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Roles of In-house Production in Firms' Supplier Management

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Abstract

Input procurement plays important roles in firms' production. In this paper, I shed light on the roles of firms' in-house production in managing relationships with their suppliers. In the existing literature on firms' procurement choices, in-house production is treated as an alternative to outsourcing from suppliers, as "outsource" versus "in-house" decisions are considered mutually exclusive. However, in reality, when firms outsource an input from suppliers, some firms also seem to produce the same/similar input in-house (IRC, 2016).

Keeping the production of an input in-house, firms would be able to accumulate know-how or soft information on the production, while outsourcing from suppliers would provide the benefit from scale economies at suppliers selling their products to multiple firms and from market competition among suppliers. In this paper, using the 2016 data book of automobile parts procurement published by the Industry Research Center Co., Ltd. (2016 IRC data book), I examine how auto parts supplier characteristics differ between the case in which Japanese carmakers partly produce the input themselves and the case in which they exclusively rely on suppliers. In particular, combining the IRC data with much broader data on buyer-supplier relationships compiled by Tokyo Shoko Research Ltd., I focus on the role of distance and incorporate supplier characteristics regarding firms' supplier networks.

Keywords: In-house, Procurement, Network, Supplier, Buyer-supplier

JEL classification: L0, L1, L2, L6

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1. Introduction

Input procurement plays important roles in firms' production. Whether a firm outsources an input or produces it in-house as well as which suppliers to outsource would influence not only the production costs but also the efficiency of the firm's supply chain management as a whole.

In this paper, I shed light on roles of firms' in-house production in managing relationships with their suppliers. In the literature on firms' procurement choices, in-house production is treated as an alternative to outsourcing from suppliers, as "outsource" versus "in-house" decisions are considered mutually exclusive.[2] However, in reality, when firms procure an input from suppliers, some firms seem to produce the same or similar inputs in-house, while dividing the scale of productions can reduce the benefit from scale economies.[3]

Why do firms keep in-house production of a given input when they also rely on suppliers for the input? Comparing the characteristics of suppliers between the case in which their buyer firms keep the in-house production for the same input and the case in which the firms rely exclusively on the suppliers, I examine to what extent relying both on the in-house production and on the suppliers for a given input would be efficient for firms.

In particular, I use the 2016 procurement data book for automobile parts (auto-parts) compiled by the Industry Research Center (IRC) Co., Ltd., which I hereafter refer as the 2016 IRC data book. The 2016 IRC data book contains the list of carmaker-supplier pairs for each of 200 main auto-parts for all the Japanese carmakers. It also provides us with a unique opportunity to observe whether an auto-parts produced by a carmaker's supplier is partly produced in-house at the carmaker. Focusing on the auto-parts procurement from suppliers, I examine when a carmaker also produces a given auto-part

[2] There are many papers examining mutually exclusive choices between firms' "outsource" versus "in-house" decisions. Some examples of empirical studies are Masten (1984), Baker and Hubbard (2003), and Ono (2003 and 2007).

[3] In Monteverde and Teece (1982), they also note that, out of 133 auto-parts (ex. crankshaft, camshaft, etc.), several auto-parts are produced partly in-house.

in-house and discuss which supplier characteristics would make it more efficient for the carmaker to keep the in-house production.

In the literature of the theory of firms, it has addressed that the input procurement from suppliers are considered to incur transaction costs but allow firms to benefit from scale economies at suppliers as well as market competition between suppliers (Coase, 1937; Grossman and Hart, 1986; Grossman and Helpman, 2001). A firm's in-house production, on the other hand, is considered to save transaction costs, while scale economies would be limited by the production level of the firm. If any fixed costs exist in transaction costs, keeping the in-house production while relying on suppliers would be inefficient.

It is, however, possible that the in-house production of a given input would allow firms to retain know-how or soft information on that input production. The benefit from keeping internal know-how on an input production at firms might exceed the costs of dividing the input production with suppliers. Keeping the production know-how would allow firms to monitor various aspects of suppliers' production more efficiently. It might also reduce difficulties for firms to find alternative suppliers, which would prevent current suppliers from being opportunistic (Monteverde and Teece, 1982; Lewis and Yildirim, 2005). If so, are firms more likely to keep the in-house production for a given input when their suppliers for the input are more difficult to monitor and/or are more likely to be opportunistic?

To study whether there is any evidence supporting such possibilities, I use the sample of all the realized carmaker-supplier pairs for auto-parts procurement from the 2016 IRC data book and examine which supplier characteristics are associated with the case in which a carmaker keeps the in-house production, performing linear probability analyses and probit analyses.

