Evolution of Inter-firm Technology Transfer and Technological Capability Formation of Local Parts Firms in the Thai Automobile Industry

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Abstract

This paper investigates the evolution of 'inter-firm' technology transfer in the Thai automobile industry, which has gradually been integrated into global production network of some specific automotive models (one-ton pickups). This paper discusses the linkage between the role of automobile assemblers in transferring technology and the way their strategic changes bring about heightened demands on the technological capacity of suppliers and the contents of technology transfer. With higher competition at the global level, local suppliers are required to improve their technical and managerial skills, especially in the area of 'product engineering' capability. The authors examine the ways local firms have adapted to these changes in their environments, as well as the ways they utilize inter-firm relationship with automobile assemblers as a means to improve their own technological capabilities. The dynamic process of capability formation in local parts firms, through intensive efforts and learning inducements brought about by inter-firm relationships, are also discussed.

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1. Introduction

Apart from its direct effects in terms of the expansion of domestic output, capital formation, employment, and export, FDI can bring about indirect benefits through technology transfer and diffusion, skills upgrades and the development of local ancillary industries through the creation of backward linkages (Dunning 1983 Borensztein et al 1995, Blomström and Kokko 1999, Markusen and Venables 1999). Multinational firms can play a crucial role in international technology transfer because they undertake a major part of the world's research and development (R&D) efforts to create and then own most of the world's advanced technology (Blomström and Kokko 1999). When making direct investments abroad by establishing overseas affiliates, these multinational firms inevitably must transfer technology to and upgrade the existing skills of the local population to assure the efficiency of their foreign operations (Sedgwick 1995). Therefore, FDI can act as a catalyst for knowledge diffusion and the provision of local capability formation in the recipient countries of FDI.

Nonetheless, prevailing understandings of the ways technology is transferred are far from complete. The existing literature has focused on the issue of international technology transfer through formal and voluntary forms such, as intra-firm

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technology transfer and arm's-length trade of technology (Reddy and Zhao 1990). However, very few studies have investigated the dynamic process of technology transfer and technological capability-formation in developing countries (e.g., Kim 1997, Cyhn 2002), and even they have not focused directly on technology transfer through informal mechanisms, such as the incidence of 'inter-firm' technology transfers.[1]

Irrespective of the mode of technology transfer, researchers have found the transfer of 'tacit' knowledge or 'software' technology more important than that of its 'explicit' or 'hardware' counterpart. Accordingly, the term technology transfer refers to the process of skill formation as experienced by the recipient as a direct result of the contributions of the technology source. The transfer process is said to be complete only if the recipient of the technology understands and is able to operate, maintain, and make effective use of the technology that has been transferred (Cohen and Levinthal 1989). Therefore, evidence of the success of any technology transfer would be an increase in the technological capabilities of the employees of the recipient firm and the enhancement of the efficiency of the firm's production process as a whole.

Conversion from tacit to tacit (called socialization) takes place when one individual's tacit knowledge is shared with another individual through training or face-to-face communication, whereas conversion from explicit to explicit (combination) takes place when discrete pieces of explicit knowledge are combined and made into a new whole. Conversion from tacit to explicit (externalization) occurs when an individual or a group is able to articulate his or her tacit knowledge into an explicit format, while conversion from explicit to tacit (internalization) occurs when

[1] Inter-firm technology transfer is defined as a relationship between a supplier and an assembler that encourages knowledge transfer to make suppliers meet the assembler's quality requirement. This is sometimes referred to as 'buyer-supplier' relationship (Capannelli 1997), or 'technology partnering' (Beecham and Cordey-Hayes 1997).

new explicit knowledge is internalized and shared throughout a firm and other individuals begin to utilize it to broaden, extend and reframe their own tacit knowledge. As more participants in and around the firm become involved in the process, such conversions tend to become both faster and larger in scale (Nonaka and Takeuchi 1995). Nevertheless, effective knowledge conversion requires two important elements: an existing knowledge base (especially the tacit element) and an intensity of effort to develop that knowledge base. This is known as 'absorptive capacity', and it is crucial in determining how fast and successfully local suppliers can internalize the transferred technology and make it their own. Intensity of effort and commitment to the process are more important than the knowledge base because the former creates that latter, but not vice versa. Thus, intensity of effort enables a firm to improve its absorptive capacity, which in turn helps it achieve technology transfer from its customers effectively.

3. Research Method and Evidence of Inter-firm Technology Transfer

3.1 Research methodology and general information about firms studied

The main purpose of this paper is to examine the evolution of inter-firm technology transfer, the role of automobile assemblers in promoting the technological capability of local parts suppliers, and internal efforts made to develop technological capability. To gain a deeper understanding of this issue, a series of exploratory interviews were undertaken in 2002 and 2003 to gauge the extent to which the changes within the industry would have an impact on the automobile-supplier relationship. The authors visited five major assemblers and interviewed their management staff. Basic information about these companies is shown in Table 1. The survey results suggested that car manufacturers were changing their purchasing and production strategies in the direction of globalization, i.e., the adoption of global sourcing policy and the integration of Thailand into their global production network. This had created substantial pressure on parts suppliers, especially in the area of engineering capability, and resulted in changes in the inter-firm relationship.

Table 1 Basic Information about Automobile Assemblers Interviewed

Assemblers	Establishment	Ownership	Main products	Production Capacity (in 2003)	Market orientation
Auto T	1960s	Japanese	Passenger cars and pickup trucks	200,000	Domestic
Auto I	1960s	Japanese	Pickup trucks	147,000	Domestic
Auto M	1960s	Japanese	Passenger cars and pickup trucks	174,000	Export
Auto A	1990s	Japanese	Pickup trucks	135,000	Export
Auto H	1990s	Japanese	Passenger cars	50,000	Domestic

Source: Information obtained from field survey during 2002 and 2003
Note: All firms currently export their products; however, if they export more than 50 percent of total production, they are classified as Export, otherwise, as Domestic, firms.

