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Enhancement of the Advanced R&D Cooperation Between Automakers and Suppliers in the Japanese Automobile Industry

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Abstract: Many studies have shown that Japanese automakers and their respective suppliers cooperate closely even in product development processes. However, most of these studies merely analyzed individual product development projects and discussed factors affecting it, such as development lead times, development man-hours, and product quality, thereby failing to cover cooperation between them in the advanced research and development processes. This paper is designed to analyze the latter aspect as quantitatively as possible.
This paper concludes that cooperation between Japanese automakers and their respective suppliers has been expanding into the development of advanced technologies, and suppliers that have the capability to participate in such advanced research and development activities have had closer relations with automakers than others.

Keywords: advanced research and development process, Japanese auto parts supplier system, long-term cooperative relationship

1. Introduction

In many industries, it is no longer realistic for a company alone to cover all product development processes; moreover, it is now essential for all companies to cooperate with each other in order to survive fierce competition (e.g., Henderson & Cockburn, 1994).

The Japanese auto sector is one of the industries wherein interfirm cooperation in product development processes plays a key role. The typical passenger car contains 20,000 to 30,000 components. As much as 70% of these components are provided by outside suppliers. These outside suppliers are often involved in design as well as manufacturing and may account for 50% or more of engineering costs.

In addition, a car is a typical product for integral architecture. Functional and structural interdependency is complicated between components comprising a car. The interfaces between these components are not standardized. It is difficult to manufacture an excellent car without knowledge of the entire car or individual components (Takeishi, 2003). In the Japanese auto industry, automakers accumulate knowledge on the entire vehicle, while automotive suppliers store knowledge on individual components. When new technologies or new-concept components are developed, automakers and suppliers must make joint development arrangements in order to integrate their knowledge.

In this respect, numerous studies at home and abroad since the mid-1980s have drawn a conclusion (e.g., Clark & Fujimoto, 1991; Cusumano & Takeishi, 1991; Dyer, 1996; Nishiguchi, 1994; Sako, 1996; Sako & Helper, 1998; Wasti & Liker, 1999; Womack, Jones, & Ross 1990): "Japanese automakers have maintained their respective long-term cooperative business relations with a limited number of suppliers and are conducting close information exchanges and coordination with them, based on their strong mutual trust. Very close cooperation between automakers and their respective suppliers have covered even product development processes. This is the source of the Japanese auto industry's international competitiveness." Since vehicle development lead times have shortened, research and development cooperation between automakers and their respective suppliers have reportedly been further enhanced (e.g., Konno, 2002).

However, vehicle development projects are not limited to improvements in existing technologies. They may include the development of advanced technologies for new-concept automotive components and new elemental technologies (e.g., materials). This type of technology development is known as advanced research and development (R&D). Advanced R&D of new technologies may precede or be integrated with new vehicle development projects.

Some studies have mentioned that automakers and their respective suppliers cooperate closely even for such advanced R&D activities (e.g., Ueda, 1995). However, most of the earlier studies analyzed individual product development projects and discussed factors affecting them, such as development lead times, development man-hours, and product quality, thereby failing to cover cooperation between automakers and their respective suppliers in the development of advanced technologies. Some studies that covered such cooperation were limited to qualitative analyses, lacking quantitative analyses.

This paper is designed to analyze as quantitatively as possible the reality of recent cooperation between Japanese automakers and their respective suppliers in the development of advanced technologies. This paper concludes that since cooperation between automakers and their respective suppliers has been expanding into the development of advanced technologies, suppliers that have the capability to participate in such development activities have had closer relations with automakers than others.

Section 2 analyzes data concerning automakers' joint patent applications in order to specify cooperation in the development of advanced technologies. Section 3 analyzes the relationship between such cooperation and business relations, based on questionnaire survey data. Section 4 covers the discussions and conclusion.

2. Analysis of automakers' joint patent applications

This section examines cooperation between automakers and their respective suppliers in the development of advanced technologies through an analysis of automakers' joint patent applications.

2.1. Source

Nine Japanese automakers' patent applications that were filed over 12 years between 1993 and 2004 and released on the official patent gazette issued by Japan's Patent Office were subject to the analysis. The nine automakers included Toyota Motor Corp., Nissan Motor Co., Honda Motor Co., Mitsubishi Motors Corp., Mazda Motor Corp., Suzuki Motor Corp., Daihatsu Motor Co., Fuji Heavy Industries Ltd., and Isuzu Motors Ltd. Applicants (multiple applicants for one patent application are all counted as applicants), publication numbers, application dates, names, international patent classification (first invention information subclasses), inventors, and other patent application data were entered into a spreadsheet software. Then, we conducted a patent map analysis of joint patents or patents for which applications were filed jointly by automakers and their suppliers.

Joint patent applications are those for which both automakers and their respective suppliers are applicants in connection with the development of advanced technologies that can be identified as novel or inventive. Thus, joint patents represent inventions to which both automakers and their suppliers have contributed.[1] Therefore, joint patents may be utilized as an indicator of successful cooperation in the development of advanced technologies.[2]