The IRC data book distinguishes auto-parts quite finely. For example, it has the procurement information on each of 16 auto-parts for the main body of car engines. While a given auto-parts can vary across car models, to the extent that the production technology/processes are substitutable across car models for the auto-parts, keeping the in-house production in addition to relying on suppliers for the auto-parts would be inefficient, unless the in-house production carry other benefit such as the know-how accumulation of the input production.

If the in-house auto-parts require systematically different technology from those outsourced from suppliers, however, we might observe different tendency from what is expected above. For example, when a carmaker develops an auto-parts for a new model, at the initial stage of the product cycle, the production of the auto-parts might still require some adjustments, for which mass production at suppliers might not be efficient, if doing so would incur transaction costs and increase the risk for the new innovation to leak. As Antras argues in his paper (Antras, 2005) on international outsourcing, it might only be after the production becomes standardized, firms find it more efficient to rely on suppliers for input procurement. Among heterogeneous suppliers, however, it is possible that carmakers find it safer to rely on suppliers under their control even in the early stage of product cycle. I discuss how consistent my findings are with each of the above stories.

In analysing how a likelihood that a carmaker produces an auto-parts in-house is related to supplier characteristics, I focus on the role of the geographic proximity between a carmaker and its supplier, including the measures of distance between them. Many empirical studies (Degryse and Ongena, 2005; Felici and Pagnini, 2008; and Oz and Stenbacka, 2005) suggest that the difficulty in monitoring increases with distance. If the in-house production at carmakers allow firms to retain production know-how and helps them to monitor suppliers' performance, the carmakers might more likely keep the in-house production to offset the difficulties in monitoring when suppliers are located farther away from the carmaker.

Note, however, that the geographic proximity between firms and their suppliers can also become a reason for the firms to strengthen the control over their suppliers. In a series of empirical studies on the relationships between the U.S. electric utilities and the coal suppliers, Joskow (1985, 1987) suggests the geographic proximity between a buyer and a seller can create site-specificity between them, reflecting "ex ante decisions to minimize inventory and transportation expense." In the literature of the theory of firms, such relation specific investment can lead to opportunistic behaviour by either party and is considered to necessitate vertical integration or contractual solutions (ex. long-term contract). To the extent that the geographic proximity between a supplier and a carmaker establishes the business practices that are costly to change, the carmaker might have a greater incentive to monitor suppliers located closer.

Finally, as I addressed above, suppose that the production of an auto-parts becomes more standardized after the initial stage of its product-cycle but still requires some control by a carmaker either for some adjustments or to prevent technology leakage. To the extent that the geographic proximity alleviate the costs for such control, we might observe that the production of the auto-parts take places both at the carmaker (producing a given auto-parts for a new model) and at its supplier (producing the auto-parts for an older model) located in a close proximity to the carmaker. I discuss more details in Section 2-4.

In addition to the distance measures, I also incorporate the degree to which an auto-parts supplier is linked to other suppliers in a carmaker's supply chain network. In a firm's supply chain network, not only the productivity but also any behavior of a supplier can influence other suppliers' production activities. The degree of such influence would be greater if a supplier is more involved in the network. To manage the relationship with such a supplier, it is possible that the firm has a greater incentive to keep the in-house production to prevent them from being opportunistic. I also incorporate other supplier characteristics, which I discuss in Section 2.4

In Section 2, I present details of the data I use for my study. In particular, in Section 2-1, I describe the IRC data book, and, in Section 2-2, I describe the TSR data. In Section 2-3, I present how I combine these data and how I construct the sample for my empirical analyses. I also present basic features of my data in relation with whether carmakers have the in-house production for auto-parts. In Section 2-4, I describe more details on how I construct variables that represent supplier characteristics. In Section 3, I show the summary statistics of supplier characteristics and show how supplier characteristics vary depending on whether or not carmakers have the in-house production. In Section 4, I present the results of the linear probability and probit analyses. Section 5 concludes my study.

2. Data

2-1. The IRC data book on auto-parts procurement

The IRC Co., Ltd. (IRC) is a private company that has been publishing data books on Japanese automobile industry since 1980. For each of all the Japanese carmakers, the IRC publishes a data book every three years including the information on production and procurement of each auto-parts. The IRC also publishes the data books on special topics such as the auto-parts procurement for all the Japanese carmakers in selected years.

