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A COMPARATIVE STUDY ON THE ROLE OF UNIVERSITY AND PRI AS EXTERNAL RESOURCES FOR FIRMS' INNOVATION

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EXECUTIVE SUMMARY

Supporting Study: Enhancing Innovation Capability using Local Universities and Public Research Institutes as External Resources

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1. Background and Objective of the Research

Improvement of the innovation capability of firms in the region depends on how successfully they have leveraged their internal and external resources. This supporting study will be focusing on how some of these firms have improved their innovation capabilities through the university – industry linkages locally available to them. Conversely, from the points of view of universities, the role of the university has evolved from the traditional activities of education and basic research to a third mission – technology transfer and commercialization. The study of triple helix has generated a number of important findings already. They are, however, primarily based on the experiences of the advanced economies. It is easy to imagine that the situation for developing countries will be quite different, with less mature technology and a short history of higher education, often constrained by limited resources.

The aim of this supporting study is to highlight the ways which external resources from universities, public research institutes, industrial associations, governmental and private- sector intermediaries and others can help local firms to develop innovative capabilities, through a variety of technology transfer and knowledge sharing activities. The study will also address the question of whether institutional variations have some impact on the ways in which these organizations interact with the local firms, such as the introduction of a Bayh-Dole-Act[3]-like

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[3] The Bayh–Dole Act or University and Small Business Patent Procedures Act is United States legislation dealing with intellectual property arising from federal government-funded research. Adopted in 1980, it gave U.S. universities, small businesses and non-profits intellectual property control of their inventions and other intellectual property that resulted from such funding

arrangement affecting the incentives of academic researchers. The study will illustrate several cases of successful collaboration between these organizations and firms across sectors and countries to provide some room for comparative analyses. In particular, any changes or variations of institutional structure affecting the incentives and R&D environments of university researchers such as the serendipity of research findings and transfer will be analyzed extensively.

The automotive sector has been selected as a case study, since it is economically very important to the ASEAN region, and to a country like India. The sector is undergoing major technological changes, and many countries would like to move up the technological ladder from being just a production base to becoming the base for more sophisticated activities like advanced engineering, design and research development. In order to do so, firms in the sector might need more interaction with local knowledge-producing agencies such as public research institutes and universities. A comparative study on the sector is therefore very timely.

2. Methodology

This research focuses on selected case studies with counterfactual narratives from Thailand, India, Indonesia and Vietnam. These countries were selected based on their having growing automotive industries. They are also in different stages of technological development, and it is therefore interesting to see what type of external players engage in the technological capability development processes of firms at different stages, and how the do it.

A Sectoral Innovation System concept was used as a framework for this research. A sectoral system of innovation and production is a set of new and established products for specific uses, and the set of agents carrying out market and non-market interactions for the creation, production, and sale of those products. Sectoral systems have a knowledge base, technologies, inputs and demand. The agents are individuals and organizations at various levels of aggregation, with specific learning processes, competencies, organizational structures, beliefs, objectives and behaviors. They interact through processes of communication, exchange, cooperation, competition and command, and their interactions are shaped by institutions. A sectoral system undergoes processes of change and transformation through co-evolution of its various elements (Malerba, 2002). Based on this concept, this research paid attention to the

(http://en.wikipedia.org/wiki/Bayh%E2%80%93Dole_Act).

roles of external agents (firm and non-firm), especially universities and research institutes, in the process of development of the capability of firms in the automotive sector.

Turning to the research method, each country team carried out ten case studies of external sources of knowledge and competences (outside the firms) and examined how these knowledge sources interact with intra-firm capabilities. These external sources of knowledge and competences are mainly local universities and research institutes. However, in some countries the roles of intermediary organizations such as industrial associations, professional associations, not-for-profit training organizations and government sectoral development agencies in the process of technological transfer and learning were investigated. Furthermore, secondary data including previous case studies were also included.

3. Main Findings

In terms of level of development of automotive sectoral innovation systems in general and linkages between firms and universities/public research institutes in particular, we can classify the four country case studies into three groups, as follows:

Group A: India and Thailand

The automotive sectoral innovation systems of these two countries are more developed. Firms have relatively higher technological and innovative capabilities, partly due to the longer times the industry has been established. Advanced technological capabilities such as engineering, design and research and development have begun. In India, some local companies began their R&D activities in the 1960s and 1970s. In Thailand, major changes in the investments of transnational companies started in the early 2000s, when they set up 'Technical Centers' performing advanced engineering, testing, product and process design and other development activities. In some cases, their activities go beyond adaptation to fit local and regional (e.g. ASEAN) market conditions.

Linkages between firms and universities/public research institutes are still not strong. Nonetheless, to some extent, they have begun to change from 'personal' relationships to 'institutional' ones. Some universities in Thailand and India have already developed specific degrees on 'automotive engineering', with a certain level of participation from industry (transnational corporations in the case of Thailand and local firms in the case of India). Beyond education, smaller firms (especially parts suppliers) tend to seek cooperation with universities/public research institutes on testing, calibration, and solving short-term problems. In contrast, larger firms tend to have longer-term and more technologically sophisticated collaborations, including R&D in several cases, through the research projects of postgraduate students. It should be noted that the R&D collaborations with universities and public research institutes are usually limited to issues not critical to the 'present' operation of firms. They tend to focus rather on issues of the 'future', such as new materials and new sources of energy. Some large companies also leverage universities' expertise on the 'fundamental' principles of doing R&D, in terms of training their R&D staff (before in-house training at their headquarters) or outsourcing them to carry out the basic analytical investigation parts of their research projects. Development activities critical for 'today's' competitiveness are mainly conducted 'within' companies or in vertical relationships between automotive assemblers and parts makers.

The issue of linkages between firms and universities/ public research institutes has a high priority in the agenda of science, technology and innovation policies of these two countries. Policy makers have already recognized the importance of this issue for the future competitiveness of countries. For example, there are projects at national levels trying to promote such linkages, though the results might not be fully satisfactory. Further there are 'intermediary' organizations, either public or private, trying to promote linkages between actors in automotive sectoral innovation systems. These intermediaries are important in bringing together the different demands and expectation of different actors, especially between firms and universities/public research institutes.

Group B: Indonesia

Indonesia is a middle case. Their automotive industry started later than those of India and Thailand and it is relatively smaller in terms of production and sales. More importantly, actors in its automotive sectoral innovation system are weaker in terms of technological capabilities, and linkages among them are much more fragmented and limited to physical transactions (versus critical knowledge and information flow).

In particular, 'institutional' linkages between firms and universities/public research institutes beyond basic education and testing services are almost none. Even though Indonesia has excellent research and educational institutes such as the Indonesian Institute of Sciences (LIPI) and the Bandung Institute of Technology, they are doing research not relevant to the 'present' activities of automotive firms. The weakness of the linkages has been recognized by Indonesian government agencies. This is very much paper recognition, however, and no serious action has been taken. In addition, unlike Thailand, there are no 'sector-specific' agencies which can perform the roles of intermediaries linking actors in the automotive innovation system.

Group C: Vietnam

Vietnam's automotive sector started up in the middle 1990s. Though it has high potential, and some sub-sectors such as motorcycles have grown impressively in terms of production volume, its sectoral innovation system is still in its infancy. Passenger car production is very small. Firms are generally weak in term of technological capabilities. Transnational corporations use Vietnam only as a production base. Development activities are carried out in other countries, including Thailand, even for motorcycles. Many local parts makers are not qualified in terms of quality, cost and delivery to enter the global value chains of transnational corporations. Those that can enter such chains are generally original equipment manufacturers (OEMs) which produce according to specifications given by the automotive assemblers.

University-industry collaborations at 'institutional level' are almost non-existent. There are' however, researchers and professors working for the industry on a 'personal' basis. Most of the work is problem solving in nature. The issue of linkages between firms and universities and public research institutes in the automotive sector has not yet been put high on the government's science, technology and innovation policy agenda. There are no major government initiatives on this matter and no sector-specific agencies acting as intermediaries.

Nonetheless, Vietnam has high potential to develop its automotive industry. It has a large stock of engineers. The state is strong enough to enforce regulations relatively well. For example, pollution emission control regulations enforced by the government have pressured local firms to upgrade their production standards to meet such requirements. A few universities have now also started to offer training programs for building up the competencies of local firms.