Once familiarized with that situation, the authors designed a set of questionnaires and sent them to about 100 suppliers in August 2003. These suppliers were in the same sample to which a similar type of questionnaire had been sent in 2000.[2] The questionnaires were distributed in this way to take advantage of existing information about the inter-firm technology transfer, which is believed to provide a clearer picture to the evolution of inter-firm relationship in the Thai automobile industry. The main questions were designed to obtain general information, the characteristics of the suppliers' relationships with their customers and the status of their technological capability. The questions also asked how the companies had acquired their production technology and the sources of the improvements to their technology, the kinds of technical linkages their customers had provided, and the technological benefits that had been derived from having established and maintained inter-firm relationship with automobile assemblers in Thailand. As will be reported in the next section, 15 questionnaires were returned; six were from foreign suppliers,

[2] Details about the structure of questions and sample firms surveyed in 2000, please refer to Techakanont (2002).

seven from joint ventures, and two were pure Thai companies (see Table 2).[3] Then, during December 2003 and February 2004, the authors conducted in-depth, follow-up interviews with local suppliers who reportedly had received direct technical assistance from customers. These interviews were undertaken to examine the dynamic process of technological capability formation through inter-firm relationships and the intensity of their efforts. The survey findings and an analysis of them are provided in the next sections.

Table 2 Characteristics of Parts Suppliers that Answered the Questionnaire

Type of firms	Foreign firms (6 firms)	Joint venture firms (7 firms)	Thai firms (2 firms)	Total (15 firms)
Establishment				
1960-1970	1	2	1	4
1980s	1	1	1	3
1990-1995	2	4	-	6
1996 onwards	2	-	-	2
Employment				
Less than 100	1	-	-	1
100 - 199	-	1	-	1
200 - 499	4	4	-	8
More than 500	1	2	2	5
Sales (in 2002)				
Sales less than 100 mB.	-	-	-	-
100-499.9 mB.	2	2	-	4
500-999.9 mB.	3	3	-	6
1000-3000 mB.	1	1	-	2
more than 3000 mB.	-	1	2	3
Percentage of export				
0%	4	1	-	5
0.1 - 10 %	-	2	2	4
10.1 - 20 %	-	-	-	-
20.1 - 50 %	2	4	-	6
More than 50%	-	-	-	-
Total	6	7	2	15

Source: Questionnaire survey in 2003

[3] Note that foreign firms refer to companies which have foreign equity not less than 80%, joint ventures to companies which have foreign equity between 20 to 79%, and Thai firms to companies which have foreign equity less than 20%

3.2 Evidence of inter-firm technology transfer in the Thai automobile industry

This part presents the field survey findings regarding the existence of inter-firm technology transfer in the Thai automobile industry. The questionnaire asked the firms to specify three important buyers (in terms of value of order) over the previous three years, to investigate the types of inter-firm relationship they had had with them. The assistance reported was of two types: 1) direct assistance, referring to the cases in which suppliers reported having some customers' staff staying on as support for a period of time, and 2) indirect assistance, referring to situations in which the respondents received some other form of advice from customers. Those who answered neither were regarded as having received nothing. The questionnaire results showed that, of the 15 firms, only three reported having received technical assistance as well as technical advice from their customers; 11 firms reported having received technical advice, while the rest appeared to have received nothing (see Table 3).

Table 3 Number of Respondents Receiving Technical Assistance from Customers (during 2000 and 2003)

Degree of inter-firm technical assistance	Foreign	Joint venture	Thai	Total
Received direct assistance from customer	1	-	2	3
Received only technical advice	4	7	-	11
Not at all	1	-	-	1
Total number of firms	6	7	2	15

Source: Same as Table 2

However, the follow-up interviews with the assemblers revealed that all of them had teams that periodically visited and followed up on the work of the suppliers to ensure the quality and timing of all parts ordered. In many cases, their staffs merely visited and provided technical advice on specific problems found during the visit or on areas for improvement. Thus, the suppliers had received various kinds of technical advice from their customers.[4] The questionnaire noted four types of such technical linkages, including advice about quality control, maintenance, design drawings for the making of dies or tooling and advice about project management. As shown in Table 4, almost all suppliers had received advice about quality control, while about half of them received advice about project management. Only few of them received advice about maintenance and design.[5]

Table 4 Technical Advice Suppliers Received from Customers

Types of technical advice	Foreign	Joint venture	Thai	Total
Quality control practice	5	7	2	14
Advice about project management practice	3	3	2	8
Maintenance	1	1	1	3
Design drawing to make die or tooling	-	-	2	2
Total number of firms	6	7	2	15

Source: Same as Table 2

By rearranging the information obtained from the questionnaires, the authors were able to correlate the technical linkages the car assemblers had created with these suppliers. As regards their answers about who their main customers were, they mentioned eight car assemblers, six of them Japanese firms and two non-Japanese firms. As shown in Table 5, the Japanese assemblers seemed to have played a more active role in providing inter-firm support, while non-Japanese firms provided only advice about quality control. The more active roles of the Japanese firms could be explained by the larger scale of their production and their longer experience in Thailand.[6]

4 Some firms may have realized that they had received nothing, despite having been visited. In this survey, there was only one case of a firm that had not received any advice from an automobile customer; hence, this firm was considered to have received nothing.

5 Based on the information obtained from the survey, only six suppliers (two are Thai firms) reported having performed design activities. As seen in the table, only two Thai firms received this assistance, while foreign and joint-venture firms did not receive it. This implies that an inter-firm technical linkage is likely to be created with suppliers that have limited opportunities. In foreign and joint ventures, this is accomplished through 'intra-firm' support.