I use the 2016 IRC data book that focuses on 200 main auto-parts (IRC, 2016), and obtain, for each carmaker, the names of suppliers of a given auto-parts and the information on whether or not the auto-parts is, in part, produced in-house at the carmaker.[4] The 200 auto-parts included in the 2016 IRC data book are identified as "main" auto-parts by the industry specialists at the IRC and used in most models of cars. Of the 200 auto-parts, I include machinery auto-parts, which are the parts related to engines, powertrain systems, steering systems, suspensions, and breaks of cars in general as well as main components of hybrid cars. I exclude other auto-parts such as interior and exterior auto-parts from my study, because, the IRC data book indicates that the in-house production at carmakers does not exist for most of these auto-parts. Included in my research as carmakers are all the 12 Japanese carmakers; Daihatsu, Fuji, Honda, Isuzu, Mazda, Mitsubishi, Nissan, Suzuki,

[4] The 2016 IRC data book also includes the description of each auto-parts and the changes in auto-parts' markets, if any.

Toyota, Mitsubishi Fuso, Hino, and UD.

Note that the IRC data book also tells us the cases in which auto-parts are produced in-house exclusively by carmakers. In this paper, however, I focus on understanding the roles of firms' in-house production in supplier management and include only the cases in which carmakers do have suppliers for auto-parts procurements.

2-2. The TSR dataset

To add supplier information on how a supplier is linked to other suppliers in a carmaker' supply networks, I use the dataset from the TSR, which regularly surveys firms to maintain its commercial datasets including buyer-supplier linkages. I use the 2014 TSR dataset that includes 50~60% of Japanese firm population; for larger firms, the coverage is quite high.[5] The TSR data provide us with supplier information such as the number of employees, sales, foundation year, number of establishments/factories, industry code, and etc.

Most importantly to this paper, the TSR dataset includes information on how each firms are connected to other firms in transaction networks; the TSR dataset lists firms' main buyers and sellers (up to 24 firms each). Note that, reporting firms are not necessarily main partners of the reported firms unless they are also reported by the firms they report. We redesign the data to capture all main and non-main transaction partners for each firm. While each firm reports only up to 24 buyers (sellers), some firms are reported by many firms, and thus the total number of main and non-main buyer- (seller-) partners can exceed 24 firms. I discuss how I construct a variable to measure the potential influence of an auto-parts supplier's behavior in a carmaker's supply network in Section 2-4.

2-3. Samples for my analyses

I perform a name-and-address matching to merge supplier information from the TSR dataset to the auto-parts suppliers in the 2016 IRC procurement data

[5] See Okubo Toshihiro, Yukako Ono, and Yukiko U. Saito (2015)

book. Note that, many suppliers in the IRC procurement data book belong to cooperative groups of one or multiple carmakers, for which the IRC accumulates information over their survey years.

For other suppliers without any memberships, however, the IRC data books provide only their names, their products, and the carmakers to which they sell each specific auto-parts. For such suppliers, because I do not have the address information in the IRC data books, I perform a name matching with the TSR dataset. For each of the suppliers, once I find matched suppliers in the TSR dataset, which can be multiple, I identify the supplier based on the information in the TSR dataset such as industry category and main buyers as well as the information on suppliers' website.

Through the above matching procedure, for almost all suppliers in the 2016 IRC data book, I could tell whether or not they are included in the TSR dataset. As a result, out of 321 suppliers providing 130 machinery auto-parts shown in the 2016 IRC data book, I find that 270 suppliers are included in the TSR dataset.[6] For these suppliers, we can obtain not only some basic supplier characteristics but also the extent to which they are involved in a carmaker's supplier network. I use the IRC's procurement information for these 270 auto-parts suppliers and obtain 1,907 realized carmaker-supplier pairs, each of which is for a specific auto-parts out of the 130 machinery auto-parts. I use this sample to examine with which supplier firms find it more efficient to keep the in-house production.

Of the 270 suppliers producing machinery auto-parts, based on the 2016 IRC data book, about half supply one machinery auto-parts (out of 130 machinery auto-parts included in the sample) to Japanese carmakers, and others supply two or more machinery auto-parts. On average, each supplier provides 6.67 auto-parts to one or more carmakers in my sample of 1,907 realized carmaker-supplier pairs. For each carmaker in the above sample, on average, there are 1.59 suppliers for the procurement of each auto-parts; there are 1,193 carmaker-parts in the sample.[7]

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[6] I remove a few cases in which auto-parts are transacted between carmakers.

[7] This number was 1.85 before dropping some suppliers due to the lack of the TSR network information.

Table 1 lists the names of the machinery auto-parts included in my sample. I categorize these auto-parts into some groups to summarize my data, while I treat every auto-parts symmetrically in my empirical analyses. Out of all the 1,193 procurements (carmaker-parts), 10% are also supported by carmakers' in-house production, while the intensity of the in-house practices varies across different auto-parts (see Table 2) as well as carmakers (see Table 3).