4. Lesson Learnt: Critical Success Factors for Collaboration between Firms and Universities/Public Research Institutes

From the four case studies, we can draw lessons learnt in terms of critical success factors for collaboration between firms and universities/public research institutes, as follows:

- *Phase of development of the technological capability of firms and the sectoral innovation system.* Effective collaboration depends very much on what phase firms in the industry are at in terms of their level of technological capability, and how the sectoral innovation system works, in terms of roles of the actors and their linkages. Universities and public research institutes are expected to play more roles when firms have higher technological capabilities, and their sectoral innovation system is more coherent. This is because on the one hand, firms at that level have a clearer 'technological development strategy' and deeper 'absorptive capacity', enabling them to work with counterparts from universities and public research institutes. On the other hand, most universities and public research institutes are conducting technologically sophisticated activities such as, R&D which is easier to match with the interests of higher-capability firms. Nonetheless, there are institutes focusing on enhancing the capability of firms at the lower level (e.g. production, basic engineering, quality control and so on). It depends, therefore, on the division of roles and missions among higher education and public research institutes in a country, which is also a critical policy issue.
- *Incentives.* Incentives, both in terms of monetary rewards and recognition and promotion are essential for the university professors and researchers who work with the industry. Without correct and sufficient incentives, most will be less willing to work with the industry.
- *Enabling laws and regulations.* This is also a crucial issue. Laws and regulations must provide flexibility and an encouraging environment for professors and researchers to work with the industry, in areas ranging from joint education, training, research and consultancy, to service providing and others.
- *Trust.* Trust between the two sides is critical. As social capital, it varies from one country to another. It can nonetheless be improved if the right environment, incentives and good demonstrating examples are provided.
- *Information gap.* In many circumstances, firms do not really know what universities are specialized in and where the experts are. On the other hand, in many cases, universities and public research institutes do not really know the demands of industry.
- *Roles of intermediaries.* In many cases, 'the invisible hand' of market mechanisms cannot deliver effective collaboration, and the 'visible hand' of intermediary organizations is needed. Universities/public research institutes have different expectations and mindsets from those of firms. The level of distrust and unfamiliarity

between the two sides can be high. They might not have prior experience in working together and do not really know what the other is doing or expecting. There are also difficult issues of contracts and the ownership of intellectual property rights, which can be obstacles for cooperation. Competent public, private or semi public intermediary organizations can step in and bridge these differences.

- *The vision and will of an entrepreneur*. This is a prerequisite for any collaboration. The mindset of entrepreneurs in exploring opportunities to collaborate with others outside their companies and usual networks is a starting point. They must then have a strong will to carry out the collaboration and overcome obstacles that might crop up.

5. Policy Recommendations

From this research project, we can derive policy recommendations at two levels: country and ASEAN Plus Six

Recommendations for Member Countries

- Collaborations between firms and universities/public research institutes should be placed on the key agenda of national science, technology and innovation policy

- *Human resource development.* It is very important to prepare enough qualified people very much in advance, as it takes many years to build a stock of qualified manpower.
  - ✓ For countries whose automotive industry is in the production (assembling) phase, vocational education to prepare competent and skillful technicians and production engineers should be given high priority. For countries whose automotive industry has begun to include development activities, design engineers and industrial designers should be a major focus.
  - ✓ It is also worth studying the necessity of having specific educational programs on 'automotive engineering', which might lead to educating engineers tailor-made for the industry.

- *Clearer division of roles and missions among educational and research institutes*. Some level of specialization might be needed. The first group of universities and research institutes may focus on advanced research for the 'future' of the industry both in terms of automotive technologies (*e.g.* hybrid engines, electrical vehicles, new materials) and related infrastructure (*e.g.* clean energy, logistics and transportation systems). The second group might focus on helping firms develop indigenous technological capabilities by providing consultancy, research and services to meet 'today's' demand. This also depends on phase of technological capability development of local firms. If local firms, at large, have low level of capabilities and are struggling to solve problems at the production and engineering level, the second group of universities and public research institutes should be a major policy focus. On the other hand, if most local firms have rather high level of capabilities, the first group of universities and public research institutes should be given higher attention. Under budget constraints, especially in some ASEAN countries, prioritization in this regard is very important for making effective use of universities and public research institutes as catalysts for development of indigenous technological capabilities.

- *Organizational setting of universities and public research institutes.* It is very important to design an organizational setting for universities and public research institutes which will help them complete their aforementioned missions. Basically the organizational setting in terms of sources of funding, human resource management, and others should try to reach a balance between achieving the role of "public good" providers (which requires some state subsidies) and encouraging and pressuring them to work with and for industry (which might require linking government funding to performance-based criteria, especially in terms of impacts on industry).

- *Law and Regulations*
  - ✓ More flexibility in curriculum development to fit the fast-changing nature of automotive technologies, and the future requirements for multi-disciplinary studies is needed. In this regard, educational and professional standards authorities should provide more freedom to universities to design new courses. They should focus on being promoters rather than simply regulators.
  - ✓ More flexibility should be granted for university professors and researchers during office hours to work with the industry.

- *Incentives for encouraging collaboration*
  - ✓ Tax incentives and/ or matching grants for R&D/innovation consortia between groups of firms and universities/R&D institutes should be considered
  - ✓ Rewards and additional career paths for professors and researchers, for example, professor of practice, should be given to those who want to focus on working with and for industry
  - ✓ Tax incentives for private universities achieving excellence in university-industry collaborations
- *Trust Building.* It is important to have a means of bringing both sides together and understanding each other better.
  - ✓ Sabbatical leave should be allowed for professors and researchers to work for industry for a certain amount of time.
  - ✓ Industry-Academia exchange programs in various forms such as guest researchers and professors should be encouraged.

- *Roles of Intermediaries*
  - ✓ Capacity building programs for intermediary organizations are needed, since not all of them can perform the role they are supposed to play effectively.
  - ✓ Authorizing and encouraging the development of 'private' intermediary organizations. Some of them know the industry better than governmental ones and are more flexible. This will also reduce the burden on government authorities.

Recommendations for ASEAN Plus Six

- As the ASEAN Community becomes realized, and collaborations in the ASEAN plus Six will be very much strengthened, joint studies on future demand on human resources for the automotive sector should be conducted. This is necessary for ensuring this region remains attractive for future investment in this sector, and for upgrading its position in the global value chain.
- Human resource mobility across member states should be encouraged. The tacit knowledge embodied in engineers and technicians will become more flexibly available. Since the automotive sector is a key sector in most member states, it should be a 'pilot sector' for cross-country human resource mobility.

- Mapping and locating talent and specializations of automotive technologies and knowledge in universities and public research institutes across the region. This sort of database is a fundamental basis for future collaboration across countries
- Encouraging collaborations between firms, and universities and public research institutes across member states. In some cases, better international matches between the two sides might be achieved easier and more effectively than domestic collaborations.
- A joint study and meetings to share good practices *of intermediary organizations* in the member states should be organized.

References

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CHAPTER 1

Enhancing Innovation Capability Using Local Universities and Public Research Institutes as External Resources: Thailand's Experiences

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The automotive industry in Thailand started in the early 1960s when transnational corporations (TNCs) started their assembly plants here. High demand from assemblers, coupled with a local component requirement imposed by the Thai government since the late 1960s, led to the emergence and growth of local manufacturers of automotive parts and components from the 1970s onwards. In the 1980s Thailand became the ASEAN automotive production centre. From the 1990s, the industry has gone through major liberalization. The local content requirement was phased out and import tariffs were reduced substantially in compliance with World Trade Organization (WTO) rules.

In 2010, Thailand produced around 1,645,000 cars of which around 900,000 were exported, equivalent to 18 billion US$. Thailand ranked as number one in ASEAN and number 12 in the world in terms of production volume. Firms in the industry can be classified into three groups: 16 assemblers, approximately 648 first-tier suppliers, and around 1641 second and third-tier suppliers (Thailand Automotive Association, 2011). All assemblers are either subsidiaries of TNCs or are joint ventures. Thailand has already become one of the key production bases of most global players from Japan, the US, and Europe.

Until recently, TNCs only carried out production in Thailand, while more sophisticated activities like design and R&D were done in their home countries. During the 2000s, TNC investment strategies in the automotive industry have started to change, as they have begun to invest in more technologically sophisticated activities in Thailand, such as advanced engineering, process and product design, and advanced testing and validation. Several major automotive TNCs (mostly Japanese) have set up technical centres in Thailand, separated from their normal production plants.