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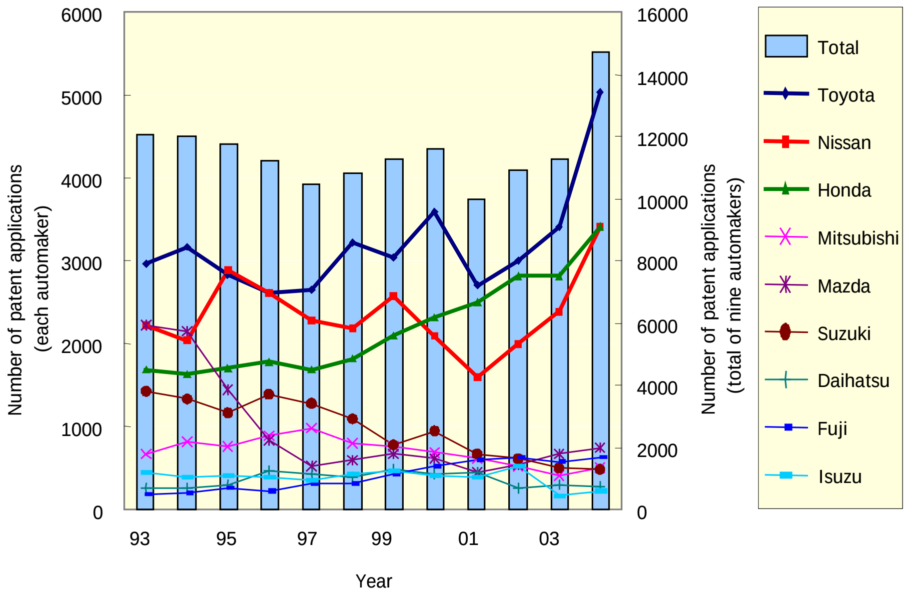
[1] Inventions subjected to patent applications may be published in the official gazette one and a half years after these applications are filed with the Patent Office. Applications may enter an examination process only if applicants pay examination fees and request examination. If novelty or inventiveness is identified in inventions, patents may be awarded.

This means that patents are awarded for only a minor portion of patent applications. Many applications are filed for defensive purposes. Manufacturing know-how and other technologies that may be difficult for rivals to imitate are not necessarily subject to patent applications. Therefore, there are various constraints on patent data. However, no alternative objective indicators exist for successful advanced technology development. As long as patent applications are filed at some cost, technologies subject to patent applications should have been screened by applicants and can be expected to feature some novelty or inventiveness. In this sense, patent data utilized as an indicator of successful advanced technology development may be permitted.

[2] Multiple applicants for a single patent may not

Figure 1. Patent applications



2.2. Overview of automakers' patent applications

First, we would like to review the overall trend. Figure 1 indicates the total number of patent applications for each of the nine automakers between 1993 and 2004.

The figure shows that the nine automakers' total patent applications began to increase circa 2002 and scored a sharp increase in 2004. Breaking down these patent applications by automaker, we find that Toyota, Nissan, and Honda account for a dominant share of the total. The three firms accounted for approximately 60%–70% of the nine automakers' total patent applications. In 2004, the three firms' share rose to 80%. Patent applications from the others have been falling or leveling off. Thus, Toyota, Nissan, and Honda have effectively been leading the development of advanced technologies in the Japanese auto industry.

2.3. Overview of all automakers' joint patent applications

Next, we would like to review the overall trend of patent applications filed jointly by automakers and their respective suppliers. Figure 2 indicates the total number of joint patent applications for the nine automakers and their share of total patent applications between 1993 and 2004.

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necessarily have made the same contributions to a particular invention. The applicants may assess their respective contributions to an invention subject to their patent application and agree on how to share gains from the patent. Such agreement may not be reflected in patent applications, but all applicants should have made some contribution to the invention. In this sense, there may be no problem with the utilization of joint patent applications as an indicator of cooperation in the development of advanced technologies.

Figure 2. Joint patent applications of nine automakers and their share of the total

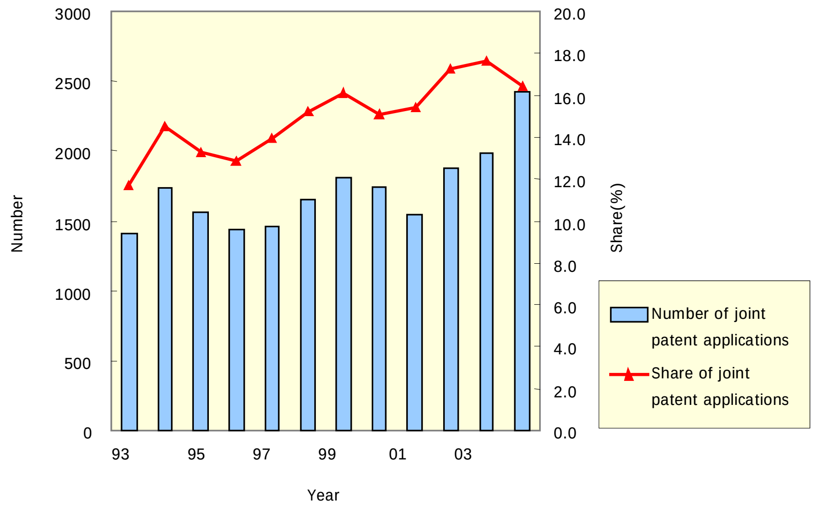


Figure 3. Joint patent applications and the share of the total for each automaker