2-4. Supplier characteristic variables

Below I describe variables to capture the distance between a supplier and a carmaker and how involved the supplier is in the carmaker's supplier network. As I mentioned above, I consider that these variables are associated with the degree of difficulty in monitoring as well as the likelihood of suppliers' opportunistic behavior.

<u>Distance between an auto-parts supplier and a carmaker</u>

Many empirical studies, especially those in the literature of financial economics (Degryse and Ongena, 2005; Felici and Pagnini, 2008; and Oz and Stenbacka, 2005), show evidence that suggests that geographic distance increases monitoring costs. If it is also the case between a carmaker and an auto-parts supplier, when the carmaker procures an auto-parts from a geographically distant supplier, it might find it necessary to use other means to reduce the monitoring costs, possibly by accumulating detailed knowledge about the input production.

In the literature of the theory of firms, however, as Joskow (1985, 1987) addresses, a supplier's construction or maintenance of its factory at the close proximity to its customer can be a form of relationship specificity, which might increase the likelihood of opportunistic behaviour. While suppliers would face the risk of opportunistic behaviour of a firm, the firm would also face the risk of opportunistic behaviour of suppliers, because the proximity would limit the number of alternative suppliers and because the established business practices with the particular supplier cannot be applied to transacting with other suppliers. In such a case, firms would prefer to keep the know-how for input production to reduce the risk of opportunistic behaviour. The coefficient for the distance would give us an idea on which effect is dominant.

I construct two measures of distance. One is the distance between the headquarter of a carmaker and that of a supplier for a given auto-parts. It is, however, possible that the distance relevant for monitoring and/or forming relationship specificity is rather the distance between the supplier's plant in which the production of the given auto-parts takes a place and the carmaker's plant that manage the transaction with the supplier. While I cannot tell the actual locations of such plants, using the information of plant locations, I also calculate the minimum distance between all the pairwise combinations of plants/HQ of a carmaker and those of a supplier as another measure of the distance.

<u>The degree to which a supplier is involved in a carmaker's supply network</u>

In the supply network of a firm, the suppliers are linked to each other and thus linked to the firm both directly and indirectly through other suppliers, which is also the case for carmakers' supply networks. Based on the 2016 IRC data book and the TSR data on seller-buyer links, most auto-parts suppliers in my sample of the realized carmaker-supplier pairs are both directly and indirectly linked to one or more carmakers. Some suppliers not only have the direct link to a carmaker but have many indirect paths to the carmaker.

For each supplier of a carmaker for a given auto-parts, as one measure of the supplier's potential influence through the carmaker's supply network, I use the number of the supplier's manufacturing buyers that are linked directly to the carmaker. If the supplier of the carmaker behaves opportunistically or if its productivity decreases, the carmaker would be affected not only directly but also indirectly through these indirect paths.

Note that we could use the measures of various degrees of such indirect effects, by, for example, identifying buyers that are indirectly linked to a carmaker through more than one other supplier. As we increase the number of suppliers in indirect paths, however, by the nature of networks, almost all buyers would be indirectly linked to any carmaker. In this paper, I focus on the above measure. I also use the number of all manufacturing buyers to see relative effects.

Note also that because the TSR dataset tells main buyers and sellers up to 24 for each, we can observe direct buyer-supplier links as far as either a buyer or a seller considers the other as an "important" partner, while the TSR dataset does not tell the names of the products being transacted.[8] I control for whether a supplier has a direct link with a carmaker that is considered "important" either by the supplier of the carmaker.[9] Note that, for a few suppliers, the IRC data book indicates that suppliers sell their auto-parts to carmakers through other firms, but such cases are few.

<u>Other supplier characteristics</u>

The TSR dataset also provides us with the information on ownership while it does not provide any specific percentage of the ownership. I include a variable that indicates whether or not a supplier is owned by a carmaker to any degree. I also include supplier age and size (employment and/or sales) to see if such characteristics are associated with whether or not firms' keep in-house production.

3. Characteristics of suppliers in carmaker-supplier pairs: descriptive facts

In Table 4, I summarize characteristics of suppliers in the sample of all the realized carmaker-supplier combinations for auto-parts transaction and those for the pairs with coexistence of the in-house production at carmakers.

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8 Even if a supplier does not supply one of the 130 machinery auto-parts to a carmaker, it is possible that it has direct relationship with the carmaker through transaction of other parts.

9 For some carmaker-supplier pairs, no direct transaction is identified at least based on the 2014 TSR data, that is, the importance of their relationships is not ranked in top 24 buyers/sellers by either carmakers or suppliers at least as of 2014. I also control for such a condition.