6 Production capacity of Auto B was about 10,000 units, while Auto G about 40,000 units per year. While that of Japanese firms were larger than 100,000 units a year, see also Table 1. Nonetheless, this

Table 5 Technical Advice Assemblers Provided to Suppliers

Types of technical assistance that each car assembler provided to suppliers	Japanese firms						Non Japanese firms	
	Auto T	Auto M	Auto I	Auto N	Auto A	Auto H	Auto B	Auto G
Quality control practice	5	5	8	1	6	5	1	1
Advice about project management practice	3	-	2	-	2	1	-	-
Design drawing to make die or tooling	-	-	1	-	1	-	-	-
Maintenance	-	-	-	-	1	-	-	-
Total number of suppliers that supply parts to each assembler	5	5	8	2	7	5	1	1

Source: Same as Table 2

The findings presented thus far confirm the existence of and reveal the current state of inter-firm technology transfer in the Thai automobile industry. The suppliers acknowledged that these linkages with automobile assemblers provided benefits in several ways, such as improving their quality-control and problem-solving capabilities and teaching them new production processes and management practices. They added that all of these had led to improvements in their technological capabilities.

All firms in the sample reported that, compared to three years previously, they had experienced technological improvements such as reductions in defect rates, shortening of time cycles and reductions in production costs. However, as discussed in the previous section, in addition to inter-firm technical linkages, there are several other possible sources of such improvements, such as internal efforts, the adoption of newer machinery, longer-term worker experience, the creation of linkages with suppliers and institutions, and even the hiring of skilled workers from other companies. Accordingly, it was also necessary to inquire about the sources of the improvements noted.

The questionnaire asked all suppliers about the importance of several potential sources of technological improvement. Theoretically, firms could improve their

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information should be interpreted with care because it is derived from suppliers' answers that they receive what kind of support or advice from their main customers. Interview with assemblers indicate that each firm has its own plan and program to support suppliers. However, this is beyond the scope of this paper. Future research may be taken by investigating in details about supplier development program of these firms to yield clearer understanding.

productivity in several ways, such as 1) acquiring new machinery (newer models of machines that were technologically more sophisticated), 2) in-house training efforts, such as training or technological activities, 3) the build-up of employees' experience (the learning-by-doing effect), 4) the hiring of skilled workers from other companies, 5) technical assistance resulting from having a relationship with the customers (inter-firm relationship with customers), 6) the improvement of the quality of the suppliers (inter-firm relationship with suppliers), and 7) technical linkages with institutions in Thailand (domestic sources of technology).[7]

In Table 6 and Figure 1, the responses are displayed in accordance with their average values, from high to low. In-house efforts and the improved experience of employees were regarded as the most important sources of technological improvement. It is interesting to observe that those improvements came from their suppliers, inter-firm technical relationships with customers, and the adoption of new machines that were expected to have a stronger impact. Technical linkages with institutions in Thailand such as universities, government laboratories, or technical training institutions were found to be less important to foreign and joint venture firms than it was for Thai firms. This finding provides evidence to support the argument that firms with foreign ownership have considerable opportunities to obtain necessary technology (both for manufacturing and for improving productivity) from their parent companies. Such opportunities are not already available to Thai firms; therefore, it is not surprising to observe that a domestic source of technology is regarded as an important source of technological improvement for independent Thai firms. As regards the last factor, head-hunting was found not to be an important factor for technological improvement; however, it received a high evaluation by Thai firms.

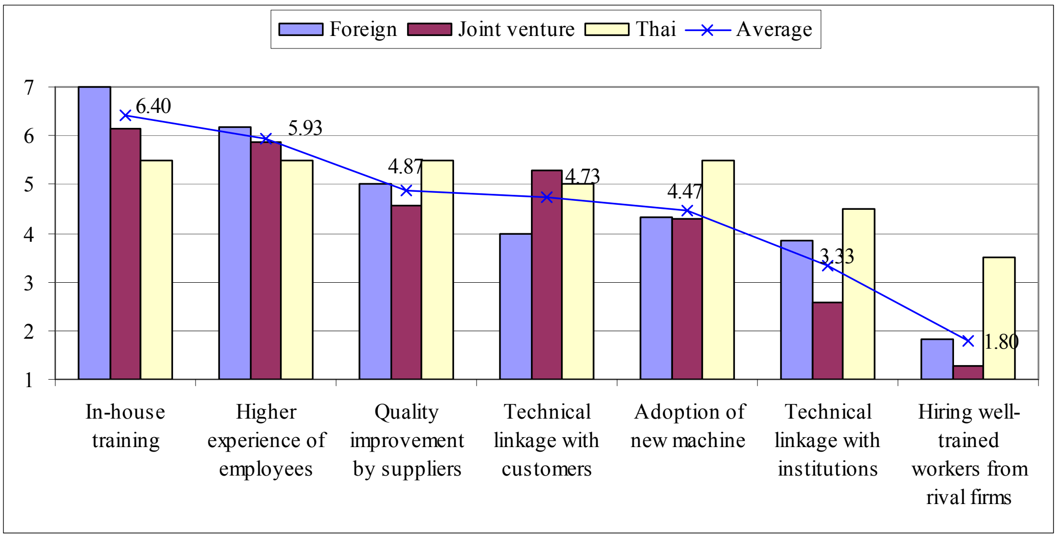
[7] They were asked to state the degree of importance of each factor, based on a Likert-scale from 1 to 7, in which 1 means that the particular source is not important at all, while 7 means that the particular source is extremely important, that it contributed to their improvement.