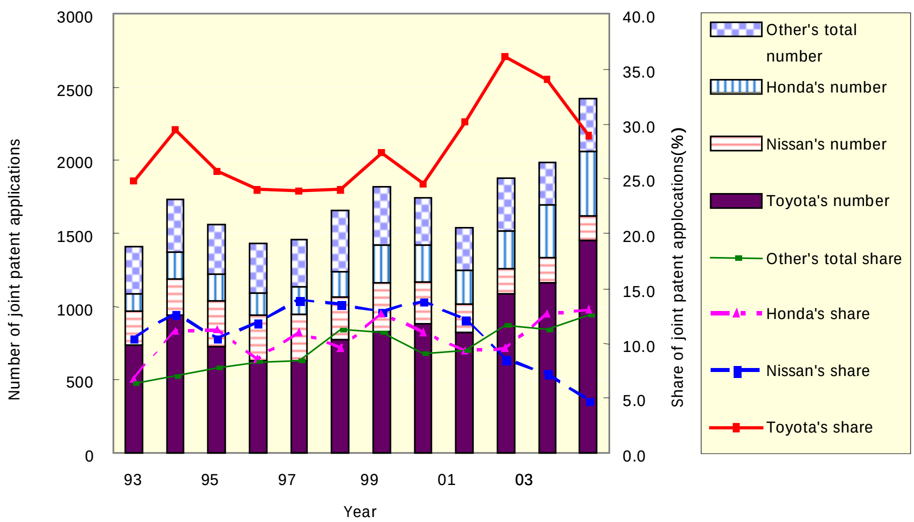
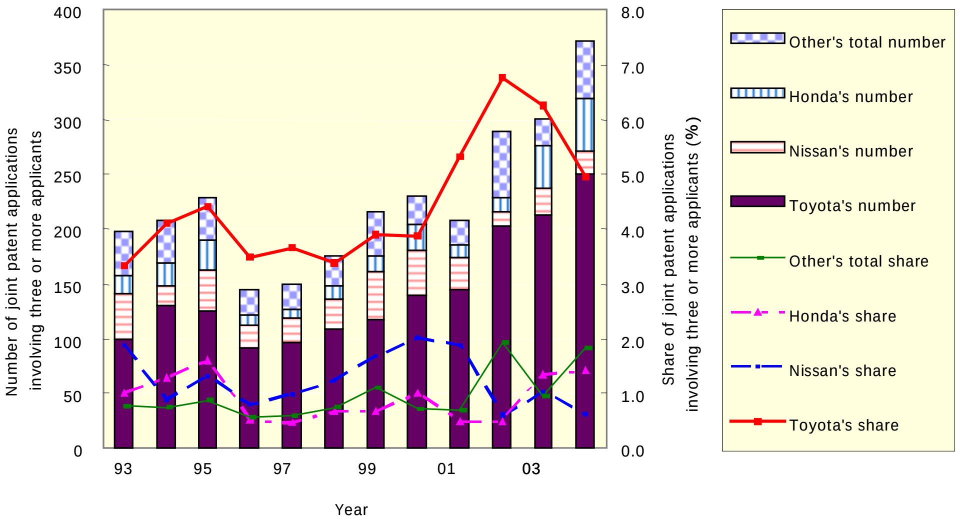


Figure 2 shows that the total number of joint patent applications and the nine firms' share of the total patent applications have continued at a rough upward trend, although some fluctuations were observed for some years. Notably, joint patent applications appear to have increased since the total patent applications of the nine firms began to rise in 2002. The joint patent applications' share of the total also indicates a rough upward trend.

Figure 3 indicates the number of joint patent applications and the share of the total for the three largest Japanese automakers——Toyota, Nissan, and

Figure 4. Joint patent applications involving three or more applicants for each automaker



Honda——between 1993 and 2004. This figure indicates that Toyota features a greater number of joint patent applications and a higher share of the total patent applications than the other two.[3]

Figure 4 indicates the number and percentage share of patent applications that each of the three largest automakers filed jointly with two or more suppliers. A patent application filed by three or more companies may represent not only dyad cooperation between an automaker and one of its suppliers but also horizontal cooperation between suppliers. The number and percentage share of such patent applications can be utilized as an indicator of advanced R&D cooperation.

This figure shows that Toyota features a far higher number and percentage share than the others for joint patent applications involving three or more applicants. Joint patent applications for Toyota mainly involve Toyota-affiliated suppliers including Toyota Central R&D Labs. Inc., Denso Corp., and Aisin Seiki Co. However, Toyota's R&D cooperation partners have not been limited to its affiliates. For example, Toyota filed a joint patent application for some telecommunications technologies in 1999 with five others——Aisin AW Co., Denso Corp., Fujitsu Ten Ltd., Pioneer Corp., and Matsushita Electric Industrial Co. We have found many large-scale R&D projects that Toyota has arranged with a wider range of suppliers.

Japanese automakers have thus expanded cooperation with their respective suppliers into the development of advanced technologies. Amid this

[3] Figures 3 and 4 do not make adjustments for Toyota's joint patent applications with Toyota Central R&D Labs. Inc. and Honda's joint applications with Honda R&D Co., although these R&D firms have personnel exchanges with their respective parent companies and are positioned as consolidated subsidiaries forming a component of their respective parents' R&D divisions. This means there is some upward bias for these companies. However, even if such adjustments are made, the conclusion here may remain unchanged.

general trend, Toyota has also made aggressive efforts to coordinate the joint style advanced technology development projects that include two or more suppliers and horizontal cooperation between suppliers. In terms of quantitative achievements through such cooperation, Toyota has progressed far ahead of other Japanese automakers.

3. Analyzing suppliers' questionnaire surveys

As indicated in the previous section, cooperation between automakers and their respective suppliers in the development of advanced technologies has been expanding in the Japanese auto industry. In a bid to examine how business relations between automakers and their respective suppliers have changed in line with such expanding cooperation, we would like to analyze a questionnaire survey of first-tier automotive suppliers that was conducted in November 2003 with Mr. Takahiro Fujimoto, professor at the University of Tokyo, and Mr. Ku Seunghwan, then assistant professor at Kyoto Sangyo University.

3.1. Survey data sources and outline

In the above questionnaire survey, we sent questionnaires to 340 first-tier automotive suppliers among the members of the Japan Auto Components Industries Association. Of these, 150 firms returned responses, resulting in a response rate of approximately 44.1%. In the questionnaire, the suppliers were first requested to select their most important product (component). Then, they were asked about their business relations with their main customer automaker regarding their most important product (component).