As you can see, based on both distance measures, among the realized carmaker-supplier pairs, the distance is shorter for the pairs with the in-house production at carmakers.

As for the intensity to which an auto-part supplier is involved in a carmaker's supply network, based on the number of a supplier's buyers with a direct link to a carmaker, the suppliers in the realized pairs with the in-house production at carmakers seem to be more involved in the carmaker's supplier network than other suppliers.

As for other variables, in the realized carmaker-supplier pairs, the suppliers in the pairs with the in-house production at carmakers are more likely to be owned by the carmakers. In the next section, I present whether such tendency is still observed in net after controlling for other variables.

4. Empirical results

Using the sample of the realized carmaker-supplier pairs, I test how the above mentioned characteristics of a supplier of a given auto-parts are associated with whether or not its customer (carmaker) keeps the in-house production for that auto-parts. I perform both linear probability analyses and probit analyses and include fixed effects of auto-parts in linear probability analyses.

As we can see in Table 5, in the specification in which I use the distance between a carmaker's HQ and a supplier's HQ, the coefficients of the distance measure are not statistically significant. When I use the minimum distance between a carmaker's plants/HQ and a supplier's plants/HQ, the coefficients turn statistically significant but obtain a negative sign, which is contrary to my initial conjecture that carmakers keep the in-house production of a given auto-parts to retain the production know-how to overcome the difficulty to monitor geographically distant suppliers.

In Table 6, I examine how the effects of the distance change depending on supplier characteristics, including the interaction terms between the distance measures and other supplier characteristic variables. The results based on the distance between a carmaker's HQ and a supplier's HQ seem to indicate that the negative effect of the distance on the carmaker's likelihood to retain the in-house production of an auto-part are relevant when the supplier is owned by the carmaker but not necessarily the case when the supplier is not owned by the carmaker. The carmaker's likelihood to produce in-house a given auto-parts increases when suppliers are owned by a carmaker of the auto-part and further increases if those suppliers are located in the close proximity to the carmaker. Again, such results are not consistent with my initial conjecture but seem more consistent with the alternative explanations I stated above.

When I use the minimum distance between a carmaker's plants/HQ and a supplier's plant/HQ, the significance of the coefficients for the interaction term between the distance and the ownership disappears, but the coefficients for the interaction terms between the distance and supplier size become significant. In particular, in column (6), which shows the result of the regression with auto-parts fixed effects, the coefficient of the distance is also positive and significant. Note also that the coefficient of the interaction term between the distance and supplier age is positive and significant. For suppliers with average age (57.3 years old) and at the average probability to be owned by a carmaker (0.176) in this sample, the effects of the distance, based on our sample, is positive for the suppliers with employment size smaller than 635 employees.

When supplier size is small, the result seems consistent with my initial conjecture that the in-house production plays a role to offset the difficulty of monitoring geographically distant suppliers. It is, however, possible that the geographic proximity of larger suppliers create non-negligible site specificity that can potentially lead to costly opportunistic behavior and its effect might be greater than that of the geographic proximity that reduces monitoring costs. As I also stated above, the explanation with product cycle could also be relevant to managing large suppliers. When the production of a car model is standardized, what gives carmakers an incentive to externalize the production would be the larger scale economies at suppliers, which are realized by larger suppliers possibly supplying to multiple buyers. If the geographic proximity allows a carmaker to have some control over suppliers' production, it is possible that the close proximity to a large supplier motivates firms to externalize the production of the auto-parts even if some adjustments are still necessary.

In Table 7, I added the network variables in the analyses. In any specifications, the coefficients for the log number of a supplier's buyers with the direct link to a carmaker are positive and statistically significant at the 1 percentage level. Apart from having the direct relationship with a carmaker, when an auto-part supplier has more indirect ties to the carmaker, the carmaker is more likely to keep the in-house production of that auto-parts. To control for the effects of the number of any buyers of the supplier, I also include such a variable. While the coefficients for the number of a supplier's buyers with the direct link to the carmaker stay positive and significant even after controlling for auto-parts fixed effects, the coefficients of the number of any buyers of the supplier lose their statistical significance once the auto-parts fixed effects are controlled for.

The findings seem consistent with the conjecture that firms keep the in-house production of an input when its suppliers of the input has greater potential influence on the firm's supply network. It is possible that the supplier's close ties to the carmaker's network would create the relationship specificity between the supplier and the carmaker in a sense that the supplier plays a unique role having relationships with the carmaker's other direct suppliers. The costs of the opportunistic behavior by the supplier would also be larger if the supplier is linked with greater number of other direct suppliers of the carmaker. This might give the carmaker a more incentive to prevent the supplier from being opportunistic, possibly by keeping the know-how of producing the input. Note that these results are obtained after controlling for other variables including a variable representing a carmaker's ownership over suppliers.

