keiretsu sourcing over market sourcing when testability is low, such preference declines as the *testability* of a component increases even though the relationship is not reversed. These results are consistent with the view that higher *testability* enables outsourcing even if the component is specific (see Proposition 1). As for the interaction between *interdependency* and *specificity*, it is not significant for either choice. The signs of the coefficients suggest that the interaction term tends to weaken the individual effects of *specificity* and *interdependency*, which is not consistent with their complementary effects. These results may reflect non-linearity (decreasing returns) of these individual effects. As for the control variables and the other variables, the estimation results are very similar to those for Model 1.

Models3 to Model 5 of Table 3 inquire the robustness of the basic findings of Table 2. Model 3 uses only the cross section data of year 2002. Since our data on the engineering characteristics of the components are available only for recent years, using these data for much earlier years may cause biased estimates. The estimation results of Model 3, however, are highly consistent with those of Model 1. *Specificity* and *interdependency* promotes vertical integration over keiretsu sourcing, and *specificity* and *testability* promotes keiretsu sourcing over market

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

sourcing. Model 4 introduces the firm by year dummies, so as to control time variant missing variables at firm levels better, such as the potential changes of the engineering capability of an OEM firm over time. The estimation results, including the sizes of the estimated coefficients, are very similar to those of Model 1, suggesting that the combination of firm fixed effects, the time dummies and the level as well as the change of the production volumes of the OEMs effectively control the time variant missing variables at firm levels.

Finally, Model 5 uses the sample of only three biggest OEMs of Japan: Toyota, Nissan and Honda. These firms are different from the other smaller OEMs in the sense that they have well developed keiretsu-supplier network (see Figure 7), so that they have more freedom and flexibility to choose the best organizational and contractual mode of component procurements. On the other hand, the other firms may have no choice but to use the keiretsu firms of three biggest OEMs (market sourcing by these other firms) , since their supplier networks are limited. The estimation results of Model 5 are, however, highly consistent with those of Model 1, with respect to the effects of s*pecificity, interdependency and testability. Specificity* has become insignificant for the choice between vertical integration and keiretsu sourcing, suggesting that specificity does not matter for that choice by a firm with a well developed keiretsu network. The variable *interdependency* remains highly significant and has larger coefficients. Appendix 2 shows the estimation results which focus on the choices in term of two alternatives and on the difference of their procurement shares. That is, we use the difference of the share of vertical integration and that of keiretsu sourcing as a dependent variable, focusing on the sample of the procurements involving no market sourcing, and the difference of the share of keiretsu sourcing and that of market sourcing as another dependent variable, focusing on the sample of the procurements using no vertical integration. The results for three key variables are very similar (See Table A5).

5. Conclusions and Discussions

We have assessed the determinants of the choice among vertical integration, sourcing from keiretsu and sourcing from the market of 54 components by seven Japanese automobile manufacturers (OEMs) in light of contract economics for 7 every-three years from 1984 to 2002.Our major findings are the following. First, consistent with transaction cost economics, the *interdependency* and (much lesser degree) *specificity* of a component make vertical integration preferred to keiretsu sourcing. Both of them also make the sourcing from keiretsu preferred to market sourcing. Second, *interdependency* is a significantly more important consideration for the choice between vertical integration and keiretsu sourcing than the choice between market and keiretsu sourcing, while the reverse is the case for *specificity*. This suggests that the hold-up risk due to specific investment can be often effectively controlled by a relational contracting based on keiretsu sourcing, while accommodating non-contractible design changes may often require vertical integration.

Third, we have found that higher *testability* of a component significantly makes the effects of *specificity* smaller, consistent with the view that high testability of an output enables contracting of a component even with high design specificity. Separate from this effect, higher *testability* of a component also makes a firm prefer keiretsu sourcing over market sourcing. One interpretation of this result is that an OEM firm may prefer using keiretsu sourcing when the testability of the component is high, since the procurement of such component can provide large opportunities for a supplier to obtain useful information for promoting quality improvement and such information can be more easily shared with a keiretsu supplier than with a non-affiliated supplier. A keiretsu supplier may have both the incentive to gather information for quality improvement in the environment of high testability of the component and to share the information with the OEM for its implementation.