Table 6 Sources of Technological Improvement

Sources of technological improvement	Foreign	Joint venture	Thai	Average
In-house training	7	6.14	5.5	6.4
Higher experience of employees	6.17	5.86	5.5	5.93
Quality improvement by suppliers	5	4.57	5.5	4.87
Technical linkage with customers	4	5.29	5	4.73
Adoption of new machine	4.33	4.29	5.5	4.47
Technical linkage with institutions	3.83	2.57	4.5	3.33
Hiring well-trained workers from rival firms	1.83	1.29	3.5	1.8

Source: Same as Table 2

Figure 1 Sources of Technological Improvement



Source: From data in Table 6

4. Inter-firm Technology Transfer and Local Capability Formation: Case Studies

Field survey results presented earlier clearly show that automobile assemblers created inter-firm technical linkages, which made local suppliers realize that that was an important source of technological improvement. However, the process of technology transfer is not static. Once the environment in which firms operate has changed, e.g., the changes in the assemblers' production and purchasing policies that were discussed previously, those changes would affect the content of the inter-firm technology transfer as well as the capability formation of local suppliers. Thus, in this section, the results of the follow-up surveys regarding the three cases that reported inter-firm technical support from assemblers over the previous three to five years will be discussed. Then, an analysis and some general observations about the evolution of inter-firm technology transfer and technological capability formation within these three firms will be provided.

4.1 Case 1

Supplier A is a joint venture between a Japanese motorcycle manufacturer (62%) and a Thai firm (38%). In 2003, its main products were motorcycle parts (50%) and automobile parts (17%) and others (die cast molds and machining services). However, the equity ratio at its establishment, in 1990, was Thai (72%) and Japanese (28 %) businesses. The ownership structure was changed after 2000, due to liquidity problems (after the economic crisis), changes in the production technology and intense competition.

From 1990 to 2000, during which time the main source of the production technology was its Japanese partner, the Thai owners had management authority. The company's main products were casting parts for motorcycles. After 1995, the company has diversified its business to include the casting of auto parts; this was possible because of the Thai majority ownership. However, the Japanese partner was passive about providing technology to assist this supplier because its business was unrelated to the firm's main business. Supplier A acquired technology through a technical assistance (TA) agreement with a Japanese casting company to produce parts for Auto I. In 1996, it received approval to supply casting parts to Auto A. It believed that it could utilize the know-how it had acquired earlier to produce the same product for new customer. However, due to the difference in production techniques and specifications of the casting product, this supplier could not simply follow the production technique of Auto I. In fact, Auto A required that Supplier A take full responsibility for production preparation. Once it was clear that Supplier A could perform such activities to a tight deadline, Auto A needed to provide technical support. That technical support included sending experts to assist, work with and train local staff members (socialization) in the preparation stage (which lasted about two years) and the provision of designs for the new production line (transfer of explicit knowledge); in addition, all expenses were borne by the buyer (Auto A).[8]

Why did Auto A have to bear this costly activity when it could not gain any monetary benefit from doing so? There are two main reasons for this. One was that this obligation was on the mandatory list of the LCR regulations. Thus, Auto A had to procure the parts locally. Another reason was that it was impossible to switch to another supplier because of lead-time constraints. Hence, to avoid the setback of the entire project because of a delay on the part of a supplier, Auto A determined that providing intensive technical assistance in the technical area that the supplier lacked was both more economical and more efficient. This is a clear example of technology transfer through a buyer-supplier relationship, in which the buyer enhanced the local supplier's capability, especially in the area of its quality-control and project-management capabilities, without receiving any monetary payment for providing such assistance.

However, because of the economic crisis, the supplier faced a severe liquidity problem. This called for a rescue plan by its Japanese investor, which had also planned to make this supplier its regional base. Since the Japanese company became the majority party, 'intra-firm' technology transfer has become the main source of technology. As a result, Auto A changed its view of this supplier, in that it no longer considered it necessary to provide direct technical assistance, as it had done from

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[8] Details about the inter-firm technology transfer activity by this firm to suppliers in Thailand, including the case study of this supplier, were provided in Techakanont (2002). However, in that report, this assembler was named 'T-firm'.

1997 to 1999.[9] In the event that quality problems arose, the Japanese partner was responsible for solving them and supplying the counter-measure.

Intra-firm support took the form of increasing numbers of Japanese expatriates from one to six to provide coordination, technical advice, and training to enhance the technological capability of the supplier. The role of the Japanese partner in assisting this supplier included a short- and long-term plan. To overcome the low utilization capacity in the short-run, due to the economic crisis, it transferred orders from Japanese headquarters to Thailand. This included the transferring of molds and machinery for producing the parts and exporting them to Japan. This process is still ongoing. As its longer-term plan, it installed a new production line for a new product, low-pressure casting for cylinder heads (for motorcycles). In addition, it set up another casting process whose production technology was somewhat similar to that of the production of cylinder heads for a new generation of diesel engines (made from aluminum, instead of using ferrous casting). This was considered part of its plan to develop the production skills of Supplier A for future orders by some automobile assemblers in Thailand. This new technology is much more difficult to carry out than ferrous casting; hence, it was disclosed that without the Japanese partner, it would have been impossible for Supplier A to acquire this technology.

Moreover, in 2001, local engineers were sent to the headquarters plant in Japan to learn about mold design. Two groups were sent; each group consisted of three engineers, and the duration of their training was about three months. They were trained on the job, and the target was to make the Thai engineers understand the details of mold design so that later they could collaborate with mold-makers in Thailand. The Japanese firm made additional investments in CAD and CAM

[9] Interview with a top management of Auto A on March 12, 2001.

technology to support this activity. As a result, the design capability of Supplier A has been enhanced and developed. Previously, Supplier A lacked the knowledge about how to make a mold. It just gave a drawing of the part to mold-makers for them to produce. The mold-makers then proceeded to make 'as cast' drawings and mold drawings, after which they produced the mold. There was always the chance that some problem might arise due to the improper mold design and that Supplier A would not realize it until the trial of the finished mold. Thus, it took longer to have a perfect mold complete. After their training in Japan, local engineers came to understand the hidden technical issues specific to the part drawing and could translate and develop the drawing into an appropriate 'as cast' drawing. It was unable to do so in the past and lacked sufficient technical knowledge to collaborate with mold-makers in the process of mold design. As a result, a complete mold could now be finished within a shorter time span, as sometimes required.[10] In 2003, Supplier A was able to produce about 50 to 60 molds, half of which were exported to its Japanese affiliate in other countries. Hence, this is clear evidence of the technological development of this supplier, and the active role of the Japanese experts should be acknowledged.