Section 5. Conclusion

Focusing on studying roles that firms' in-house production might have in managing the relationships with suppliers, I examine the Japanese carmakers' procurement of machinery auto-parts. The results seem to elicit a possibility that the geographic distance between a supplier and a carmaker represents several roles in determining firms' choice of retaining the in-house production of a given auto-parts when the carmaker also relies on suppliers for the same/similar auto-parts.

In particular, using the minimum distance measure between the supplier's plants/HQ and the carmaker's plants/HQ, I find that, when the scale of the carmaker's supplier is small, the suppliers' proximity to the carmaker can reduce the carmaker's likelihood to keep the in-house production for the specific auto-parts produced also by the supplier. This possibly reflects that the geographic proximity between a firm and a supplier makes monitoring easier for the firm even without the firm's internal know-how on the production of the input. For the suppliers of larger scale, however, I find that the geographic proximity increases the carmaker's likelihood to keep the in-house production. This seems rather consistent with alternative story based on the site-specificity established by the geographic proximity between a firm and a supplier as well as that of product cycles.

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Table 1. Machinery auto-parts being procured by carmakers in my samples

Engine: Main Body	Engine: Valve Train	Engine: Fuel realted	Engine: Intake and Exhaust	Engine: Lubrication and Cool	Engine: Electric	Hybrid &Erectric Ca Main parts	Powertrain	Steering	Suspension	Break
ConnectingRod	Camshaft	Canistor	AirCleaner	CoolingFan	Alternator	DC-DCConverter	AT	CandleHydraulicType	CoilSpring	ABS
CrankShaft	EngineValve	ElectronicTypeDiese	Catalyst	CoolingFanDriveEquipment	Gasoline/DieselCar	EngineAssist/DriveM	ATControlCable	CandleHydraulicType	FrontSuspention・Low	BrakeBooster
CylinderHead	RockerArm	FuelFilter	CatalystConverter	OilFilter	GrowPlug	HybridTransmission	ATShiftLever	ElectricPowerSteering	FrontSuspention・Up	BrakeDiskRotor
CylinderHeadBolt	TimingBelt	FuelPomp(Gasoline)	EGRValve	OilPan	IgnitionCoil	Inverter	CVT	ElectricPowerSteering	LeafSpring	BrakeDrum
CylinderHead・Cover	TimingBelt(Chain)	FuelTank	ExhaustManifold	OilPomp	SparkPlug	MainBattery	ClutchCover	PowerSteeringHose	RearSuspention・Low	BrakeHose
CylinderHead・Gasket	TimingCamPulley	FuelTube	ExhaustPipe	OilStrainer	Starter	SystemControlECU	ClutchDisk	SteeringJoint	RearSuspention・Upp	BrakeLining
CylinderLiner	TimingChain	Injector(Gasoline)	IntakeManifold	Radiator		VehicleEmbendedCh	ClutchFacing	SteeringLinkEquipment	ShockAbsorber	BrakeMasterCylinder
DrivePlate	TimingCrankPulley	PressureRegulator	InterCooler	Thermostat			ClutchMasterCylinde	SteeringShaft	Stabilizer	BrakeShoeA'ssy
EngineBlock	TimingTensioner	ThrottleBody(Gasolin	Muffler	WaterPomp			ClutchReleaseCylind	SteeringWheel	SuspentionBallJoint	BrakeTube
EngineMetal	ValveGuide		O2Sensor				Differencial	Steeringcolumn		BrakeWheelCylinder
FlyWheel	ValveLifter		TurboCharger				Electric4WDMotor	SteeringcolumnCover		DiskBrakeCaliper
Piston	ValveSheet						MT	Steeringknuckle		DiskBrakePad
PistonPin	ValveSpring						MTShiftLever			ESC
PistonRing	VariableValveLift						MechanicalLSD			ParkingBrakeLever
RingGear	VariableValveTiming						Passive・CupRing			ProportioningValve
VBelt							PropellerShaft			Retarder
							ShiftFork			
							SynchronizerRing			
							TorqueConverter			
							Transfer			

(Source: author’s summary based on the 2016 IRC procurement data book)

Table 2. The number of carmaker-parts by procurement type

Category of parts	Keeps IH production	Rely only on Suppliers	Total
Engine: Main Body	19	135	154
Engine: Valve Train	14	102	116
Engine: Fuel	3	82	85
Engine: Intake and Exhaust	11	104	115
Engine: Lubrication	2	99	101
Engine: Electric	0	55	55
Hybrid & Erectric Car: Main	7	35	42
Powertrain	24	149	173
Steering	11	106	117
Suspension	3	66	69
Break	8	158	166
Total	102	1091	1193