Our empirical analysis also indicates several other interesting observations on the structure of supplier system. Larger volume production by an OEM and more standardization within the firm promote keiretsu sourcing both over market sourcing and over vertical integration, which may indicate the importance of the economy of scale and scope base for the development of keiretsu network. In addition, the scale of an OEM does not affect the share of the components supplied by in-house suppliers. Furthermore, *safety* concern promotes the choice of keiretsu sourcing over both market sourcing and vertical integration.

There are, however, several remaining issues. First, we do not consider the value of multiple mode procurement policy. We have simply assumed that there is a single best mode of procurement for each component, even though multiple mode procurement policy may be the optimal policy. An OEM takes into account the importance of preserving procurement competition in selecting suppliers. Second, we have assumed the exogeneity of the engineering characteristics of the components, which are constructed from the surveys on the engineers of four OEMs. However, we may expect that these characteristics are affected by the organizational or contract characteristics, e.g. whether a supplier is vertically integrated or not. Third, further analysis would be needed to search for the optimal boundary of firms, with respect to creation of new information and innovation. Our analysis suggests a view that a keiretsu system may have a certain advantage in generating the incentives for both autonomous innovation and collaboration with an OEM. An interesting question would be how the keiretsu system would survive in the environment of “open” innovation.

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Appendix1: 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 have manufactured mainly passenger cars and light trucks. Other Japanese OEMs that have 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 characteristics 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. The engineers from four 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 characteristics).

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"	market sourcing	
	relational	keiretsu sourcing	vertical integration

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Choice	2603	2.49	0.63	1	3
VIKR	591	−0.63	0.71	−1.00	1.00
MRKR	2275	0.28	0.88	−1.00	1.00
specificity	2603	3.90	0.96	1.50	5.00
spectest	2603	13.28	3.80	4.88	20.42
interdepent	2603	3.89	0.54	2.34	4.84
intdpntspec	2603	15.30	4.71	4.73	24.22
testability	2603	3.45	0.67	2.00	4.67
complexity	2603	2.88	0.74	1.36	4.82
safety	2603	3.71	1.04	1	5
custmvalue	2603	3.55	0.86	1.88	5.88
firmstndrd	2603	3.63	0.53	2.35	4.6
prdvlm	2603	1.38	1.03	0.42	4.22
prdvlmchg	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
HND	2603	0.14	0.35	0	1
MZD	2603	0.14	0.35	0	1
SZK	2603	0.14	0.35	0	1
DHT	2603	0.14	0.35	0	1
FHI	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 Organizational Choices (I)

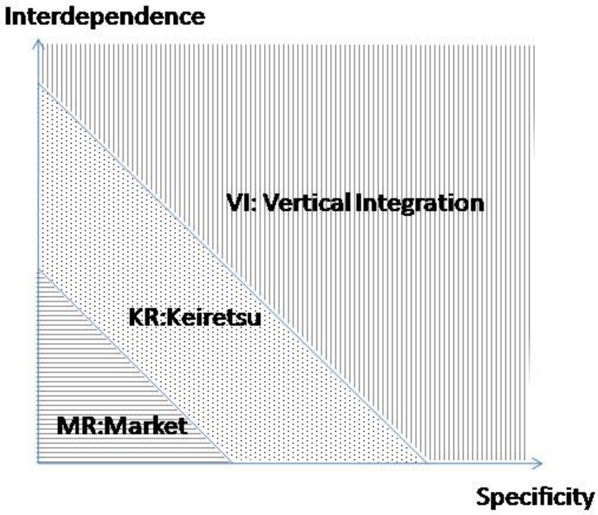


Figure 3 Organizational Choices (II)