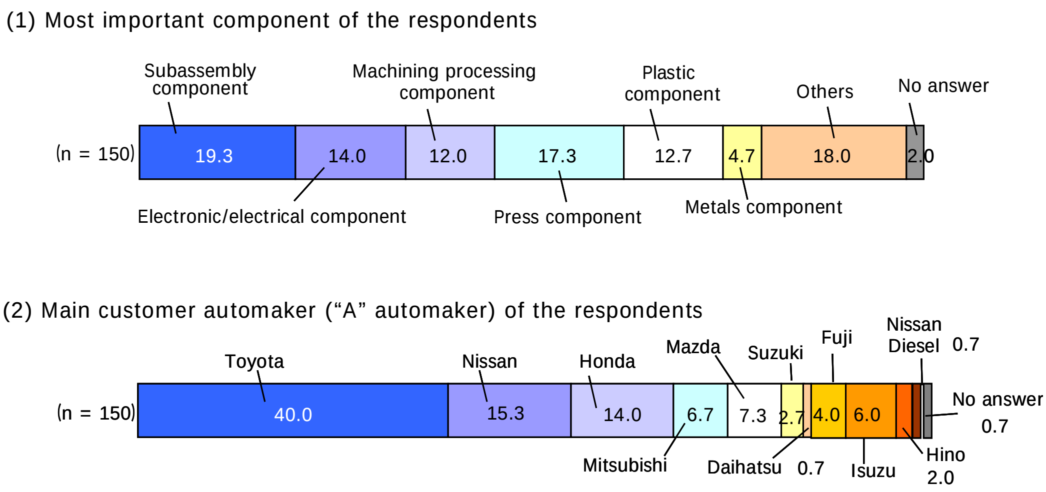
Note that the following are the components chosen as the most important, spread over seven categories: subassembly components, electronic/electrical components, machining processing components, press components, plastic components, metals (molding/casting) components, and others. Of the total, subassembly components accounted for 19%; press components, 17%; and electronic and electrical components, 14%. The main customer automaker mentioned by the questionnaire respondents were Toyota (40%), Nissan (15%), Honda (14%), Mitsubishi (7%), and Mazda (7%). These percentages roughly represent their respective domestic auto production shares.

Of the suppliers, 58% stated that they "undertook more than half of the development workload" themselves. When queried on the change in the percentage over the past 4 years, 56% responded that they observed an upward trend. These results reveal that many suppliers are responsible for a rather high ratio of the component development.

With regard to the suppliers' transactions with automakers, 69% belonged to the "approved drawing components," [4] 17% belonged to the "assigned

[4] Under the approved drawing components' practice, a supplier conducts detailed engineering based on rather rough specifications provided by the customer automaker. After the automaker approves the drawings, the supplier owns the final drawings and produces components based

Figure 5. Outline of component transactions (1)



drawing components,”[5] and 10% belonged to the “detailed-controlled drawing components.”[6] “Supplier proprietary components” were subjected to 3% of these transactions. These data indicate that suppliers participated in detailed engineering as part of the development of components in more than 86% (combining the approved drawing components and assigned drawing components) of the total transactions.

With regard to competition, 67% of the responding suppliers stated that they were selected by development competitions. Some 23% stated they received exclusive orders from automakers. The remaining 11% cited biddings.

The respondents were also requested to select the most important capability from the five alternatives for winning a competition. The most important capability, selected by 53%, was proposing and developing new component technologies or new-concept components beyond the improvement of existing technologies. The second most important capability, selected by 23%, was lowering costs through manufacturing process improvements. The third, selected by 17%, was reducing costs through design improvements. The fourth, selected by 4%, was developing components in accordance with specifications provided by automakers. The fifth, selected by 3%, was guaranteeing quality and just-in-time delivery.

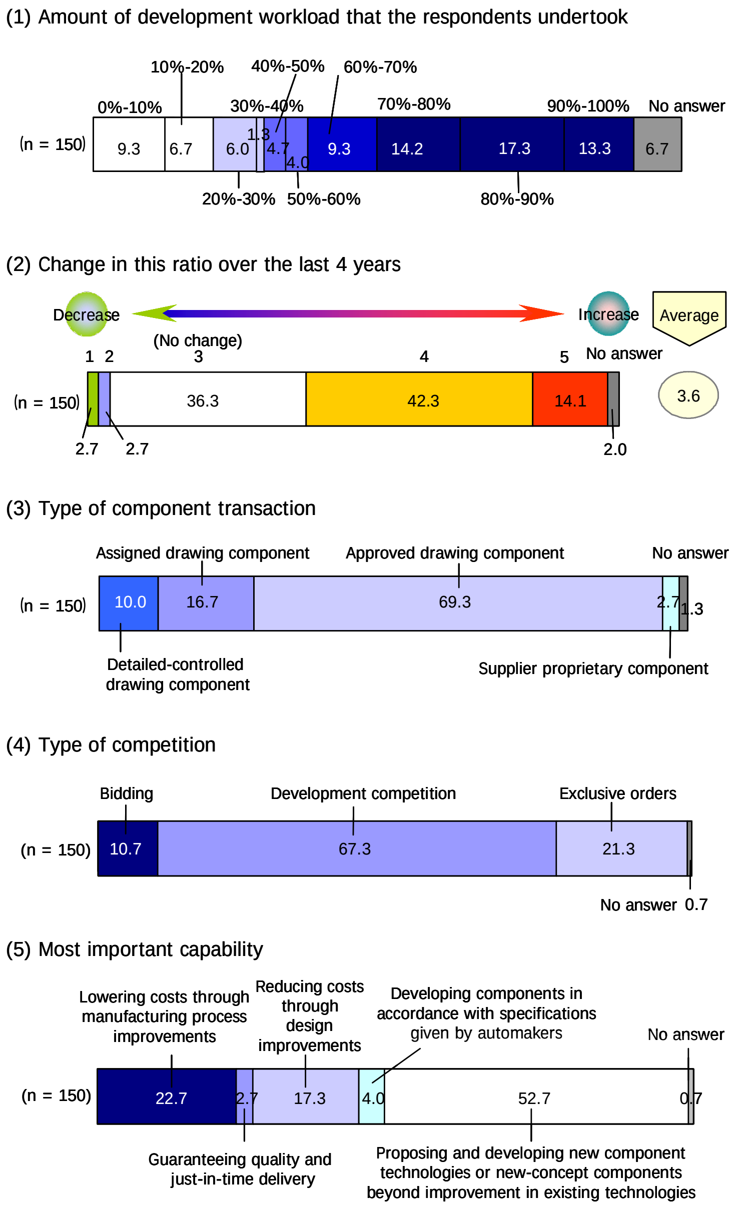
Regarding the relationship with a main customer

on it for delivery to the automaker. See Asanuma (1989) and Fujimoto (1999).