(Source: author's calculations based on the 2016 IRC procurement data book)

Table 3. The number of auto-parts by carmaker and by procurement type

Car Maker	Keeps IH production	Rely only on Suppliers	Total
Daihatsu	8	90	98
Fuji	2	106	108
Hino	8	79	87
Honda	7	97	104
Isuzu	4	84	88
Mazda	6	99	105
Mitsubishi	11	102	113
Mitsubishi Fuso	2	85	87
Nissan	11	102	113
Suzuki	9	99	108
Toyota	33	85	118
UD	1	63	64
Total	102	1091	1193

(Source: author's calculations based on the 2016 IRC procurement data book)

Table 4. Supplier characteristics in carmaker-supplier pairs

	Realized carmker-supplier pairs			
			Realized pairs with IH prod at carmaker	
N of carmakers-supplier pairs	1907 pairs	270 suppliers	170 pairs	91 suppliers
Characteristics specific to a carmaker-supplier pair				
ln distance from a supplier HQ to a carmaker HQ	4.42	4.17	4.2	4.31
min ln distance supplier plants/HQ and carmaker plants/HQ	3.75	3.57	3.18	3.35
ln (N of an auto-parts supplier's mfg buyers directly sell to a carmaker +1)	0.937	0.966	1.3	1.14
ln (N of an auto-parts supplier's all mfg buyers+1)	3.33	2.76	3.27	3
D=1 if Important direct pair	0.892	0.912	0.936	0.913
D=1 if a supplier is owned by a carmaker to any degree	0.176	0.252	0.365	0.33
Characteristics specific to a supplier				
Age	57.3	57.4	58	59.8
Size: ln employment	7.43	6.3	7.47	6.87
(Source: Author's calculations based on the 2016 IRC procurement data book and the 2014 TSR data)				

Table 5. The effect of distance on carmakers' likelihood to keep the in-house production of an auto-parts provided by suppliers

Dependent variable: =1 if a carmaker produces a specific auto-parts in-house						
	Distance measure					
	Distance between a carmaker HQ to a supplier HQ			Minimum distance between a carmaker's plants/HQ and a supplier's plants/HQ		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	Probit	Fixed-Effect OLS	OLS	Probit	Fixed-Effect OLS
ln distance	-0.00241	-0.0111	-0.00323	-0.0115**	-0.0604**	-0.0127***
	(-0.612)	(-0.428)	(-0.854)	(-2.168)	(-2.150)	(-2.644)
D1=1 if a supplier is owned by a carmaker	0.112***	0.564***	0.0573***	0.0946***	0.467***	0.0380*
	(5.065)	(5.954)	(2.990)	(4.110)	(4.441)	(1.950)
Supplier size (ln employment)	0.00174	0.00580	0.0115**	0.00153	0.00197	0.0107**
	(0.401)	(0.209)	(2.345)	(0.355)	(0.0721)	(2.217)
Supplier age	-6.90e-05	-0.000230	-1.78e-05	-5.86e-05	-0.000216	-1.85e-06
	(-0.292)	(-0.141)	(-0.0764)	(-0.248)	(-0.132)	(-0.00799)
D2=1 if not an important direct pair	-0.0200	-0.159	0.00609	-0.0186	-0.149	0.00643
	(-1.103)	(-1.016)	(0.344)	(-1.022)	(-0.951)	(0.360)
Constant	0.0731*	-1.447***	0.00807	0.113***	-1.212***	0.0536
	(1.959)	(-5.792)	(0.200)	(2.910)	(-4.833)	(1.263)
Auto-parts fixed effects			YES			YES
Observations	1,906	1,906	1,906	1,906	1,906	1,906
R-squared	0.025		0.330	0.027		0.332
Robust t-statistics in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
(Source: Author's calculations based on the 2016 IRC procurement data book and the 2014 TSR data)						

Table 6. The interaction effects of distance on carmakers' likelihood to keep the in-house production of an auto-parts provided by suppliers