This change highlights the increasing importance of other local actors in Thailand's automotive innovation systems, especially universities and public research institutes, in supporting TNCs and local suppliers to upgrade their activities from production to the more technologically sophisticated activities already mentioned. The Thai country study, therefore, will examine the roles of nine non-firm players in the Thai automotive innovation system. These are; a sector-specific development agency (the Thailand Automotive Institute); four public universities (Chulalongkorn University, King Mongkut's Institute of Technology Ladkrabang, King Mongkut's University of Technology Thonburi, King Mongkut's University of Technology North Bangkok); one private-sector technology development promotion agency and its private university (the Technology Promotion Association: Thai-Japan and Thai-Nichi University); one Thai-Japanese higher education program; one research institute (the National Science & Technology Development Agency) and, one sector-specific private sector association (the Thai Auto-Parts Manufacturer Association). We also cover one case study of a leading local 1st and 2nd tier supplier (Somboon Group) which has extensive interaction with both local 3rd-tier suppliers and customers (automotive assemblers).

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1. Thailand Automotive Institute (TAI)

1.1. Background

The Thailand Automotive Institute (TAI) was established by Cabinet resolution on July 7, 1998 with the aim of strengthening co-operation between the government and private enterprises for the enhancement of competitiveness of the Thai automotive industry. As a result, TAI is a *sector-specific* promotional and intermediary agency for the automotive industry. Administratively, TAI is not a part of the national bureaucracy but comes under the Industry Development Foundation set up by the Ministry of Industry. Therefore, the organization's administration is rather flexible. It is not subject to the rules and regulations of the ordinary government agencies and state enterprises. TAI's governing committee, headed by the Permanent Secretary of Industry, comprises representatives from the government and private sector, as well as academics. The committee is responsible for defining operational objectives and scope of work, and supervising the management of the institute.

1.2. Resources

TAI has around 100 employees. Only around 10% of them have masters degrees. The rest (90%) have bachelor degrees or lower. Within this group, around 30 have engineering degrees (mostly mechanical and industrial engineering). Twenty (technicians) have vocational qualifications. The rest are support staff with social science backgrounds.

In terms of its budget, TAI received direct funding from the government only for the first 5 years from its inception. After that, it was expected to be a self-financed agency. In reality, TAI has to ask other government agencies in the Ministry of Industry (namely, the Office of Industrial Economics, the Permanent Secretary's Office, the Department of Industrial Promotion) for funds on a project by project basis, or else undertakes projects proposed by these agencies. In essence, therefore, TAI has budget difficulties.

1.3. Official Mission

(1) To research and recommend guidelines, policy, strategic plans, and measures to develop the automotive industry, as well as to solve the problems related to production, technology, human resources and marketing in this industry.

(2) To support the operations of various organizations in both private and government sectors to facilitate the achievement of industry development goals; namely, productivity improvement, design, research and technology development, product standards and testing, human resource development, information database, and others.

(3) To liaise and cooperate with various organizations and both domestic and overseas institutes for automotive industry development

(4) To provide services to enterprises in the area of databases, product testing and inspection, training, working skill development and certification

(5) Other assigned tasks

1.4. Roles and Activities

In practice, TAI performs the following roles:

(1) Study and Analysis

The Institute compiles, studies, and analyzes data, information and related situations, which are used as supporting data for recommendation, guidance and warning to the private sector, or directly and indirectly related organizations in the automotive industry. This will enable those organizations to plan their operations in both the short and long terms, and to recommend guidelines for policy, invasive industrial planning and direction for automotive industry development.

The most prominent study conducted by TAI is the Master Plan for the Thai Automotive Industry. So far, TAI has been commissioned by the Office of Industrial Economics under the Ministry of Industry to draft two master plans for the industry. The first master plan covers 2002-2006, and the second one covers 2007-2011. TAI started the drafting process by organizing a CEO Forum. Though it seemed to be engaging with the private sector, key participants were from the subsidiaries of transnational corporations in Thailand, not from their headquarters. It has therefore been difficult to get clear commitment from the TNCs to implement what was set out in the plan. Also the master plan was too comprehensive, and tries to satisfy everyone for political reasons. No clear priorities were been set, i.e., what should be done first? Ironically, the most significant policy decision recently, that is, to pick the 'eco passenger car' as a product champion (in addition to the one-ton pick-up truck) was not specified in the plan.

(2) Development of Parts Manufacturers

TAI has defined competitive capability building of the parts manufacturers as one of its important tasks. The Institute has provided consultancy to improve production processes and organization management, led by its experts and engineering teams with expertise in each area. Moreover, the Institute has co-operated with international experts and organizations to solve problems in the product development and production processes of parts manufacturers.

TAI has a database of 2000 parts manufacturing companies. TAI would like to upgrade the technological and innovative capabilities of these companies through its consultancy and testing services (through its testing centre in Bang Pu, close to Bangkok). Most of its activities in this regard consist of testing whether components and parts produced by these companies are up to international standards (hence, qualifying to be exported or to be part of the value chains of TNCs). This task is critical to Thai parts manufacturers which do not have expensive and sophisticated testing facilities in house. Nonetheless, due to lack of funds and personnel, TAI cannot do much in terms of upgrading the capability of these companies to meet such international standards.

(3) Personnel Development

TAI provides both public and in-house training and capability testing, with concentration on the content required by the automotive industry, such as productivity, quality systems, administration and management. The Institute also provides the system to certify the capability of people in the following critical areas of the automotive industry: metal fabrication, metal moulding, plastic injection, and lathe and milling machine operation. The training and capability testing are both theoretical and hands-on. Capability certification helps to promote personnel development systematically, and enhances the acceptance of personnel capability standards. At the same time, the parts manufacturers in this industry are able to reduce cost and increase their competitive capability.

The most important human resource development program organized by TAI is the Automotive Human Resource Development Program (AHRDP). This is a joint collaboration between Thailand and Japan. Apart from TAI, the Federation of Thai Industries also joined the program. The Japanese side was led by the Japan International Cooperation Agency (JICA), the Japan External Trade Organization (JETRO) and the Japanese Chamber of Commerce (JCC). The program aims to upgrade the capability of local parts manufacturers. Its mission is centred on enhancing Thai automotive workforce capabilities through a large-scale "train the trainer" program, and establishing a skills certification framework. Eventually, graduates of the program should be able to train other people in their companies or their supplier networks. Four leading Japanese companies participated in the program by providing training experts and course materials: these were Toyota (the Toyota Production System), Honda (mould and die technology), Nissan (scheme for skill improvement), and Denso (manufacturing skill and mind management). The training covered theoretical knowledge, hand-on skills, and attitude. Thai university professors were also invited to teach theoretical courses. The parts manufacturers (both foreign owned or joint venture and local) needed to shoulder some costs either in kind or in cash. Executives of these companies had to show commitment to the program and send qualified people to participate. They were required to share their knowledge and skills with other companies and allow others to visit their factories.

All in all, this is a remarkable program. It has created a pool of talented trainers and has improved awareness of the importance of human resource development in the sector. However, results in terms of the actual upgrading of Thai automotive workforce are ambiguous. Some companies, especially larger ones, set up training centers or training courses after joining AHRDP. Uptake was less enthusiastic for smaller companies. TAI also conducted a follow-up investigation only once; one year after the program had ended. During the economic and political crisis recently, some trained technicians have left the industry to work in unrelated business with no requirement of using automotive skills.

TAI has proposed a second phase of AHRDP, and worked hard to have the program included in the recently-signed Japan-Thailand Economic Partnership Agreement (JTEPA). The new phase will focus more on higher and more comprehensive levels of knowledge and skill in the engineering and R&D activities which are necessary for upgrading the Thai automotive industry in the global value chain. Nevertheless, the project has not yet been carried out due to political conflicts both at international and domestic levels.

The qualified success of AHRDP highlights the important role of an 'intermediary' in facilitating the collaboration of key players in the sector. TAI has performed a crucial role in bringing TNCs, parts manufacturers (both local and foreign-owned), Thai universities and other government agencies to work together for the overall benefit of the industry. It has somewhat successfully bridged different expectations and interests and overcome a high level of mutual distrust among the players mentioned. This is a rare phenomenon in Thailand, whose national and sectoral innovation systems are largely weak and fragmented, and where trust among companies, and between companies and other actors such as government agencies and universities is generally low.

1.5. Policy Implications

The case of TAI has a few interesting policy implications.

1. Having an agency specifically taking care of promotion and upgrading of the sector is very important. It is not enough to have only a general agency looking

after the overall development of all industries. Each industry has a different path of development, requires different policy support and needs to have an agency that truly understands the industry and is committed to its promotion.