4.2 Case 2:

Supplier B, an independent Thai firm, was established in 1986. It belongs to S-group, the largest auto parts group in Thailand, which consists of more than 30 companies. The origin of S-group can be traced back to the establishment of the S-firm, which was founded in 1972 as an OEM producer for motorcycle seats, trimming parts and other parts. It began business as an OEM supplier because it had a close business relationship with, and been receiving considerable assistance from, Auto M from the beginning. The inter-firm relationship benefited S-firm by allowing it to

[10] It could complete the design process about 5% faster than it could three years previously. Currently, for a similar type of mold, the lead time for making a mold used by Supplier A is about 30% longer than at the best practice plant of the Japanese firm.

acquire manufacturing technology. As an example, Auto M had introduced S-firm to its Japanese suppliers for the purpose of strike technical assistance deals with them, and, at the same time, Auto M had dispatched Japanese experts to work, assist, and to transfer technology, particularly in the area of stamping and die-making technology, to S-firm. Since then, its production and technological capability has been developed.

In the mid-1980s, Auto M requested S-firm to expand its production of auto body parts and other stamping parts. Auto M recognized that S-firm had investment capability but not technical expertise; therefore, it decided to provide technical support.[11] In 1986, S-firm established Supplier B and received a technical assistance agreement with Auto M for the stamping die-manufacturing technology. Since then, Supplier B has developed its technological capability and become an indispensable supplier for Auto M. It currently produces a wide range of products, such as stamping dies, press parts, bumpers, chassis frames, door hinges, fuel tanks, car bodies and exhaust pipes and mufflers; it also supplies products to almost all automobile manufacturers in Thailand. This company acquired technology through technical agreements with many foreign companies (almost all of them Japanese firms) that specialize in particular products; however, for stamping and die-making technology, it mainly received technical advice from Auto M.

It has been reported that Auto M transferred substantial technology, especially in the area of metal-stamping and die-making technology, to assist Supplier B in acquiring the necessary operational capabilities to produce good-quality parts. From the beginning, in addition to setting up the production line and installing machinery,

[11] In fact, there were three options for Auto M to localize stamping parts: 1) to import, 2) to produce in-house, or 3) to outsource from local suppliers. The first option might not be justified because of its bulkiness and in part because of the LCR regulations; hence, the firm had to choose between in-house production or subcontracting out. However, it was the company's strategy to outsource stamping parts and to develop local suppliers, such as Supplier B. At present, it also outsources outer panels, a practice that is completely different from other car makers, which usually produce these parts in-house.

Auto M shared information assets, such as the standards for die-making (explicit knowledge), and sent a number of Japanese experts to work with Supplier B.[12] Supplier B's engineers shared experience through 'socialization' with Japanese experts and assimilates such explicit knowledge into their own tacit knowledge (internalization). Auto M's die-making standard has been revised, adapted, and developed to local working conditions.[13] The revision of this die-making standard was done through brainstorming by the responsible engineers and technicians to find the solution (internal socialization). Once they found that solution, the standard was revised and added to the stock of explicit knowledge (externalization). Over time, localized versions of the company's own die-making standard has been established (combination).

An important step of inter-firm collaboration came in the years 1993 to 1995, when Auto M requested that Supplier B conduct an engineering study of stamping parts of competitors' vehicles in order to feed that information back to Auto M's design center, which was developing a new model of pickups to be launched around 1995. This activity is called 'tear down', and essentially it is very similar to 'reverse engineering,' i.e., disassembling all the stamping parts of existing competitors' products to analyze the specifications of the raw material, stamping processes, parts designs, and, in total, the stamping technology. Supplier B had to make an enormous investment in computerized software, such as computer-aided design (CAD) and computer-aided manufacturing (CAM) programs, as well as in much testing equipment. A designated group of engineers worked closely with experts from Auto

[12] It has been reported that there have always been Japanese staff people working with this supplier, but the total number has varied from time to time. Over the past three years, there were on average four Japanese experts working at Supplier B.

[13] It should also be noted that die-making standards have been revised because Supplier B was supplying stamping parts for other automobile assemblers whose design standards were slightly different. Technical advice from automakers has been acknowledged as an important source of information as well.

M (socialization). Close supervision and guidance from the Japanese experts helped Supplier B broaden and deepen its capacity in very important basic engineering area, e.g., raw materials, die design and process engineering technologies, all of which added to its own stock of knowledge (socialization and then externalization). Combining the intensity of Supplier B's efforts with the technical support from Auto M, Supplier B could achieve significant technological development.[14]

After 1996, the firm experienced a significant change in customers' technical requirement, when it received a new order from a newly established car maker, called Auto A, which had just transferred all of its pickup production to Thailand.[15] It planned to produce and export new models of pickups, the upper bodies of which were newly designed; thus, no master model was available. This reflected a departure from the previous production experience of Supplier B. The information assets that Supplier B received were by way of the parts drawings of 87 ordered parts; this was based on the fact that it needed to accomplish all the 'process engineering' tasks[16] on its own. However, because of Supplier B's limited experience in the preparation the entire engineering process and the tight schedule, Auto A realized that there was a possibility that this supplier might not be able to finish that preparation on schedule; hence, it decided to provide intensive technical assistance.[17]

[14] This reflected the commitment of top management and the intensity of the effort in expanding its technological capability, induced by the inter-firm relationship. Many senior engineers have acknowledged this collaboration as the most important step, and it marked the milestone in achieving greater self-reliance in the engineering capability of Supplier B. It should be noted that, in addition to this activity, Supplier B also invested in a new stamping plant at Laemchabang, immediately next to the Auto M plant. The main activity of this new plant was to provide a stamping service mainly for Auto M, while Supplier B placed more emphasis on supportive activities, such as die and tooling design and production-process development.