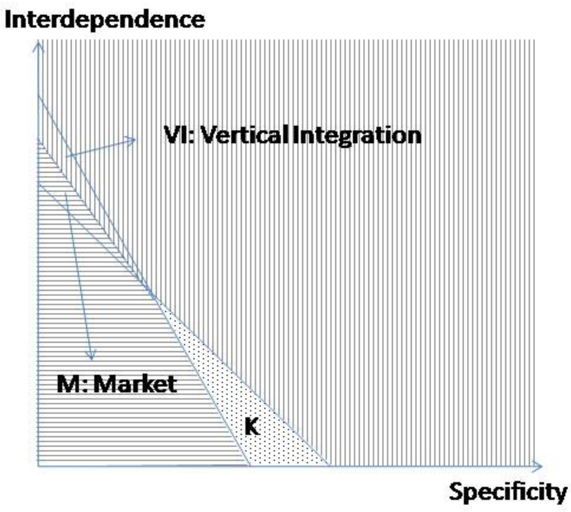


Figure 4 Combination of organizational and contractual choice for component procurement

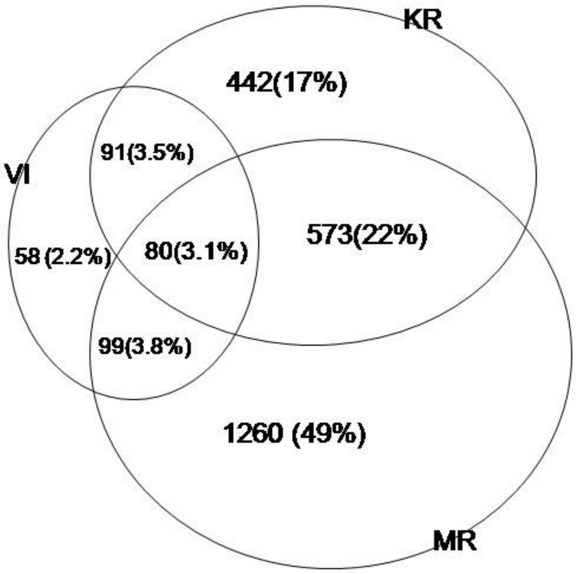


Figure 5. Make-or-Buy Choices over Time

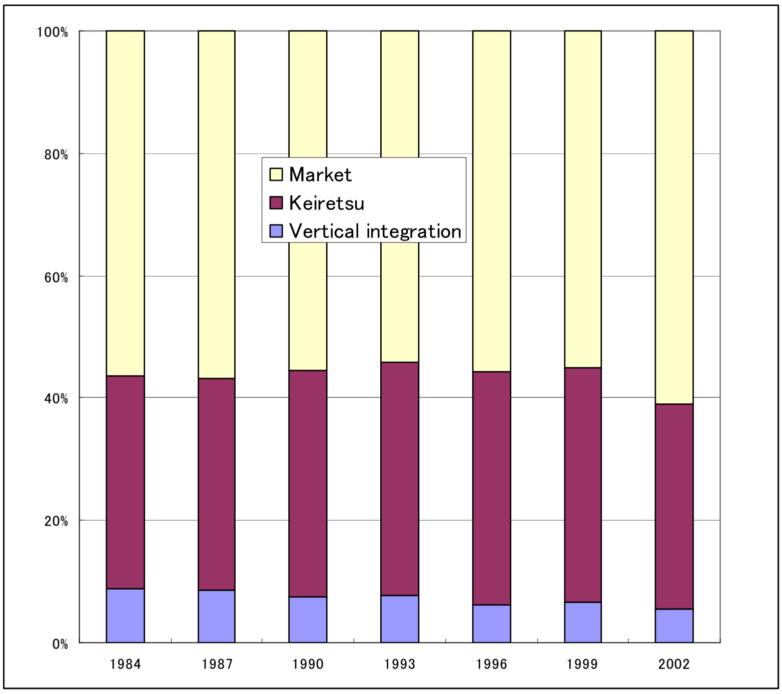
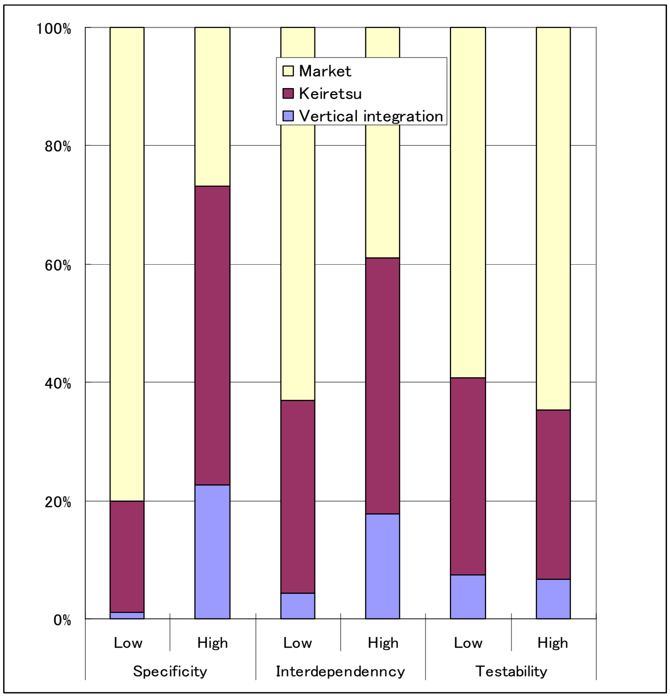