2. Organizational set up and budgetary supports are also crucial for the effectiveness of a sector-specific industrial development organization. TAI's ambiguous status, as either a government agency having a policy formulation mandate and/or a truly flexible private organization, makes it difficult for it to initiate policies and coordinate with large players in both the public and private sector (especially TNCs). This is a question of authority and creditability. Also the lack of annual direct government budgetary support makes it difficult for TAI to perform "public good" activities necessary for the technological upgrading of firms in the sector, such as providing important but expensive training in critical skills and knowledge which cannot be privately accessed by most local firms, and initiating R&D programs in the fields critical for the survival and value chain upgrading of the industry (e.g. hybrid and/or electrical vehicles and parts). Instead, TAI has to survive in the short run by offering services which easily make money but may not be so critical for long-term upgrading, and are in direct competition with private service providers. Also TAI have had to join projects initiated by other government agencies. Some of these projects might not match the key missions of TAI, nor be a high priority for the automotive industry. Therefore it is important that TAI should receive sufficient continuous budgetary support from the Thai government (for example, as a percentage of the value-added it can generate for the industry). Its official organizational status should also be clarified and strengthened in the eyes of large government and private-sector players in the industry. This needs to be studied further and publicly debated.

3. The role of *intermediary* is very significant. Such a sector-specific development agency not only performs policy initiation roles but also policy implementations, requiring interactive collaboration with key players in the sector. The effectiveness of an intermediary organization also depends on the authority, politically and financially, and creditability of the agency. This needs to be taken into account by the policy makers.

2. Chulalongkorn University's Programs on Automotive Engineering

2.1. Background

The Mechanical Engineering Department of the Faculty of Engineering at Chulalongkorn University was the first university offering specific study programs in automotive engineering, beginning in 1996. It started with a bachelor's degree conducted in Thai. The program has been quite small with only 15 students per year. In 1997, the department followed up by initiating the Automotive Design and Manufacturing (ADM) bachelor's program in English. This program was larger, with 100 students. Due to high tuition fees and demanding admission criteria, the number of students in the English program has now come down to forty. With the establishment of the International School of Engineering at the faculty in 2005, the master's degree in automotive engineering began. The number of foreign students in the English programs is about 10%.

2.2. Resources

There are five professors in the automotive program, and another two from the standard mechanical engineering programs can also participate in teaching.

2.3. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

In terms of education, the teaching programs have had close collaboration with Toyota. Toyota helped in drafting curriculums, a rather unusual practice for Thai universities. It also provided both up-to-date equipment and instructors especially in the specific courses, such as automotive manufacturing, which required insightful and practical knowledge and experience. Toyota managers frequently take turns to teach classes. Most linkages with private firms are with the Toyota Group. However, other companies also have relationships with the programs but they are not as intensive, interactive, and frequent. For example, Isuzu has provided no-obligation scholarships to master's students. Several automotive paint making firms have also sent their employees to teach in a paint-related subject. Interestingly, in response to recent investments in design and development activities by Japanese TNCs in Thailand, the teaching content, especially in the English program, has lately changed to focus more on knowledge and skills for design and development. There has therefore been a co-evolution of what is being taught at the university and what is going on in the industry, which does not usually happen in Thai universities.

Research collaboration with the industry, both with car makers and parts suppliers, is very limited. However, companies are contracting research from departments and research institutes of universities on the topics of polymers and developing new materials.

The Thailand Society of Automotive Engineering (TSAE) co-located at the automotive program centre of Chulalongkorn University was set up in 1997. It is a bridging organization between firms, government agencies and academics. Professors of the programs play an active role in the activities of the society. The activities include diffusing technical knowledge by organizing seminars, helping companies in adjusting to standards, working with public organizations like TAI, and, through its monthly meeting, facilitating cooperation between members. The society also provides training in quality systems (ISO 9000, QS 9000, TQM, TQC), productivity improvement, jigs & fixtures , CAD/CAM/CAE, supervisory skills, and cost reduction.

2.4. Results of linkages

Interestingly, the best students graduating from the programs tend not to work for automotive companies, even TNCs. They prefer either to work in well-established and promising Thai firms, such as the Siam Cement Group or for TNCs in other industries, both in Thailand and abroad, such as oil exploration companies (e.g. Chevron and Schlumberger) which can offer much high salaries. Even though automotive TNCs like Toyota and Honda have started their design and development activities in Thailand, this group of elite students still have other more attractive alternatives. Also automotive factories, located far away from the city centre, do not offer the comfort and lively lifestyle expected by the top graduates. This is another reason why they do not want to work in the automotive industry.

Regarding the quality of graduates, Chulalongkorn University graduates have strong theoretical backgrounds. They also do not have the English language problems of other graduates of Thai universities, although even the Thai programs use English text books. Of course, the reading and writing skills of these graduates are better than their speaking skills. The big problem is the lack of creativity of these graduates, a prerequisite for climbing up the value chain to the development and research activities which the Thai authorities want to see. The programs have acknowledged this problem and responded by changing teaching styles in some courses, becoming more problem-based, i.e., encouraging critical thinking and active participation from students.

2.5. Obstacles of Linkages

One major obstacle for developing such a specialized program as automotive engineering is the rigid regulations imposed by the Commission of Higher Education (CHE) and the Council of Engineers (a professional association having authority to issue the certificate necessary for an engineering career). CHE’s regulations require all programs to study several basic subjects (social sciences and humanities) which are not related to automotive engineering. Therefore there are limited time slots in the curriculum for specific courses specialized in automotive engineering, especially if the programs are to have focus on preparing students for R&D activities. The Council of Engineers, on the other hand, requires students to study several out-dated subjects which are not useful at the present but are compulsory for getting a professional engineering certificate.

Another obstacle is the different expectations between universities and firms regarding the working ability of graduates. Many local firms expect that students can work immediately they graduate. However, most Japanese firms do understand the relity of the situation. They expect students to have enough theoretical engineering knowledge. The practical knowledge and skills they need will be trained in-house, either through formal or on-the-job training.

In addition, discontinuous government support can also affect the linkages between universities and firms. For example the department purchased equipment from government funds, to be used for research cooperation with the private sector.

Government, did not provide funds for maintenance. Therefore equipment is available but not in use.

2.6. Policy Related Issues

1. It is rather obvious that more flexibility is needed in curriculum development for new programs aimed at rapid technical change and changing demand from the industry. Both education and professional authorities should therefore play a facilitator and not only a regulator role.
2. In this regard, the role of intermediaries in facilitating interaction among key actors in the industry is also critical, since these actors have different expectations and time horizons. Intermediaries can be either public (such as the Thailand Automotive Institute) or private (for example TSAE).
3. Continuation of policy support both in terms of attention and budget, is necessary for collaboration between firms and universities, especially in the case that universities alone cannot shoulder the high costs of purchasing and maintaining equipment.
4. A professor of the program felt that better division of labour between universities teaching and doing research in the automotive industry should be a point of concern. The idea of having designated centres of excellence specializing in different areas of automotive engineering in different universities should be seriously considered. Funds and equipment could be allocated to each university according to its specialization. As a result, a university would be a node for collaboration with other universities in terms of teaching and research in a specific designated area.

3. King Mongkut’s Institute of Technology, Ladkrabang

3.1. Background

King Mongkut’s Institute of Technology, Ladkrabang (KMITL) was established in August 1960 as the Nondhaburi Telecommunication Training Center with cooperation from the Government of Japan. The institute has changed its name several time and became King Mongkut’s Institute of Technology, Ladkrabang in 1986. KMITL aims to provide education and research in science and technology, as the foundation of the development of the nation. Currently, KMITL offers both undergraduate and graduate programs in 7 faculties and 4 colleges, which are: the Faculties of Engineering, Architecture, Industry Education, Science, Agricultural Technology, Information Technology, and Agro-Industry, and the International College, the College of Nanotechnology, the College of Data Storage Technology and Applications, and the Administration and Management College.