[15] The details regarding the inter-firm technology transfer activity by this firm to suppliers in Thailand, including Supplier B, has been reported in Techakanont (2002). See also footnote 8.

[16] Process engineering tasks include a series that consisted of planning, designing, drafting a drawing, die-making, finishing, and stamping, trouble shooting and trying out, prior to the launch of mass production.

[17] Although Japanese experts from Auto M were working at Supplier B's plant, they played no role in filling other firms' orders.

On average, there were seven Auto A staff members working at Supplier B's factory for about two years, and nearly 40 experts came to provide support on a short-term basis at each stage of preparation (socialization). The content of the inter-firm technology transfer by this company was in the area of 'process engineering' capability.[18] Supplier B benefited from Auto A's intensive technical assistance by learning new project management practices and improving its die design standards, which became acceptable to many other assemblers thereafter.[19]

Since the industry became more liberalized, in 2000, many assemblers have pursued a strategy to make Thailand their production and export base, and that has resulted in significant changes in purchasing and supplier relationship policies. The practice of Auto A, i.e., requiring suppliers to take full responsibility for process engineering activities, apart from QCD criteria, has become a basic requirement for other makers. They have increasingly adopted a global sourcing strategy to obtain good parts at the lowest price. Moreover, they now demand higher technological involvement from parts suppliers, to provide full component design and development capabilities, or, at least, to respond to engineering changes in design that could take place during the process leading up to mass production.

In 2000, after about 15 years' experience in providing stamping services, Supplier B's first challenge for this company in the area of product development and engineering activity was the order from Auto I. Supplier B won the bidding as a Tier-

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[18] The process of knowledge conversion took place through interactions between Japanese and Thai staff members. Technical support was provided through the OJT method, to provide training in all the processes step by step. First, they transferred tacit skills through OJT (socialization), and assisted Supplier B in developing working and quality standards (externalization). Then, they revised and improved it to create a new standard (combination) and used that to train local staff member to acquire basic operation skills (internalization). Technical assistance effectively enhanced local workers' skills. Improvement of the operators' skill resulted in a significant reduction in the defect rate. Moreover, Supplier B has made exceptional improvements in its project-management capabilities, and it has acknowledged that it was accredited QS9000 because of the knowledge acquired from working with Auto A experts. Clearly, the content of the knowledge conversion was in the area of 'process engineering'.

[19] Interview with a senior engineer of Supplier B, on August 25 and December 4, 2003.

1 supplier for front bumpers and reinforcements of this global model. It received only a sketch drawing of the bumper and some minimum states of the requirement regarding the engineering specifications from Auto I.[20] Because of the limitations of this information, Supplier B needed to develop finished parts and supply them to the customer on the planned schedule.

Nevertheless, Supplier B found that, given its existing level of explicit and tacit technology, it would not be able to meet Auto I's schedule. Hence, purposeful investment (of more than 50 million baht) in CAE and simulator software necessary for the development task was approved by the top management and made during 2001 and 2002. This new investment enabled Supplier B to simulate and test its design and allowed it to have its first 3-D design finalized. That process required some 'guest engineers' to be sent to Auto I's headquarters to collaborate throughout the entire process of 'product engineering', including the development of detailed blueprints for each component and major systems; after that, prototypes of components and vehicles were built based on those preliminary drawings, following which, prototypes were tested against established targets; finally, the tests were evaluated and the designs modified as necessary. The cycle was repeated until an acceptable level of performance was achieved.[21]

In total, Supplier B sent 'guest engineers' to Auto I three times, until the final parts drawings were approved. Each time, it sent two to three veteran engineers who stayed in Japan about one week. All expenses were borne by Supplier B. The guest engineer system exposed the company to the real product-development activities of Auto I (socialization). It enabled this company to understand how the activities were

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[20] This is normal practice for Japanese or other Tier-1 suppliers, because they have design and development capability. However, for Thai firms, this reveals significantly higher technical requirements by suppliers than in the past.

[21] This definition is from Clark and Fujimoto (1991, pp. 116-117).

managed and made it possible to help Supplier B to translate the knowledge gained from direct experience into actual product-development activities (internalization of embedded knowledge). After the guest engineers returned to Thailand, the knowledge they had acquired was shared with local staff members (socialization) and then incorporated into the company's design standards (externalization). Clearly, despite the absence of direct technical support from the customer, the combining of its existing knowledge base with purposeful investment and increasing the intensity of its in-house efforts to perform the 'product engineering' activity, Supplier B was able to benefit from the inter-firm technical linkage, and its technological capabilities were enhanced.

In 2003, it was disclosed that Supplier B already had about seven parts designed and developed in-house that met the customer's requirements. It was also able to produce for export two sets of transfer dies, weighting 23 tons, to Germany. In addition, to improve productivity at its Laemchabang plant, it installed a new, automated production line. Although it purchased machines from a Japanese machine maker, it had the ability to evaluate and select the appropriate equipment and could design the production line by itself. Hence, it can be said that within less than 20 years, inter-firm technology transfer and internal effort synergistically made Supplier B attain appreciable technological capability development. Thus, it is reasonable to expect that, as Supplier B gradually becomes more self-reliant in manufacturing technology, direct support from Auto M would be diminished. Internal efforts to develop technological capability will become the most important element in the sustaining of the business.