Figure 6　Make-or-Buy Choices over Component Characteristics



Note.　Low: lowest 25%, High: highest 25%

Figure 7　Make-or-Buy Choices by 7 OEMs

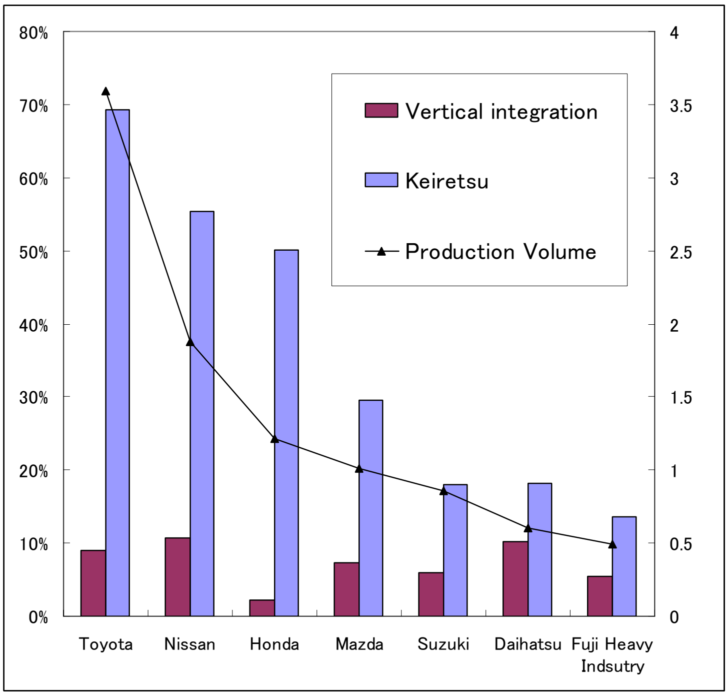


Table 2 Basic Estimation Results (Multinomial Logistic Regression)