[5] Under the assigned drawing components practice, a supplier conducts detailed engineering based on the customer automaker’s basic drawing. The automaker owns the final drawing. This type of component is positioned between the approved drawing components and the detailed-controlled drawing components. See Fujimoto (1999).

[6] Under the detailed-controlled drawing components practice, an automaker undertakes detailed engineering for a component. Further, the automaker owns the final drawing and presents it to a supplier for production. See Asanuma (1989) and Fujimoto (1999).

Figure 6. Outline of component transactions (2)



automaker, 63% of the responding suppliers selected "Started to participate in development activities from a much earlier stage than before," 43% selected "We have increased the number of onsite guest engineers who work at the main customer automaker," 62% selected "Face-to-face communication during the development process increased," and 75% selected "There was more frequent overall communication (includes all forms of communication——emails, phone calls, and face-to-face)." These results suggest that the relationship between suppliers and their main customer automakers is becoming tighter and closer with regard to R&D activities.

In the modern Japanese auto industry, as indicated above, major suppliers have deepened relations with their main customer automakers. Meanwhile, in order to survive fierce competition, suppliers are required to have the capability to develop new cutting-edge components or technologies beyond improvements in existing technologies.

3.2. Stages for R&D cooperation

Next, we would like to examine the reality of cooperation in the development of advanced technologies.

Responses to Question 1 on the stages for R&D cooperation with a major customer automaker or receiving assistance from such cooperation are compiled in Figure 7. Of the total responding suppliers, 23% selected "Stages for R&D into new-concept components or modules, or new elemental technologies (such as new materials), including pilot studies on technologies that are not planned for specific models"; 43% selected "Stages for R&D of components for specific models, including new technologies or concepts beyond improvements in existing technologies or products"; 28% selected "Stages for R&D of components based on improvements in existing products"; 3% selected "No help from the main customer automaker or no participation in the automaker's R&D projects"; and 1% for "Others." Based on discussions in section 1, the advanced technology development cooperation is identified for the first and second cases. When queried about any change in the stages for cooperation over the past 4 years, 63% stated that they began to cooperate with the main customer

Figure 7. Outline of component transactions (3)

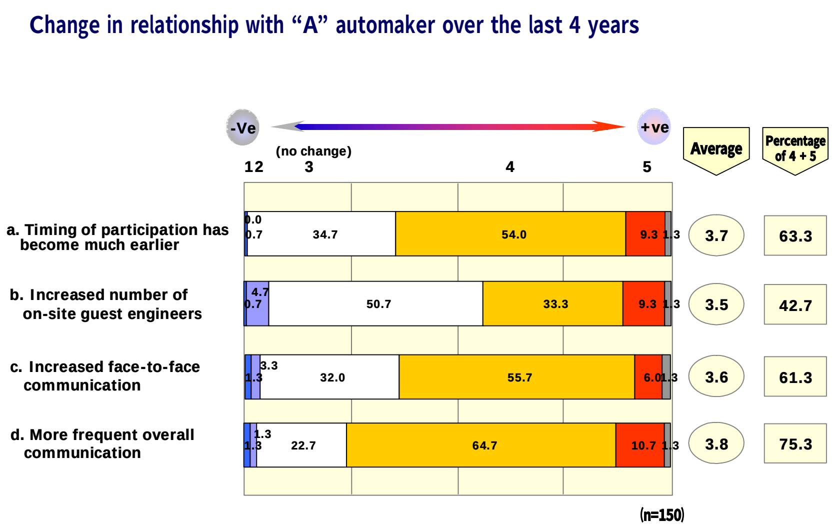
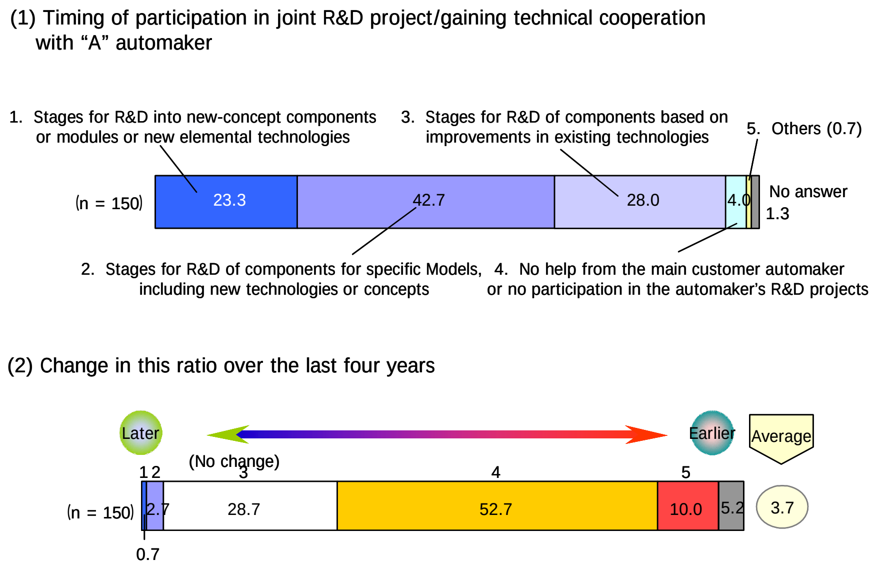


Figure 8. Stages for R&D cooperation



automakers in earlier R&D stages than in the past.