The Faculty of Engineering was the first faculty in KMITL. It has been the core of KMITL since it was the Nondhaburi Telecommunication Training Center in 1960. Nowadays, the Faculty of Engineering offers bachelor’s degree programs in Telecommunications Engineering, Electrical Engineering, Electronics Engineering, Computer Engineering, Control Engineering, Mechanical Engineering, Civil Engineering, Agricultural Engineering, Chemical Engineering, Food Engineering, Industrial Engineering, Information Engineering, Mechatronics Engineering, Instrumentation Engineering, and Automation Engineering. The Faculty of Engineering also has master’s degree programs in Telecommunications Engineering, Electrical Engineering, Electronics Engineering, Computer Engineering, Control Engineering, Mechanical Engineering, Civil Engineering, Agricultural Engineering, Chemical Engineering, Industrial Engineering, Information Engineering, Instrumentation Engineering, Microelectronics Engineering, Construction and Management Engineering, Biomedical Electronics Engineering, Automotive Engineering, and Automation Engineering. In addition the Faculty of Engineering also offers 3 PhD programs in Electrical Engineering, Mechanical Engineering, and Chemical

Engineering. The Automotive Engineering program is a joint program with National Science & Technology Development Agency (NSTDA) and Tokyo Tech, and is explained as a separate case. This case will discuss the relationship that KMITL itself has with the automotive industry.

3.2. Resources

There are around 20 professors in the Mechanical Engineering Department and about 100 undergraduate students. KMITL cannot check how many people have worked in the automotive or related industries after graduation. but, it is estimated that around 25% of the graduates go to automotive or related industries.

3.3. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

Even though KMITL does not have an automotive engineering program, apart from the joint program with NSTDA and Tokyo Tech, KMITL has an automotive club. This club has joined the Student Formula SAE Competition every year. This competition is organized by the Society of Automotive Engineers, Thailand, to encourage students' interest in designing racing cars. This competition is international, and this year took place in Japan. The racing car developed by KMITL finished in 6^{th} position and received the Best Cost and Best Design Awards.

During the development of the racing car, students from the automotive club worked closely with many firms in the automotive industry and received financial support through sponsorship. The key sponsors were Suzuki, providing the engine for the car, and Cobra who supported the use of carbon fibre material and also allowed students to work side-by-side with its employees. The total cost of developing the racing car is more than a million Baht (around 33,300 US$).

KMITL has a very close relationship with Cobra. Cobra makes surfboards and windsurfers using carbon fibre material imported from Germany, and mainly exports its products to other countries. Cobra aims to expand its scope into automotive parts, but it has neither knowledge nor experience in designing automotive parts in carbon fibre. Cobra therefore wished to gain know-how from research with KMITL through the racing car program. KMITL students designed the parts using CAD and also simulated the strength of the parts. The simulation of carbon fibre is challenging, because carbon fibre is a new material and no one knows in detail the simulation parameters of carbon fibre.

Another close relationship that KMITL has with an automotive firm is the relationship with Suzuki. Suzuki fully sponsors its engine for the KMITL racing car team as well as sponsoring the research done by professors at KMITL. One of the research projects is to create an engine that can use 100% ethanol. In general, an engine using 100% ethanol has a problem when starting at a low temperature. A KMITL professor has found how to modify the Suzuki engine so that it can be started, using 100% ethanol, at 0 degrees Centigrade. After the research finished, KMITL invited the president of Suzuki Thailand to learn about the research. In the case of the racing car, the racing team was able ask Suzuki for any engine or parts they needed, and Suzuki Thailand would order from Japan for them. Many times the racing team modified the engine, and it broke down. Suzuki were also able to study the weak points of the engine, and the reasons for breakdowns.

The relationship that KMITL has with Suzuki is close because the advisor of the automotive club graduated from the same school in Japan as the president of Suzuki Thailand. At the time when the president of Suzuki Thailand first came to Thailand, the professors in Japan recommended this KMITL professor to the president.

Beside the racing car, KMITL also has an automotive lab to test engines. KMITL is one of four establishments in Thailand that have the infrastructure and equipment to run theses tests; the others are PTT Public Company Limited, the Thailand Automotive Institute, and the Pollution Control Department. An example of the equipment used is the chassis and engine dynamometer.

3.4. Results of Linkages

From the relationship that the racing team of KMITL has with Cobra, Cobra can produce new products from carbon fibre, such as steering wheels. However, most of the developed products are made-to-order parts. Cobra was able to learn how to design products and to simulate carbon fibre from working with KMITL. Suzuki were able to study the reasons why their engine broke down from the racing car project, and also to study the new technology stemming from the research done by KMITL, using the Suzuki engine.

3.5. Obstacles to Linkages

An obstacle to the linkage that KMITL found with Suzuki is the language and cultural barrier. Most Japanese firms cannot use English well, and the same is true of Thai people. It is therefore hard to communicate in order to understand complex situations. Culture is also a problem. Japanese people tend to be very disciplined, while Thai people are usually not. Also, Japanese people have different ways of saying the same thing in different situations.

Another problem is that most of the time the university expects to get help from the firms without giving anything back. In order to attract firms to do research with the university, it also needs to be professional and to have something that the firms want, such as some specific infrastructure or knowledge.

These problems are being tackled through an informal lecture. The racing team advisor graduated in Japan, so he understands the Japanese culture and language quite well. He is able to advise his students about the cultural gap and how to deal with Japanese firms.

3.6. Policy Related Issues

The problem of the relationship between the university and firms is that there is no Thai car maker or big Thai firm that can design a car. It is hard to deal with the Japanese firms because the Japanese firms do not want to share their technology, but it is much easier to deal with Thai firms such as Cobra.

The universities need to have better equipment/machines than the firms. This is the case in other countries. The firms will do joint research, or hire the universities to do research, only if the universities have better equipment or skills to do it. However, this is not likely to happen in Thailand because the budget for the universities in Thailand is very limited. If the professors need equipment, they have to build it and do its maintenance themselves.

4. King Mongkut's University of Technology, Thonburi

4.1. Background

King Mongkut's University of Technology, Thonburi (KMUTT) was set up as Thonburi College of Technology on February 4, 1960 as the first technological college in Thailand responsible for producing industrial technicians with the highest level of secondary schooling. In 1971, Thonburi College of Technology was merged with North Bangkok College of Telecommunication Technology to become King Mongkut's Institute of Technology, Thonburi and later changed the name to King Mongkut's University of Technology, Thonburi.

KMUTT has a vision of commitment to the search for knowledge. It is determined to be at the forefront of technology and research, to maintain the development of morally correct and proficient graduates, to seek success and honor in order to be the pride of the community, and to strive to become a world-class university.

KMUTT consists of the faculties of engineering, science, industrial education and technology, the schools of information technology, architecture and design, t bio-resources and technology, energy, environment and materials, liberal arts, the graduate school of management and innovation, and the institute of field robotics. The main sector that deals directly with the Thai automotive industry is the department of mechanical engineering and the department of tools & materials engineering.

4.2. Resources

The department of mechanical engineering provides education from bachelor's degrees to doctoral degrees in mechanical engineering and related fields. The mechanical engineering department has around 30 lecturers. There are around 500 undergraduate students, 80 master's students, and 20 PhD students. Of 30 professors, about 5 are connected with the automotive industry.

Another related department is the tools & materials engineering department. This department has around 20 lecturers. There are about 500 undergraduate students. Half of them are in the tools major and the other half are in the material major. The department also has around 20 master's students and 7 PhD students.

4.3. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

The mechanical engineering department provides two courses that are directly related to the automotive industry. These are the automotive technology course and the internal combustion engine course. Even though the industry has a role in designing the curriculum, the curriculum of mechanical engineering does not have room to customize its teaching to specific industry requirements because more than 90% of the courses are set by the Council of Engineering. Students can choose only two free elective courses during the whole four years of study. Besides, when the students graduate they rarely use what they have learnt about automotive engineering because most of the automotive industry in Thailand focuses on production of parts. Design and engineering or research has just started and is mostly carried out by TNCs. Therefore it is the goal of the department that its graduate will be a diversified mechanical engineer who knows all the basics and can go to any industry. For master's and PhD students, the focus will be based on the topic of their thesis and dissertation.

The tools and materials department, in this case, has stronger linkages with the automotive industry than the mechanical engineering department, since moulding is a key activity in the production part of the industry. The relationship between the tools and material department and the automotive industry is through students' internships, research projects, and consulting work and most relationships are long-term. By volume of work, around 80% of the work the tools and material department has done was with the automotive industry.

Most research projects that the tools and material department have done with the automotive industry were through PhD dissertations. This type of work usually involves 1st tier suppliers such as the Somboon group. The topic of the PhD dissertation comes from a problem that the firms face. In general, the firms support the research by providing materials and infrastructure. The capital usually comes from a government agency in terms of a scholarship or research funding. The department also works with 2nd tier and 3rd tier firms through the master's theses and undergraduate senior projects. Besides the research, the department also has a linkage with the firms through cooperative education since the students need to work in a firm as an employee for one semester or more. Around 80% of the students go to the automotive industry during this period.