4.3 Case 3

Historically, Supplier C had had a relationship with the S-firm. The presidents of Suppliers B and C are brothers and established the S-firm together. Five years later, in 1977, the younger brother, the president of Supplier C, decided to establish his own company. Its main business lines were plastic and metal products for motorcycle parts, auto parts, and electronics and electrical parts. Its development started with an order from two Japanese motorcycle manufacturers to produce seats. Similarly to the case of Supplier B, at the time it was established, it had investment capability; thus, the buyers provided the technical assistance necessary for the production technology. Later on, this supplier diversified to produce other plastic parts for motorcycles and electronics and electrical appliances parts, and auto parts. It acquired the necessary technology through technical assistance agreements or by forming new businesses through joint ventures with Japanese firms that specialized in particular products. The company has grown and gone on to become one of the biggest Thai auto parts groups, the T-group business.

The history of the development of Supplier C's technological capability is that, from its early stage, it acquired technology through various channels, from purchasing state-of-the-art machinery, forging technical assistance agreements in some areas of production technology (plastic parts), and having inter-firm relationship with automobile assemblers. Inter-firm relationships with motorcycles buyers and Auto M were important for acquiring the technology related to stamping and die-making. Supplier C has developed its capability mainly through inter-firm relationships with motorcycle manufacturers in Thailand and with Auto M.

In the early 1990s, the automobile industry grew rapidly, and the demand for auto parts surged significantly. Because of their close relationship, Supplier C established a new factory at Laemchabang industrial estate at the request of Auto M. Auto M dispatched Japanese experts to work at this plant and played a role similar to the one it played in the case of Supplier B, giving advice and assisting the supplier to prepare for the production of new product and to improve its daily operations through greater attention to detail. The main role of the Laemchabang plant was to perform the mass production and deliver the parts to the customer on time. Most of the large and bulky parts have been produced there.

To respond quickly to the surge in demand and the rapid changes in the technological requirements from automobile customers, Supplier C's president decided to divide the engineering and mold-making sections to form three new companies, still located in the same area, however. Two companies perform the stamping die and tooling-making for metal parts, while the other one attends to injection molds, blow molds, and die-cast molds to make plastic and aluminum parts.[22] An interview with a manager of Supplier C indicated that, prior to 1992, customers normally provided the data about the part, part drawings, die designs and die drawings. Using these information assets, Supplier C made the dies and prepared the production process, which it was able to do quite easily. In the process, if some problems arose, customers normally sent engineers to provide advice and troubleshoot problems.

From early 1990s on, the technical requirements customers imposed on suppliers changed drastically. In 1993 and 1997, customers provided sample parts, part drawings, and inspection jigs, but not the die drawings.[23] This meant that Supplier C needed to design the die itself. Inter-firm technical assistance came by way of

[22] Since 1998, for the company that attends to plastic molds, it has used a Japanese company to obtain technical consultant and assistant service in the fields of operation, design, and obtaining information about tooling, machine, and equipment. Thus, it can be said that Supplier C utilized a TA agreement in order to supply some technical knowledge that it did not possess.

[23] Inspection jigs were provided because the customers wanted to ensure the quality of the parts.

advice given during periodic factory visits, which were made to ensure that the supplier could accomplish the preparation process on time. During this time, Supplier C had to invest in computerized software such as CAD and CAM and hardware such as a new CNC machine and testing equipment to enhance its technological capabilities sufficiently to meet the higher requirements of its customers. After 1998, almost no customers provided sample parts or inspection jigs. Supplier C received only the data about the part in CAD data format. Using this data, it needed to design and make the dies, establish the production processes and make the inspection jigs to produce the part to the exact specifications. The knowledge it accumulated and its previous investment in CAD/CAM helped this supplier meet the customer's higher technical requirements. However, apart from assistance from Auto M at its Laemchabang plant, it did not receive any direct assistance from other makers. It received only some technical advice regarding quality control and die and tooling design.

After 2000, the industry became more liberalized, and automobile assemblers required that suppliers be able to develop their own drawings, which meant that suppliers needed greater design capabilities. In some of the new orders, Supplier C won the bidding as a Tier-1 supplier. Similarly to the case of Supplier B, it received only sketch drawings of the parts with statements of the requirements. It had to design and develop the part drawings, which need to be approved by Auto I. It has been reported that, during the preparation process, Auto I sent some engineers to follow up and to give advice on the part-design process. Thus, Supplier C was able to learn some specific technical information about die design through a socialization process with Japanese experts. Also, it has been learned that Supplier C had made an additional investment of more than 60 million baht for CAD and CAE software to improve its design and engineering capabilities.

However, in many cases, Supplier C still lacked sufficient capabilities to provide full service from design and part development as a global Tier-1 supplier. To overcome that limitation, a TA partner that had such design capability played a collaborative role in the development stage in Japan, to finalize the design of parts. After the part drawings were finalized, Supplier C designed the dies and prepared the production process based on the part drawings developed by its TA partner. This is the process by means of which it has now accumulated sufficient capability. Hence, it can be said that it is vital to make continuous internal efforts to develop technological capability and that some external source of technology, such as a TA agreement, can be used to supplement knowledge in a technical area that the supplier still lacks.

4. Concluding Remarks

On the basis of these three prominent case studies, this paper has found that the changes in assemblers' technical requirements affected the pattern of inter-firm relationships and technology transfer. This section analyzes the matter and offers general ideas about the evolution of inter-firm technology transfer.

This study has found that inter-firm technology transfer in the Thai automobile industry began during the early stages of the introduction of LCR regulations (after 1970). To make the required use of locally made parts, assemblers both produced them in-house and subcontracted them out. During the period between1970 and 1990, when they subcontracted, they sometimes helped suppliers establish production facilities, as is clearly seen in the case of Suppliers B and C, both of which needed only to have only sufficient investment capability and fair operations capabilities.