Consequently, a majority of suppliers are now cooperating with their respective customer automakers even in the development of advanced technologies at an earlier time than before.

3.3. R&D cooperation and intercompany relations

Next, we used the questionnaire survey data to consider any differences between suppliers that cooperate and those that do not cooperate with the main customer automakers in the development of advanced technologies.

As mentioned earlier, relations between automakers and their respective suppliers are predominantly based upon the approved drawing components practice. Therefore, no significant difference was noted between various components' drawing type. Classification by the components' drawing practice may be too imprecise to be useful.

The suppliers' average workload portion of their joint R&D operations with their main customer automakers was significantly higher (the significance level at 1% in *t*-test) for suppliers cooperating with automakers in advanced technology development than for those refraining from such cooperation. With regard to any change in such workload portion over the past 4 years, the former (suppliers cooperating with automakers in advanced technology R&D operations) pointed to a more significant expansion (1%) than the latter (those refraining from such cooperation). With regard to relations with main customer automakers, the former feature cooperation in earlier R&D stages (1%) as compared to the latter, a faster increase (5%) in face-to-face communications, a faster increase (5%) in overall communications, and a greater expansion (1%) in onsite guest engineers stationed at automakers. These data suggest that suppliers cooperating with automakers in advanced technology R&D operations have closer relations with automakers than those refraining from such cooperation.

3.4. Suppliers' capabilities and cooperation with automakers in advanced technology development

Next, we would like to examine the relationship between suppliers' capabilities and their cooperation with automakers in advanced technology development activities.

From the resources-based view of the firm, the core elements of resources and capabilities that define corporate competitive advantage are knowledge and know-how accumulated in the companies (e.g., Barney, 1997; Teece, Pisano, & Shuen, 1997). This may mean that the higher the knowledge and know-how accumulated in a supplier, the more likely it is for that supplier to be permitted to participate in advanced technology development. Therefore, the following hypothesis is proposed: The higher the knowledge and know-how accumulated in a supplier, the more likely it is for that supplier to be permitted to participate in advanced technology development.

We have utilized the abovementioned supplier questionnaire survey data for verification. As incomplete responses were excluded from the data, the number of samples or responding suppliers for this analysis came to 145.

As an indicator of advanced technology development cooperation as an explained variable of the working hypothesis, we have constructed a dichotomous variable—"1" for the first and second responses to "Question 1" in Section 3.2 and "0" for the third and fourth responses. One respondent selected the fifth alternative ("Others") and was excluded from the samples because no details were provided.

As for the suppliers' knowledge levels as the defining variable, component-specific knowledge is separated from architectural knowledge, based on Takeishi (2003).[7] For control variables, we have used the technology change for controlling changes in the relevant component technologies, the external interdependency for controlling the external architecture characteristics of relevant components, and the internal interdependency for controlling the internal architecture characteristics of the components, based on earlier studies such as Takeishi (2003), Nobeoka (1999), and Han (2002). For details including original questions that constitute variables, see Table 1.

The logit analysis has been used for the verification of the hypothesis since the explained variable is a dichotomous variable. Table 2 indicates averages of major variables, standard deviations, and the correlation matrix. Table 3 shows the results of the

[7] Component-specific knowledge is the knowledge of performances, costs, and production processes for specific components. Architectural knowledge is the knowledge of the coordination of components that are structurally and functionally related to each other (Takeisihi, 2003).

Table 1. Explanations of variables

Variable	Specification	Note
Participation in the advanced technology development	The dichotomous variable is set at "1" for Alternatives 1 or 2 of the five listed on the right side and at "0" for Alternatives 3 or 4.	**Question:** In what stage of component R&D operations at the major customer automaker do you participate or gain help from the customer? (Choose one alternative) 1. Stages for R&D into new-concept components or modules, or new elemental technologies (such as new materials), including pilot studies on technologies that are not planned for specific models 2. Stages for R&D of components for specific models, including new technologies or concepts beyond improvements in existing products. 3. Stages for R&D of components based on improvements in existing products. 4. No help from the main customer automaker or no participation in the automaker's R&D projects 5. Others (Specifically:)
Component-specific knowledge	Average score of responses to 10 right questions	**Question**: What is your estimated level of knowledge about the following points compared to the levels for automakers? (A five-point Likert scale for each question) a. Functional design b. Structural design c. Material design d. Durability design e. Core technology f. Manufacturing process g. Quality control h. Manufacturing cost i. Material cost j. Components cost
Architectural knowledge	Average score of responses to 8 right questions	**Question**: What is your estimated level of knowledge about the following points compared to the levels for automakers? a. Final customers' needs and preferences regarding Component X (main component) b. Automakers' manufacturing processes (particularly, availability for assembling) c. Functional coordination with other components d. Structural coordination with other components **Question**: What is your estimated level of knowledge compared to the levels for automakers about the following points regarding "other components" linked closely to Component X? a. Knowledge of engineering b. Knowledge of production c. Knowledge of evaluation d. Knowledge of costs
Technology change	Score of responses to the right question	**Question**: How do you evaluate the following item in comparison with other components in general? a. Technological changes are fast
External interdependency	Total of the following scores of responses to right questions: External interdependency = -a-b-c+d-e+f	**Question**: How do you evaluate the following items in comparison with other components in general? a. External interfaces are standardized within the company. b. External interfaces are standardized within the industry (adopted at two or more companies). c. Component X functions independently (can be designed without considerations to functions of other components) d. Component X functions multidimensionally. e. Component X is structurally independent (can be designed without considerations to structures of other components).
Internal interdependency	Total of the following scores of responses to right questions: Internal interdependency = g+h	**Question**: How do you evaluate the following items in comparison with other components in general? g. If a subcomponent design is modified, most other subcomponent designs must be modified. h. If a mix of materials is modified even slightly for Component X, the production method and production process conditions (pressure, temperature, timing, time, procedures, etc.) must be modified considerably.
Toyota dummy	A dummy variable set at 1 for Response 1 of responses to right questions and 0 for any other response	**Question**: What is you main customer automaker? (Choose one) 1. Toyota 2. Nissan 3. Honda 4. Mitsubishi 5. Mazda 6. Suzuki 7. Daihatsu 8. Fuji 9. Isuzu 10. Hino 11. Nissan Diesel 12. Others

logit analysis.