Dependent variable: =1 if a carmaker produces a specific auto-parts in-house						
	Distance measure					
	Distance between a carmaker HQ to a supplier HQ			Minimum distance between a carmaker's plants/HQ and a supplier's plant/HQ		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	Probit	Fixed-Effect OLS	OLS	Probit	Fixed-Effect OLS
ln distance	0.0251	0.163	0.0171	0.0299	0.135	0.0397*
	(1.213)	(1.145)	(0.900)	(1.194)	(1.111)	(1.886)
ln distance×D1=1 if a supplier is owned by a carmaker	-0.0421***	-0.179***	-0.0522***	-0.0157	-0.0367	-0.0171
	(-2.714)	(-2.704)	(-3.989)	(-1.262)	(-0.626)	(-1.502)
ln distance ×Supplier size (ln employment)	-0.00291	-0.0172	-0.00348	-0.00586*	-0.0294*	-0.00890***
	(-1.032)	(-0.918)	(-1.443)	(-1.775)	(-1.843)	(-3.215)
ln distance ×Supplier age	-2.41e-06	-0.000141	0.000232*	0.000141	0.000777	0.000362*
	(-0.0173)	(-0.141)	(1.754)	(0.569)	(0.627)	(1.749)
D1=1 if a supplier is owned by a carmaker	0.274***	1.241***	0.256***	0.141***	0.567**	0.0854**
	(4.067)	(4.587)	(4.566)	(2.996)	(2.494)	(2.005)
Supplier size (ln employment)	0.0133	0.0727	0.0241**	0.0235	0.105	0.0440***
	(0.980)	(0.847)	(2.015)	(1.568)	(1.598)	(3.439)
Supplier age	-2.34e-05	0.000572	-0.000934	-0.000651	-0.00342	-0.00149
	(-0.0384)	(0.131)	(-1.643)	(-0.580)	(-0.644)	(-1.587)
D2=1 if not an important direct pair	-0.0203	-0.164	0.00165	-0.0236	-0.178	-0.00150
	(-1.101)	(-1.038)	(0.0917)	(-1.274)	(-1.137)	(-0.0834)
Constant	-0.0411	-2.162***	-0.0669	-0.0406	-1.882***	-0.136
	(-0.403)	(-3.234)	(-0.729)	(-0.356)	(-3.672)	(-1.413)
Auto-parts fixed effects			YES			YES
Observations	1,906	1,906	1,906	1,906	1,906	1,906
R-squared	0.031		0.339	0.032		0.340
Robust t-statistics in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
(Source: Author's calculations based on the 2016 IRC procurement data book and the 2014 TSR data)						

Table 7. The effects of the degree of a supplier's involvement in a carmaker's supply network on the carmaker's likelihood to keep the in-house production of an auto-parts provided by the supplier

Dependent variable: =1 if a carmaker produces a specific auto-parts in-house						
	Distance measure					
	Distance between a carmaker HQ to a supplier HQ			Minimum distance between a carmaker's plants/HQ and a supplier's plant/HQ		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	Probit	Fixed-Effect OLS	OLS	Probit	Fixed-Effect OLS
ln distance	-0.00247	-0.00582	-0.00318	-0.00786	-0.0315	-0.0102**
	(-0.621)	(-0.219)	(-0.836)	(-1.470)	(-1.087)	(-2.102)
D1=1 if a supplier is owned by a carmaker	0.0747***	0.338***	0.0312	0.0649***	0.295***	0.0183
	(3.275)	(3.209)	(1.572)	(2.765)	(2.671)	(0.909)
Supplier size (ln employment)	0.00978	0.0491	0.0165*	0.00972	0.0477	0.0159
	(1.100)	(0.885)	(1.657)	(1.103)	(0.865)	(1.624)
Supplier age	0.000118	0.000632	0.000198	0.000127	0.000651	0.000199
	(0.438)	(0.314)	(0.754)	(0.472)	(0.327)	(0.766)
ln N of Supplier's mfg buyers selling to the same carmker	0.0524***	0.343***	0.0407***	0.0499***	0.329***	0.0373***
	(5.102)	(5.100)	(4.087)	(4.826)	(4.753)	(3.732)
D2=1 if not an important direct pair	-0.00534	-0.0639	0.0206	-0.00512	-0.0614	0.0196
	(-0.294)	(-0.402)	(1.144)	(-0.281)	(-0.386)	(1.078)
ln N of Supplier's mfg buyers	-0.0344**	-0.219**	-0.0253	-0.0337**	-0.215**	-0.0242
	(-2.207)	(-2.114)	(-1.553)	(-2.192)	(-2.091)	(-1.498)
Constant	0.0730*	-1.441***	0.00721	0.0958**	-1.324***	0.0403
	(1.841)	(-5.449)	(0.166)	(2.355)	(-4.940)	(0.894)
Auto-parts fixed effects			YES			YES
Observations	1,906	1,906	1,906	1,906	1,906	1,906
R-squared	0.040		0.337	0.041		0.338
Robust t-statistics in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
(Source: Author's calculations based on the 2016 IRC procurement data book and the 2014 TSR data)						