Even though KMUTT has done research with the automotive industry, most research is on process improvement. There is no product development research. The department cannot register patents on the research outcome. Therefore, the department cannot license their findings, and also has no problem on intellectual property rights with the industry.

Another method of collaboration is through the professorial exchange program. KMUTT allows its professors to work in an industry for a period of time in order to bridge the gap between the university and the industry. However, the result is not as successful as the plan because the Thai automotive industry is mainly a manufacturing sector and a professor cannot learn much besides day-to-day operations. Moreover, the knowledge and capability of firms and the professors are limited because the university does not have high-technology infrastructure, as used in the industry in developed countries, and neither do the firms.

These connections between the firms and the university have arisen through personal contact and government programs. NSTDA has come up with the Industrial Technology Assistance Program (ITAP) project, linking the university and the industry together by working as an intermediary. From interviewees' perceptions, ITAP could significantly help the university to build linkages with the industry. KMUTT also has a unit to coordinate with firms. However, this unit works passively, mainly acting as a delegator to assign projects to departments when a firm makes a request. This unit does not carry out marketing, nor does it go to the firms to seek projects.

4.4. Results of Linkages

Less than 25% of the graduates from the mechanical engineering department join the automotive industry. Working with the tools and material department, firms can improve their efficiency and reduce defects as a result of advice from the university.

4.5. Obstacles to Linkages

The university and the firms have different understandings about research projects. The firms think that research projects are always about product development. Moreover, there is a research timeframe problem. When firms come to the university, they tend to have a critical problem which exceeds their capability to solve. They want results within a week or two, and the university cannot do that.

The professors also have difficulties when working with the firms. Research projects that the professors engage on with the firms are hard to turn into publications due to the characteristics of the research, and the confidentiality that the firms insist on. KMUTT provides salary increases based on the research projects that the professors carry out with the firms. However, to be promoted to associate professor and full professor, only the publications are counted.

4.6. Policy Related Issues

1. Government should assign responsibility and strengthen a university to become the center of excellence in a particular of field of expertise/technology. It should provide continuous financial and infrastructure support (as it takes a long time to build an excellence centre). Without being a really ‘excellent’ centre on something, a university cannot help industry much.
2. The criteria for promotion of academic staff to assistant professor, associate professor, and full professor should encompass research projects that the professors engage on with the industries irrespective of publication.

3. The Council of Engineering should loosen their rules on the curriculum and let each university design its courses to match their goals, whether to be a general or a specialized school.

5. The Sirindhorn International Thai-German Graduate School of Engineering (TGGS), King Mongkut's University of Technology, North Bangkok (KMUTNB)

5.1. Background

TGGS is a joint institution established by RWTH Aachen University in Germany and KMUTNB, in order to transfer the RWTH Aachen Model of Graduate Industry-oriented Engineering Education, Technology Innovation and Business Development to South East Asia. The TGGS project was initiated in 1996 and started its first M.Sc. courses in 2001. Since 2009, TGGS has accepted Southeast Asian students into the program. Currently, TGGS has around 20 full-time faculty members

RWTH Aachen is the largest university of technology in Germany, and one of the most renowned technical universities in Europe, with around 32,000 students and 300 full Professors and Chairs. About 83% of its students are in engineering, natural sciences and human medicine. In Aachen, around 5,000 international students and scientists benefit from the internationally recognized world-class courses and lab facilities. Traditionally, nearly all RWTH students register directly for their master's degree. In addition, RTWH Aachen has around 3,000 research assistants enrolled in Ph.D. work, and the total amount of external funding acquired (from industry, federal Government and the European Commission) was 193 million Euros in 2008. RWTH Aachen achieved top results in the German Federal Excellency Initiative, obtained the status of being an Elite University (resulting in extra funding of around 165 million Euros.) The industry-oriented profile of RWTH Aachen is due to the fact that nearly all of its Engineering Chairs and Full Professors have typically 10 to 15 years of industry experience, and students are enrolled very early in mini-projects, part-time research support jobs, industry internships and research-oriented master's theses. Within RWTH Aachen, numerous affiliated institutes (operating like companies) have been established and, since 1985, about 1,000 technology oriented spin-off companies have been founded with the University's direct or indirect support, in the region in and around Aachen. Last but not least, 25% of all engineers with a doctoral degree in German industry are graduates of RWTH Aachen University.

KMUTNB has more than 50 years experience of cooperation with Germany, has adopted elements of the German system for many years, and has grown to be a university since 1986. Today, KMUTNB is one of the largest technical universities in Thailand with more than 20,000 students.

RWTH Aachen first approached Rajamangala Institute of Technology (RIT) to create a joint program. However, RIT had limited capability in terms of lab infrastructure and qualifications of the faculty. RWTH Aachen Then approached KMUTNB and an agreement was signed.

TGGS is an autonomous International Graduate School of Engineering within KMUTNB and has its own autonomous Thai-German administration. TGGS aims at the R&D-oriented education of engineers (M.Sc. and Ph.D. level) and consequently at technology innovation and associated business development in Thailand. TGGS serves as an example for new, industry-oriented structures in the Thai higher education system, and has an effective system of engineering education, technology development and research. For RWTH Aachen and its network of collaboration in Thailand, TGGS will become the main hub for R&D and business development in Southeast Asia.

TGGS milestones have been:

1996	Letter of Intent signed by RWTH Aachen on developing a new "Thai-German Graduate School of Engineering" in Thailand, based on the RWTH Aachen Model of engineering education
1997	Core network with KMITNB, RIT, RWTH Aachen, BMBF, MWF NRW, MUA Thailand, the Embassies and the first industrial sponsors established
1999	Memorandum of Understanding between RWTH Aachen, KMITNB, RIT,

	and DIHT (GTCC Bangkok)
2001	Launching of substantial project support through DAAD, start of first M.Sc. courses at TGGS in Mechanical Engineering Simulation and Design
2004	TGGS Contract of October 22 (25 million Euros budget 2006-2011), Foundation Stone of 11-storey TGGS building
Since 2005	Privilege granted TGGS to carry the name of HRH Princess Maha Chakri Sirindhorn
Since Mid 2006	Transitional TGGS offices in KMITNB New Research Building, recruiting of TGGS permanent academic staff started, total of 80+ staff to be recruited by 2009
2007	Completion of TGGS building and move into new offices, TGGS Co., Ltd. registered , purchasing of first basic equipment for TGGS started, name of Thai Partner changed into KMUTNB
2008	TGGS Co., Ltd. received its Bol Certificate , TGGS Autonomy and TGGS Council established officially, extension of labs and start with R&D projects
2009	Delivery of significant R&D equipment for the Technical Groups, first larger batch of students from Southeast Asia (Vietnam, Malaysia, Indonesia, etc.)
2010	First German-ASEAN (GAST) Conference on Mass Transport Technologies

The mainstream activities of TGGS can be categorized into three areas. The first is provision of industry-oriented engineering education following the RWTH Aachen Model by, providing international M.Sc. courses including block lectures by RWTH professors, cooperative engineering education with project-oriented internships, training and guidance of Thai Lecturers/Researchers in Aachen, and human resource development, scholarships, and alumni activities. The second aspect focuses on technology innovation through the expansion of collaboration links with industry in Thailand and Germany for Thai M.Sc. and Doctoral students, third-party funded R&D projects, development of state-of-the-art TGGS labs and research activities, technology-upgrading for Thai industry, and build up of TGGS as a platform for R&D projects in the whole of Southeast Asia. The last aspects is business development through the expansion of and support for Thai-German industry links, establishing technology spin-offs in Thailand, business development in new technical fields, and links and resources in Bangkok used to create joint Thai-German business development projects.

Currently, TGGS offers 8 international M.Sc. and 4 international Doctoral Programs based on the RWTH Aachen Model. The M.Sc. programs offered are Mechanical Engineering Simulation and Design, Automotive Engineering, Production Engineering, Chemical and Process Engineering, Materials and Metallurgical Engineering, Communication Engineering, Electrical Power and Energy Engineering, and Software System Engineering. All programs are taught in English by professors from RWTH Aachen University and local professors with Ph.D.s from abroad. For the Ph.D. program, TGGS can offer degrees in Mechanical Engineering, Electrical Engineering, Materials Engineering, and Computer Engineering. However, in order to be accepted as PhD students, RWTH Aachen University must also approve candidates. Up to now, RWTH Aachen has not approved any Ph.D. candidates.

The administrative body of TGGS consists of representatives from both KUMTNB and RWTH Aachen. TGGS has one German director and one Thai director. Each program also has one Thai and one German program coordinator.