First, Model 1 of Table 3 indicates that the suppliers' component-specific knowledge has a positive effect on their cooperation with automakers in advanced technology development. The effect is observed at a 10% significance level. This means that the working hypothesis has been supported in regard to component-specific knowledge. Second, the model indicates that component-specific knowledge is more important than architectural knowledge for suppliers to be permitted to cooperate with automakers in advanced technology development. Architectural knowledge is thus insignificant. Third, the model also indicates that the technology change as a control variable has a positive effect at a 1% significance level and the external interdependency has a positive effect at a 5% significance level. These indications mean that the faster the technology change and the

Table 2. Descriptive statistics and the correlation matrix of major variables

	Variable	AV	SD	1	2	3	4	5	6	7
1	Participation in the advanced technology development	0.67	0.47	1.00						
2	Component-specific knowledge	3.80	0.61	0.23	1.00					
3	Architectural knowledge	2.97	0.67	0.06	0.22	1.00				
4	Technology change	3.43	0.79	0.28	0.14	0.07	1.00			
5	External interdependency	-4.57	3.21	0.24	0.01	-0.11	0.18	1.00		
6	Internal interdependency	6.77	1.52	0.02	0.10	0.12	0.06	0.04	1.00	
7	Toyota dummy	0.39	0.49	0.15	0.01	-0.11	-0.19	0.03	-0.06	1.00

Note: If the absolute value of a correlation coefficient ≦ 0.22 then it is significant at the 1% level, and if the absolute value is ≧ 0.18 then it is significant at the 5% level.

Table 3. Logit analysis results

Model	1			2		
Explained variable	Participation in the advanced technology development					
	β	S.E.	*p*	β	S.E.	*p*
Component-specific knowledge	0.52	0.30	0.08	0.49	0.30	0.10
Architectural knowledge	0.13	0.27	0.63	0.19	0.28	0.49
Technology change	0.65	0.26	0.01	0.80	0.27	0.00
External interdependency	0.16	0.07	0.02	0.16	0.07	0.02
Internal interdependency	-0.05	0.13	0.71	-0.03	0.13	0.81
Toyota dummy				1.02	0.43	0.02
Constant term	-2.76	1.55	0.08	-3.81	1.65	0.02
-2logL	162.9			156.9		
Negelkerke R2	0.19			0.24		
Sample size	145			145		

Note: A yellow cell means $p < 0.10$

more interdependent the components compared to others, the higher is the probability for suppliers to be permitted to cooperate with automakers from the advanced technology development stage. This finding is an interesting theme for future study.

Thus, these results suggest that suppliers that are identified as having relatively higher-level component-specific knowledge and the capability to develop advanced technologies or new components beyond improvements in existing technologies are more likely than other suppliers to have cooperated with automakers from the advanced technology development stage and have eventually developed closer business relations with automakers.

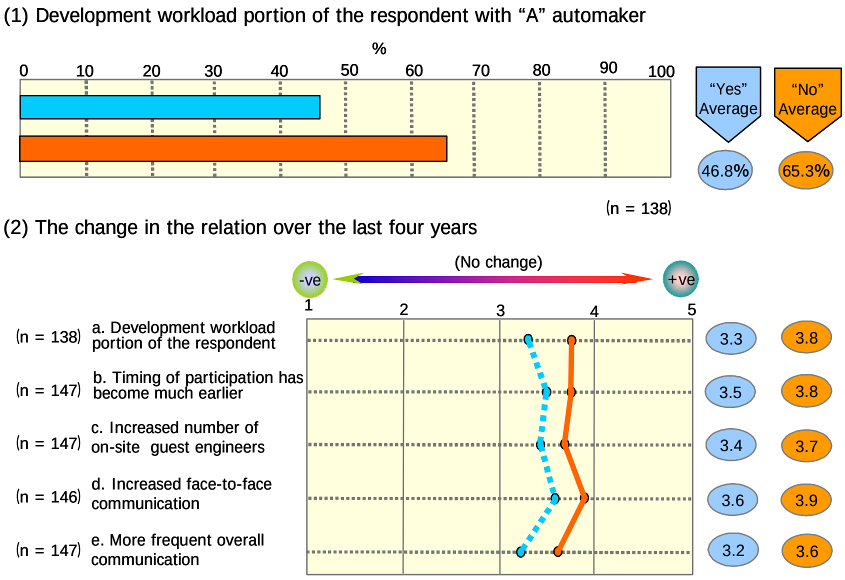
3.5. Progressive practice of Toyota's suppliers

The analysis in section 2 found that Toyota has progressed ahead of other Japanese automakers in cooperation with suppliers in the development of advanced technologies. Therefore, this subsection examines the differences between suppliers whose main customer automaker is Toyota (Toyota's suppliers) and the other suppliers.

Figure 9 shows a comparison of the responses provided by Toyota's suppliers and the others to "Question 1" in section 3.2. Of Toyota's suppliers,

Enhancement of the advanced R&D cooperation

Figure 9. Advanced technology R&D cooperation and business relations



those in the first category accounted for more than 35%. This percentage more than doubled the level for the other suppliers. Of Toyota’s suppliers, those in the second category also accounted for more than 35%. This percentage is slightly lower than that for the other suppliers; however, a combination of the first and second categories for Toyota’s suppliers was 16.2 percentage points larger than for the other suppliers. The difference between Toyota’s suppliers and the others was at a 1% significance level.