Moreover, prior to 1990, almost all of the car models produced in Thailand were the same models produced in other countries. When production of a model was transferred to Thailand, Japanese automakers normally sent experts to perform all of the tasks that were critical in preparing for the production, until the quality of the tryout parts was acceptable. Then, local staff members were trained in how to operate the machinery and how to control quality during mass production. The implication from this is that information assets such as sample parts, parts and die drawings, production process (and in some cases even the stamping dies) were available to local suppliers. Suppliers did not need to do the whole preparation process, ranging from designing the facility to designing the tooling and designing the production process; thus, they did not have opportunity to perform the whole series of engineering activities, but only the operations.[24] Therefore, it can be argued that the content of inter-firm technology transfer was to a large extent at the operational level. However, it should be noted that, apart from receiving technology from assemblers, suppliers also acquired technology from other channels, such as technical assistance agreements or joint ventures.

Between 1990 and 1995, the situation changed slightly. Assemblers generally required that suppliers have investment, operational and some aspects of process engineering capabilities. A main reason for this was that information assets that assemblers provided suppliers were reduced. Suppliers were required to have the capability to design dies, toolings, and production processes. The technical

[24] In fact, it has been found that other car assemblers used the same strategy, i.e., sending Japanese experts to prepare the production process and simply use Thai suppliers as service providers (Techakanont 2002). There are at least two reasons that accounted for this practice. On the one hand local suppliers were in the initial stages of acquiring the requisite technology; as a result, Japanese assemblers preferred to complete the preparation in order to meet the scheduled deadlines. On the other hand, the industry was still protected by LCR regulations and high import tariffs; therefore, it was possible that assemblers would have to bear this high-cost activity in order to comply with the regulations, while still keeping the operation profitable. For details about government policies, please see, for example, Doner (1991), Buranathanang (1995), Terdudomtham (1997), and Techakanont and Terdudomtham (2004).

collaborations between Auto M and Supplier B confirm this fact. Supplier B was able to improve its engineering capabilities by obtaining inter-firm technical assistance through 'socialization' with Japanese experts, 'combination' of the explicit knowledge of the assembler, and, finally, 'internalization' and 'externalization' of that knowledge into its own knowledge base. However, the intensity of the effort of local firms that were important for such knowledge assimilation, conversion and formation should not be overlooked.

Between1995 and 1999, some assemblers started producing new models first in Thailand. The relevant information assets were drastically reduced. No part drawings or master parts was available to suppliers; instead, only CAD data was distributed. Thus, suppliers had to prepare all the production process by themselves. The cases of Supplier A and B in dealing with Auto A show that the contents of inter-firm technology transfer had gone beyond the operational and QCD to include 'process engineering' capabilities. The 'socialization' process between local staff and Japanese experts was essential for suppliers to assimilate the technology effectively.

As the industry became more liberalized, after 2000, many assemblers pursued the strategy of making Thailand their production and export base. Global sourcing and competitive bidding systems were adopted, and assemblers demanded their Tier-1 suppliers in Thailand to provide a full component design and development capability, or, at least, to respond to engineering changes in the designs that might occur during the process prior to the mass production. In this respect, the research findings in Section 3 and the case studies reveal that inter-firm technology transfer became less intensive than it had been in the past. The more active role of suppliers and their increased ability to take part in the product engineering process have become increasingly important. In other words, local suppliers must show their strong will to participate in such processes and must possess sufficient engineering capability; otherwise, they will not be selected as Tier-1 suppliers and cannot benefit fully from inter-firm relationships.

Given the rapid changes in the automobile industry, suppliers need to have design capability. Nevertheless, it takes time and resources to develop that capability, as confirmed by the case of Supplier B. Thus, suppliers have needed to be aware that there were also other ways to respond to the heightened technical requirements, especially as regards design and product development capabilities, of automobile assemblers. Local suppliers may acquire technology from technology partners, which can be either by striking joint venture deals (case of Supplier A) or technical assistance agreements (case of Supplier C) to supply and assimilate the knowledge in the particular technical area that had been lacking and to retain their customers' business. This will allow them to benefit from inter-firm technology transfer and provide them with the opportunity to take part in the product-development stage with customers in the future.

The case studies show that inter-firm technology transfer has undergone significant evolution as regards its contents and the roles and the degrees of intensity of effort of both the transferors and the transferees. It has been found that over the previous 20 years, the content of the technology transferred has increased the degree of difficulty of the transfer, in areas from the operational to process engineering and product engineering. There is ample evidence that local suppliers had been able to start business with appropriate levels of investment capability but significantly less technical capability. Their viability as businesses was made possible because of the intensive inter-firm technology transfer initiated by the assemblers. Local firms were then able to improve and develop their technological capabilities through a variety of means, the most important of which has been their internal efforts to improve their capabilities. Over time, during each stage – i.e., from the operational to process engineering and product engineering – the level of effort of the transferor has become less intensive, while it has taken a greater degree of effort on the part of local suppliers to keep up with the accelerating pace and heightened technical requirements of the assemblers, particularly with respect to design and engineering capabilities. Assemblers are demanding a higher level of engineering capability from their suppliers to improve their own competitiveness.

Throughout this process, the suppliers have to upgrade their QCD to survive and grow, and in some cases their engineering to become more profitable and finally to become Tier-1 suppliers, at which point they are eligible to benefit from a higher level of technology transfer including 'product engineering' capabilities. In some instances, internal efforts and endeavors may not have been sufficient to reach the desired levels; thus, alliances with foreign partners may turn out to be a good way to attain these targets.[25] Overall, the suppliers' own efforts in human-resource development seem to have been the most crucial factor in maintaining and continuously developing their technological capabilities; that, in turn, opens them to the benefits of inter-firm technology transfer.

[25] In the short run, local firms should remain focused on and attempt to retain the business they have, i.e., to maintain the orders from assemblers as global Tier-1 suppliers. Since they lack both the financial resources and some of the technology, they should not be over-concerned about being Tier-1 or Tier-2 suppliers, or attempt to maintain their majority ownership if their financial and technology status is fragile. In the long run, because many Thai firms still do not have their own indigenous production technology, they inevitably must search for an appropriate technology partner, even if that entails entering into forms of acquisitions such as striking deals regarding technical assistance or entering joint-venture agreements.

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