		Model 1(Multinomial Model with no interactions)						Model 2(Multinomial Model with interactions)					
		Vertical integration/ Keiretsu			Market/Keiretsu			Vertical integration/ Keiretsu			Market/Keiretsu		
		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.	
transaction cost and testability	specificity	0.63	0.37	*	−1.38	0.09	***	8.778	2.542	***	−4.724	0.950	***
	specificity × testability							−1.445	0.459	***	0.779	0.141	***
	interdependency	1.87	0.31	***	−0.35	0.12	***	5.103	1.999	**	−0.695	0.654	
	interdependency × specificity							−0.673	0.443		0.106	0.159	
	testablity	−0.03	0.13		−0.58	0.09	***	6.611	2.064	***	−3.745	0.579	***
Control variables	complexity	−0.72	0.19	***	−0.12	0.10		−0.487	0.175	***	−0.211	0.104	**
	safety	−0.24	0.10	**	−0.22	0.06	***	−0.187	0.087	**	−0.219	0.062	***
	custmvalue	1.01	0.19	***	0.31	0.10	***	0.796	0.179	***	0.277	0.099	***
	firmstndrd	−0.42	0.18	**	−0.10	0.10		−0.458	0.181	**	−0.150	0.108	
	prdvlm	−0.22	0.48		−0.64	0.31	**	−0.204	0.485		−0.650	0.314	**
	prdvlmchg	0.00	0.02		0.01	0.01		0.004	0.016		0.009	0.009	
Firm dummies	TYT	−0.12	1.51		−1.74	0.99	*	−0.092	1.536		−1.784	0.987	*
	NSN	−0.06	0.73		−1.90	0.48	***	−0.017	0.750		−1.935	0.478	***
	HND	−2.05	0.53	***	−1.71	0.29	***	−2.023	0.541	***	−1.741	0.293	***
	MZD	−0.20	0.41		−0.84	0.25	***	−0.173	0.424		−0.867	0.250	***
	SZK	−0.03	0.43		−0.21	0.24		−0.030	0.440		−0.219	0.238	
	DHT	0.55	0.34		−0.46	0.21	**	0.569	0.351		−0.482	0.213	**
Year Dummies	YR87	0.00	0.32		0.07	0.20		−0.016	0.328		0.073	0.202	
	YR90	−0.22	0.34		−0.01	0.22		−0.234	0.351		−0.008	0.217	
	YR93	−0.27	0.41		−0.17	0.22		−0.275	0.415		−0.169	0.222	
	YR96	−0.64	0.35	*	−0.29	0.21		−0.655	0.362	*	−0.285	0.208	
	YR99	−0.54	0.35		−0.29	0.20		−0.552	0.360		−0.291	0.203	
	YR02	−0.60	0.37		0.10	0.21		−0.621	0.376	*	0.105	0.207	
	_cons	−10.55	2.30	***	11.76	0.89	***	−48.689	11.287	***	25.704	4.014	***
		Number of obs = 2603						Number of obs = 2603					
		Log likelihood = −1607.7585 Pseudo R2 = 0.2992						Log pseudolikelihood = −1577.78 Pseudo R2 = 0.3122					

Table 3 Estimation Results for Robustness Check

		Model 3(Multinomial Model, cross-section for 2002)						Model 4 (Multinomial Model with firm by year dummies)						Model 5 (Multinomial Model with firm by year dummies; Toyota, Nissan and Honda)					
		Vertical integration/ Keiretsu			Market/Keiretsu			Vertical integration/ Keiretsu			Market/Keiretsu			Vertical integration/ Keiretsu			Market/Keiretsu		
		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.	
transaction cost and testability	specificity	1.955	0.649	***	−1.126	0.208	***	0.632	0.374	*	−1.392	0.087	***	−0.085	0.319		−1.215	0.082	***
	interdependency	2.737	1.221	**	−0.523	0.328		1.890	0.308	***	−0.356	0.123	***	2.362	0.538	***	−0.509	0.174	***
	testablity	0.395	0.452		−0.593	0.241	**	−0.031	0.132		−0.586	0.089	***	−0.152	0.173		−0.800	0.129	***
Control variables	complexity	−0.751	0.474		0.050	0.257		−0.723	0.194	***	−0.115	0.105		−1.148	0.232	***	−0.773	0.153	***
	safety	−0.261	0.300		−0.001	0.154		−0.246	0.102	**	−0.224	0.063	***	0.089	0.114		−0.323	0.085	***
	custmvalue	0.641	0.629		0.071	0.248		1.024	0.191	***	0.314	0.099	***	0.953	0.238	***	0.841	0.137	***
	firmstndrd	0.041	0.496		−0.199	0.285		−0.432	0.184	**	−0.104	0.106		−0.730	0.256	***	−0.412	0.156	***
Firm dummies (or firm by year dummies)	TYT	−0.828	1.125		−3.611	0.556	***	firm by time dummies						firm by time dummies					
	NSN	−0.463	1.065		−1.799	0.522	***												
	HND	−1.896	1.244		−2.075	0.515	***												
	MZD	0.570	0.992		−0.547	0.540													
	SZK	−0.545	1.211		−0.825	0.518													
	DHT	1.245	0.975		−0.503	0.557													
	_cons	−22.736	6.340	***	10.947	2.368	***												
		Number of obs = 376						Number of obs = 2603						Number of obs = 1115					
		Log pseudolikelihood = −223.17 Pseudo R2 = 0.2845						Log pseudolikelihood = −1594.78 Pseudo R2 =						Log pseudolikelihood = −748.29 Pseudo R2 = 0.2313					

Note The coefficients for the firm by year dummies are not reported.