Model 2, in which a Toyota dummy is added to Model 1 of Table 3, indicated the Toyota dummy’s positive effect at a 5% significance level even after all the other variables were controlled. Moreover, Model 2 indicated that the addition of the Toyota dummy improved the regression’s explanation power. In short, Toyota’s suppliers are more likely than the others to participate in the main customer’s advanced technology development projects. The probability gap was calculated at approximately 36 percentage points.

In this way, Toyota’s joint R&D operations with major suppliers from the advanced technology development stage are more positive than the other automakers.

4. Discussions and Conclusion

4.1. Cooperation in advanced technology development and intercompany relations

The above analyses indicated that Japanese automakers and their respective suppliers have expanded their cooperation into the development of advanced technologies over the past decade.

In the Japanese automotive market, the automakers need to realize sufficient functionality and product quality at a low price. Furthermore, for example, the automakers need to realize not only the basic drive, turn, stop, and gasoline mileage functions but also user-friendliness, huge baggage area, airbags, active safety, and CO_2/NO_X reduction features. Thus, today, automotive technology development races have grown fiercer.

For most of the automotive components, technological innovations are rapid, including development and utilization of new materials (particularly a shift from metals to plastics) and advanced IT technologies, miniaturization, and lightening. In addition, a shift has made rapid progress to modules over the recent years. The new design concepts for automotive components have been proposed one after another and some have been put into practice.

Under these circumstances, automakers have been prompted to cooperate with their suppliers for the development of advanced technologies excluding cores (e.g., Konno & Okuda, 2005). Such conditions have apparently exerted a great impact on business relations between automakers and their suppliers.

The advanced technology development projects are more difficult to manage than projects that only involve making improvements to existing technologies. The former projects are not free from a high level of uncertainty; therefore, the parties find it difficult to precisely judge in advance what each of them should do, to what extent, what level of resources (human, materials, financial, or knowledge) should be provided, and the probability of success.

Additionally, with the advanced technology development projects, new and innovative technology is only actualized when both parties provide their latest technology and know-how to each other, engage in extended information exchange, and repeat trial and error processes. This kind of knowledge transfer, fusion, and creation process is bilateral, highly sophisticated, and invisible; therefore, it is difficult to manage. In addition, even if an automaker and a supplier succeeded in generating new innovative technologies, it is difficult to measure how much of the contribution was made by which party, or how much of the resulting profits should be attributed to which party.

Furthermore, in case either of them disclose proprietary information to third parties, the repercussions are tremendous. Even if parties signed NDA (Non-Disclosure Agreement), it is difficult to prove illegal activity or wrongdoing on an objective basis.

According to the above discussion, we can conclude that because the joint style advanced technology development activities are difficult to manage only by way of contracts, automakers tend to collaborate with true core suppliers. Core suppliers, in this sense, refers to suppliers with whom the automaker has a long-term, cooperative, and trustful relationship, as well as suppliers who have high R&D capabilities. Consequently, although the number of core suppliers that can participate in automakers' advanced technology development is limited, the relationships between automakers and the core suppliers should become closer (Konno, 2002).

4.2. Progressive practice of Toyota's suppliers and future problems

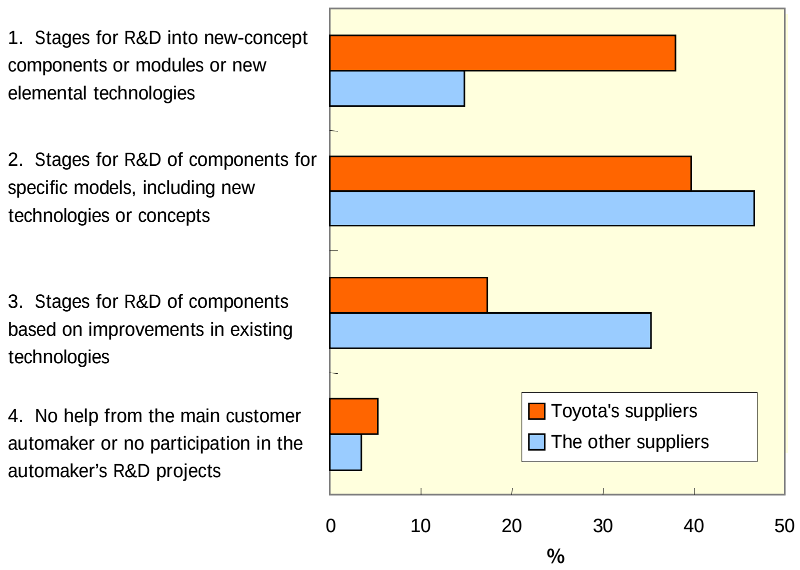
Even amid this general trend, our findings indicate that Toyota has progressed ahead of other automakers. Toyota has cooperated with major suppliers from the advanced technology development stage more positively than other automakers. Its quantitative achievements in this regard are far more than those of the other automakers. Toyota has also proactively coordinated the joint style advanced technology development projects that include two or more suppliers (which include horizontal cooperation between suppliers).

Since automotive technologies have been advancing rapidly, Toyota's excellent production and product development operations cannot guarantee its future competitiveness. If it fails to develop advanced technologies, even Toyota could be outperformed by the others. Given Toyota's recent success, it seems that the network that Toyota has constructed for cooperation with suppliers in the development of advanced technologies might have contributed to the firm's international competitive edge.

The progressiveness of the network that Toyota has built for cooperation with suppliers in the development of advanced technologies indicates the firm's excellent management of cooperation. This paper does not address details on automakers' management of cooperation with suppliers in the development of advanced technologies. However, this is a very interesting theme.

In any case, studies have not been conducted in

Figure 10. Differences between Toyota's suppliers and the others



this area. In the future, multifaceted surveys should be conducted to examine the management of cooperation in advanced technology development.

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