In close linkage with its German Industry Network in Thailand and with IHK (CC) Aachen, TGGS not only interacts with industry for internships and engineering projects, but also as a communicator, supporting business development and recruitment of qualified Thai graduates. TGGS has a broad network of partners including well-known companies in Thailand and Germany e.g. Siemens, SAP, Bayer, ABB, BMW, Daimler, FESTO, TUV Rheinland, and Siam Cement Group.

TGGS also established the TGGS Company Limited as the legal platform for international accounting, management and contracting, transfer of financial and human resources (R&D lab equipment) and for flexible handling of R&D projects with financial and IP issues, particularly for projects with the industry. Thai and German Directors are also directors of TGGS Co., Ltd. Similar to the concept of the affiliated institutes of RWTH Aachen, TGGS Co., Ltd. provides mechanisms to allow TGGS to act without the bureaucratic ties of the Thai Government System, and to implement the RWTH Aachen Model with all its entrepreneurial aspects in Thailand

TGGS also set up the German-Thai Engineering Technology Alliance (G-TETA) through an alliance between TGGS/RWTH, Siemens and the Thai-German Institute

(TGI). G-TETA aims to increase the participation of German companies in technology and infrastructure projects, and to enhance in a sustainable manner the development of local know how in manufacturing and engineering in Thailand. Possible technology areas in the focus of this alliance are transportation, drives and automotive, renewable energies (wind turbines, solar, new fuels), wireless communications, ICT and medical technology. A first project proposal, made to the Royal Thai government in 2009, is participation in the governmental infrastructure/mass transit plan for Bangkok, where Siemens has already a proven record and long experience of building and maintaining mass transit systems. In conjunction with this project, TGGS plans to build up a 4-semester M.Sc. Course on "Mass Transit Engineering" based on the practice and research-oriented M.Sc. course "Traffic Engineering" already implemented at RWTH Aachen.

TGGS has also developed joint activities with other German institutes in Southeast Asia such as the German Institute of Science and Technology (GIST) in Singapore, the Swiss-German University (SGU) in Indonesia and the Vietnamese German University (VGU) in Vietnam to enhance scientific networking in this region. Since November 2009, the 3 institutions TGGS, GIST and SGU have organized the German-ASEAN Science and Technology Network (GAST) in order to establish the German TU9 Model of Education and Research in the Asia-Pacific Region. A common German-ASEAN Conference on Mass Transport Technologies (focus on railway technology) was arranged for Bangkok, Jakarta and Singapore in May 2010, supported by the German Federal Ministry of Education and Research (BMBF)

5.2. Automotive Engineering Program

The Automotive Engineering program at TGGS was started in 2004 and focuses on industrial R&D practice and on modern manufacturing processes for vehicles and their subsystems. This program is supported by one of the world's leading departments of Automotive Engineering, "ika" at RWTH Aachen University, which also closely collaborates with companies like BMW, Daimler, Siemens, as well as Asian and American manufacturers. The program also contains elements to enhance the students' ability to lead and coordinate project teams and to strengthen their skills of scientific documentation and communication.

The course structure was developed by RWTH Aachen University. The course is mainly industry-oriented, practice-based and developed from the knowledge and experience gained from the research done by RWTH Aachen University. The courses offered in the Automotive Engineering program include Automotive Engineering I-III, Structural Design of Vehicles, the Combustion Engine, Mechatronics and Vehicle Acoustics. The school also provides German language classes for students. Outstanding students also have opportunities for internships and thesis preparation in Germany. Based on their record, only one student per year is selected for an internship and thesis in Germany. Most of the time an internship in Germany for work at RWTH Aachen but working on an industrial problem because RWTH Aachen has a strong relationship with the industry.

The course structure of the Automotive Engineering program at TGGS is as follows:

1st Semester – Automotive Engineering I, Automotive Engineering II, Structural Design of Motor Vehicles, Internal Combustion Engine I, Selected Topics in Automotive Engineering, and Elective or German Language I

2nd Semester – Automotive Engineering III (Automotive Systems & Production), Mechatronics in Vehicle Engineering, Vehicle Acoustics, Automotive Engineering Lab I, Automotive Engineering Lab II, and Elective or German Language II

3rd Semester – Management and Economics, Industrial Internship (18 weeks), and Seminar

4th Semester – Master's Thesis

Automotive Engineering I explains the basic design concept of the car, power demand, transmission, engine, brake, *etc*. Automotive Engineering II is about the dynamics of the car, the mechanics, horizontal and vertical dynamics of the car, etc. Automotive Engineering III is about the production line for the vehicle. For their lab work, students will study in the lab of College of Industrial Technology, KMUTNB with faculties from College of Industrial Technology. The Management and Economics course is to teach students on industrial and production management and economics, economical feasibility studies, etc.

The differences between the Automotive Engineering program of TGGS and other institutes are unknown because this comparison has not so far been made. However, the Automotive Engineering program at TGGS concentrates on the design concept of all parts and subsystems of the vehicle, not only the function of each part. In other words, TGGS focuses on “know why” instead of “know how”.

The goal of this program is for graduates to work in either production or R&D departments of automotive firms because staff on the production line needs to understand the design concept in order to solve problems on the line.

5.3. Resources

TGGS has around 20 full-time faculty members. TGGS plans to have at least 3 full-time members for each program. Faculty members must have direct knowledge and experience of their field, not just the knowledge gained from books. However, for the Automotive Engineering program, TGGS has only 2 full-time members of staff. One has a master’s degree in Automotive Engineering and a Ph.D. dissertation on automotive brake systems while the other has expertise in general Mechanical Engineering but received his Ph.D. from RWTH Aachen under a scholarship which requires him to work for KMUTNB for a period of time.

The Automotive Engineering program at TGGS is able to accept 15 students per year. However, there are only 6-7 applicants each year due to the language barrier, because this course is taught in English and also requires an English proficiency level equivalent to TOEFL 550 or higher in order to gradate, and to the tuition fee which is considerably higher than for other domestic institutes. Even though TGGS provides a partial university scholarship to almost all students, the financial issue is still a problem.

Most students have an undergraduate degree in mechanical engineering or related subject because the master’s degree courses do not provide the basic foundation knowledge that is covered in the bachelor’s degree. The lecture notes are also a barrier for students with other undergraduate backgrounds because the notes are based on the research profile of RWTH Aachen and there is also a language barrier.

5.4. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

TGGS has limited relationships with the private sector. The firms do not have a role in designing the course structure in the first place because all courses are developed by RWTH Aachen University. However, TGGS has received suggestion from the firms and adjusted the program accordingly later.

All master's theses must concern real industrial problems. In order to ensure that students know the problems of the industry, every student needs to do an internship with the firms to study the real industry, and select one problem to be the subject of a master's thesis. However, there is a problem that when students work in industry, they generally do so for longer periods than just the internship, which delays their studies.

The advisors for the master's theses are not limited only to TGGS faculty members. Students can select their advisor from other institutes if they know that topic well, and are qualified to be an advisor for a master's thesis.

To ensure that all faculty members are active in research and have linkage with industry, all faculty members are required to do research. The measures for evaluation of faculty members are the number of publications, teaching hours, and research funding. Consulting projects in industry have been TGGS research projects an example of a consulting project was measuring the efficiency of additives to reduce oil usage. TGGS also have registered patents and have licensed them out to firms, but this is rare.

TGGS also provides seminars and training for local firms. In some cases, when the professors from RWTH Aachen University come to Thailand to give lecture, TGGS also invites representatives from the firms to attend the sessions.

5.5. Results of Linkages

More than half of the students work as lecturers. The rest works in industry. The graduates who work in the automotive industry mainly work in 1^{st} tier, 2^{nd} tier and 3^{rd} tier firms such as the Somboon group. No one has yet been selected to work with a carmaker such as Toyota or Honda. The reason is that Toyota only hires workers with bachelor's degrees, and then provides internal training.

5.6. Obstacles to Linkages

Most of the firms that TGGS is dealing with are small and medium-sized local firms. They do not usually consider research as an essential factor, except to solve problems. In many cases the firms try to avoid hiring the university to do research by asking for very detailed proposals which then has all information they need to do the work by themselves without paying to the university. When the firms do decide to work with the university, payments are usually late. Another problem is that firms sometimes want a certificate from TGGS but are reluctant to follow all criteria. They then try to cut corners by negotiating with TGGS not to test on all the criteria.