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		●					
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	●						
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.

Table A4 Correlations among variables

	VICHOICE	VIKR	MRKR	specificity	spectest	interdepent	intdpntspec	testability	complexity	safety	custmvalue	firmstndrd	prdvlm	prdvlmchg
VICHOICE	1													
VIKR	0.202	1												
MRKR	0.768	0.751	1											
specificity	−0.385	−0.133	−0.359	1.00										
spectest	−0.309	−0.160	−0.323	0.729	1									
interdepent	−0.222	0.094	−0.104	0.309	0.015	1								
intdpntspec	−0.405	−0.044	−0.320	0.899	0.553	0.684	1							
testability	0.041	−0.055	−0.006	−0.263	0.455	−0.365	−0.375	1						
complexity	−0.096	0.086	−0.018	0.129	0.013	0.418	0.292	−0.202	1					
safety	−0.015	−0.021	−0.031	−0.111	−0.037	0.025	−0.080	0.078	0.176	1				
custmvalue	−0.175	0.119	−0.056	0.202	0.168	0.491	0.371	−0.065	0.703	0.271	1			
firmstndrd	0.160	−0.021	0.102	−0.368	−0.210	−0.199	−0.386	0.173	−0.065	0.272	−0.113	1		
prdvlm	−0.318	−0.299	−0.418	0.002	0.000	0.001	0.002	−0.002	0.001	0.001	0.000	−0.003	1	
prdvlmchg	0.042	0.043	0.057	0.001	0.001	0.000	0.001	0.001	−0.001	0.000	0.000	−0.002	0.032	1
TYT	−0.239	−0.214	−0.310	0.003	0.002	0.002	0.003	−0.001	0.000	0.000	0.000	−0.007	0.885	0.086
NSN	−0.169	−0.151	−0.215	0.002	−0.002	0.001	0.002	−0.005	0.004	0.003	0.003	0.003	0.197	−0.208
HND	−0.024	−0.126	−0.092	−0.007	−0.001	0.000	−0.005	0.007	−0.002	−0.002	−0.006	0.009	−0.068	0.043
MZD	0.044	0.044	0.068	0.001	0.000	−0.004	−0.001	−0.003	0.001	−0.004	0.002	−0.004	−0.147	−0.132
SZK	0.135	0.140	0.178	−0.001	0.000	−0.006	−0.004	0.002	−0.004	0.002	−0.002	0.006	−0.208	0.234
DHT	0.081	0.162	0.161	0.001	0.001	0.003	0.002	0.000	−0.001	−0.001	0.001	−0.008	−0.312	0.092
FHI	0.172	0.146	0.211	0.001	0.000	0.004	0.002	−0.001	0.002	0.002	0.003	0.001	−0.354	−0.114
YR87	−0.006	0.016	0.005	−0.003	−0.003	−0.001	−0.002	0.000	−0.001	0.001	−0.001	0.007	0.044	−0.108
YR90	−0.008	0.001	−0.007	−0.003	−0.003	−0.001	−0.002	−0.001	−0.001	0.002	−0.001	0.003	0.107	0.199
YR93	−0.017	−0.012	−0.018	0.003	0.002	0.002	0.003	−0.001	0.000	0.000	0.000	−0.007	−0.037	−0.548
YR96	0.003	−0.019	−0.014	0.003	0.001	0.001	0.003	−0.002	0.001	−0.001	0.002	−0.007	−0.043	0.266
YR99	−0.005	−0.016	−0.008	0.003	0.002	0.002	0.003	−0.001	0.000	0.000	0.000	−0.007	−0.062	0.037
YR02	0.040	0.015	0.043	0.002	0.004	0.002	0.002	0.004	−0.002	−0.001	−0.001	−0.002	−0.030	0.125

Note. We do not report the correlations among dummy variables.

Appendix 2. Estimation results focusing on the choices over two alternatives in terms of the difference of procurement shares

This appendix reports the results of the estimations using the ordinary least squares model on the choice over two alternatives: that between vertical integration and keiretsu sourcing and that between keiretsu sourcing and market sourcing. The motivation for this exercise is that a firm may not have three alternatives for its choice. In addition, we use the difference of the shares of two alternatives in procurements, rather than a binary variable as dependent variables:

There are two dependent variables: (1) the difference between the internal procurement share and the keiretsu sourcing share by firm *i* in time *t* for the component *j* which does not use market sourcing ($VIKR_{i,j,t}$) and (2) the difference between the market procurement share and the keiretsu sourcing share by firm *i* in time *t* for the component *j* which does not use vertical integration ($MRKR_{i,j,t}$):

$$VIKR_{i,j,t} / MRKR_{i,j,t} = g(specificity_j, \text{int}erdependency_j, testatibility_j, crossterms_i, controls_{i,t}, firmdummies_i, yeardummies_t, \varepsilon_{i,j,t}) \quad \text{(a.1)}$$

As shown in Table A5, the results are very similar to those in Table 2, as far as the coefficients for three key variables are concerned.

Table A5　Estimations assuming two alternatives for each choice between vertical integration and keiretsu sourcing and between keiretsu sourcing and market sourcing

	Model2 (OLS Model with no interactions)						Model4(OLS Model with interactions)					
	Vertical integration − Keiretsu			Market − Keiretsu			Vertical integration − Keiretsu			Market − Keiretsu		
	Coef.	Rob. Std. Err.		Coef.	Rob. Std. Err.		Coef.	Rob. Rob. Std. Err.		Coef.	Rob. Rob. Std. Err.	
specificity	0.215	0.077	***	−0.334	0.015	***	−0.618	0.491		−0.473	0.157	***
specificity ×testability							0.092	0.091		0.093	0.028	***
interdependency	0.193	0.063	***	−0.127	0.035	***	−0.385	0.221	*	0.105	0.130	
interdependency × specificity							0.134	0.057	**	−0.054	0.035	
testablity	0.005	0.069		−0.154	0.024	***	−0.410	0.391		−0.514	0.100	***
complexity	0.368	0.073	***	0.022	0.028		0.347	0.074	***	0.017	0.028	
safety	−0.147	0.044	***	−0.074	0.014	***	−0.143	0.043	***	−0.073	0.014	***
custmvalue	−0.079	0.072		0.059	0.026	**	−0.085	0.074		0.033	0.027	
firmstndrd	0.060	0.053		−0.001	0.030		0.078	0.054		−0.016	0.031	
prdvlm	0.064	0.147		−0.166	0.091	*	0.067	0.147		−0.167	0.090	*
prdvlmchg	0.000	0.006		0.003	0.003		−0.001	0.006		0.003	0.003	
TYT	−0.290	0.465		−0.678	0.284	**	−0.286	0.464		−0.675	0.283	**
NSN	−0.291	0.236		−0.695	0.140	***	−0.292	0.236		−0.700	0.139	***
HND	−0.245	0.142	*	−0.551	0.085	***	−0.258	0.142	*	−0.553	0.084	***
MZD	−0.217	0.135		−0.208	0.070	***	−0.216	0.135		−0.210	0.070	***
SZK	0.168	0.155		−0.047	0.061		0.175	0.156		−0.050	0.061	
DHT	0.241	0.152		−0.081	0.052		0.248	0.152		−0.083	0.052	
YR87	−0.039	0.093		0.028	0.057		−0.040	0.093		0.028	0.057	
YR90	−0.062	0.102		−0.001	0.060		−0.064	0.102		−0.002	0.060	
YR93	−0.080	0.117		−0.022	0.064		−0.083	0.117		−0.022	0.064	
YR96	−0.046	0.110		−0.070	0.057		−0.045	0.110		−0.071	0.057	
YR99	−0.044	0.113		−0.045	0.057		−0.046	0.113		−0.046	0.057	
YR02	−0.084	0.119		0.080	0.055		−0.086	0.119		0.080	0.055	
_cons	−2.725	0.541	***	3.111	0.219	***	0.915	2.114		3.741	0.544	***
	Number of obs = 591 R-squared = 0.2304			Number of obs = 2275 R-squared = 0.3695			Number of obs = 591 R-squared = 0.2338			Number of obs = 2275 R-squared = 0.3728		