5.7. Policy Related Issues

In order to help TGGS to do research with firms, the government should act as a middle man to match the firms' demand with the skills and capability of each university, coordinate the research project among both parties, and also handle all legal issues including the type of contract, the method of payment, the schedule and the deliverables, etc.

6. Technology Promotion Association (Thailand-Japan)

6.1. Background

The Technology Promotion Association (Thailand-Japan) or TPA was established, as a response to anti-Japanese sentiment in 1973, by Japanese alumni and people who had been trained in Japan with the Association for Overseas Technical Scholarships (AOTS). Mr. Sommai Huntrakul, who later became Finance Minister, was the president of the TPA Committee. The TPA was supported by Professor Goiji Hosumi, the former president of the board of the Japan-Thailand Economic Cooperation Association. Despite receiving Japanese support, the TPA's internal management was conducted solely by Thais. The purpose of the TPA is to be the center for promoting knowledge, and disseminating and transmitting new technology to Thai personnel for the growth and advancement of the Thai economy and industry. The TPA received donations from Japan without any pre-conditions to manage the operation of the TPA for 36 years. The donations stopped in the 2009.

The TPA has five main activities:

1) Training, seminars, consultancy, especially for SMEs. The most notable program is the 'industrial doctors' (shindan sha) developed in cooperation with the Department of Industrial Promotion (DIP);

2) Language and cultural school, offering Japanese, Thai, English, and Chinese courses;

3) Calibration and metrology services conducted by mostly Japanese-trained Thai staff-mainly for private companies (some being automotive assemblers);

4) Publication on technology and quality (30-40 volumes/year);

5) Web-based training and certification, especially for skilled technicians.

The TPA's total revenue is around 450 million Baht (around 15 million US$). The main sources of revenue are from language and cultural school, seminar and training, consulting, and calibration.

6.2. Thai-Nichi Institute of Technology (TNI)

Based on industrial experience gained from many consulting projects, the TPA wants to distribute this knowledge to new generations. It therefore established TNI in 2005 to provide education in order to develop people with specialized technological knowledge to work in Thai industries. Financially, TNI was started with funds from TPA (around 50 million baht or 1.6 million US$). The rest (150 million Baht or 5 Million US$) had to be borrowed, with the TPA offering guarantees, Donations also came from Japanese companies through the Japanese Chamber of Commerce, and as direct support from some Japanese companies in Thailand such as Toyota and Honda. The objectives of TNI are:

- To provide education at undergraduate and graduate levels in the fields of science, technology, social sciences and humanities, focusing on practical knowledge
- To be a leading academic institute in the area of research and development, and to create modern knowledge continuously
- To be a center of competent academics and consultants of the nation as well as to promote cooperation of high level knowledge research, to strengthen the role of researchers in creating enterprise and industry in Thailand
- To transfer technology from Japan and other countries by linking with academic institutes, governmental and private organizations in Japan and other countries so as to create cooperation by exchanging in terms of experts, research and development programs, educational training and study tours to other countries
- To provide academic services to society, such as short-term courses, training, consultancy for industrial entrepreneurs as well as the exchange of knowledge in technology with entrepreneurs, administrators, engineers and industrial technicians
- To encourage activities which help preserve the arts and culture of Thailand and Japan

Japanese firms also provide almost all the scholarships and the equipment and infrastructure of TNI.

TNI offers bachelor's degrees in engineering, information technology and business administration, and a master's degree in business administration. The bachelor's degree in engineering offers majors in Automotive Engineering, Production Engineering, and Computer Engineering. For the Automotive Engineering major, the course structure is developed from a Japanese Automotive Engineering course structure and from Chulalongkorn University. TNI also offer Japanese courses to its students. The program focuses on the practice based work. TNI also plans to offer a doctoral program in future.

6.3. Resources

The TPA is now financially independent (from the Japanese) and has around 300 full time and part time employees. TNI has accepted around 1000 students in total every year, which make the total number of students currently studying in TNI around 5000. The first group of graduates was 73 people and al worked or pursued further degree in Japan after their graduation.

6.4. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

The TPA provides consulting services (the famous Shindan sha Program) to medium and large-sized local firms. The majority of the consulting projects are done with the Department of Industrial Promotion (DIP) as the direct customer. DIP assigns the TPA to provide consulting services to local SMEs in Thailand to improve their productivity and efficiency. The type of consulting mainly uses Shindan (industrial doctors) to diagnose the problems faced by a company and subsequently arrange further problem solving projects if the firm wants them.

TNI has very strong connections with 24 Japanese firms. TNI received donations from Japanese firms through the Japan Chamber of Commerce without any pre-conditions. The donations have been so large that TNI has had a positive income since its first year. In addition, TNI also received extra funding from Japanese firms in terms of scholarships, equipment, machines, infrastructure, etc. With these strong connections, the majority of TNI's students do their internships with universities and companies in Japan.

TNI also has plans to provide consulting and training services to firms although this project is still at an early stage.

Through TPA's long training and consulting experience with private companies, TNI has high potential to be a very industrially oriented university. This will differentiate TNI from other Thai universities. At present, however, TNI and TPA are not working very closely together, although the aspiration does exist to systematically link the two together. TNI has just started up and is currently focused on drafting its curriculum and structuring its internal management.

6.5. Results of Linkages

Following consulting projects by TPA, local firms have gained benefits in terms of reducing cost, improving product and process quality, and also enlarging market size.

In the case of TNI, students have opportunities for internships in firms in Japan, due to the strong linkage that TNI has with the firms. Many students also work with Japanese firms after graduation, because of this connection.

6.6. Obstacles to Linkages

One problem that TPA faces is its customer. DIP is the TPA's largest customer. Since DIP is a government body, DIP's decisions on whether to hire TPA or not can be changed from year to year according to its budget. This situation makes the income of TPA very volatile.

6.7. Policy related issues

It is quite obvious that government should support a private association like TPA to act as intermediary and technical provider to companies. The support of government should be firm and continuous. A private university with hand-on knowledge and experience such as TNI should also be promoted. It should be held aloft as a successful model of developing a private education institute with strong linkages with industry. Government support programs in higher education should also integrate initiatives in setting up private higher education institutes. Government promotion for excellence of public higher education institutes should support and leverage initiatives of the private sector, rather than alienating them.

7. NSTDA - Tokyo Tech - KMITL

7.1. Background of Tokyo Tech

Tokyo Institute of Technology (Tokyo Tech) was established by the Japanese Government in May 1881 as the Tokyo Vocational School, then was renamed Tokyo Technical School, Tokyo Higher Technical School, and then became Tokyo Institute of Technology in 1929. Nowadays Tokyo Tech provides undergraduate degree programs in Sciences, Engineering, and Bioscience and Biotechnology, as well as graduate degree programs in Science and Engineering, Bioscience and Biotechnology, Interdisciplinary Science and Engineering, Information Science and Engineering, Decision Science and Technology and Innovation Management. As of May 2008, Tokyo Tech has 1,719 staff, 4,911 undergraduate students, 3,448 master's students, and 1,566 doctoral students. From these, 1092 students are international students from 77 countries. Tokyo Tech also has academic cooperation agreements with around 30 countries all over the world, including Thailand.

7.2. Background of Joint Program in Automotive Engineering between Tokyo Tech, National Science & Technology Development Agency (NSTDA), and KMITL

The joint degree program in Automotive Engineering started when Tokyo Tech set up an office in NSTDA. It was willing to have a collaboration agreement with Thailand because of a change in the Japanese university funding system, where one criterion for funding is to have an international linkage. At that time, Tokyo Tech approached NSTDA because NSTDA had infrastructure, labs, and was also doing research, so it would be beneficial for NSTDA and Tokyo Tech to offer a 2-year master's degree program. Students could use the labs at NSTDA and NSTDA could also have research assistants. However, there is a condition that NSTDA must provide scholarships, including tuition fees and living costs, to all students. Tokyo Tech and NSTDA decided to start with 2 programs – Automotive Engineering and ICT.

Because NSTDA is not an educational institution, it cannot under Thai law grant degrees. Therefore, they need to partner with the university. For the automotive engineering program, NSTDA made an agreement with KMITL and for the ICT program with King Mongkut's University of Technology Thonburi.

Students who want to follow a program must apply through a Thai university, which is KMITL for the automotive engineering program. Professors are from both Tokyo Tech and KMITL. Professors from Tokyo Tech will come to Thailand using their funding and teach block courses in Thailand. Students will learn not only the theory but also from the experience of the professors from Tokyo Tech, because professors from Tokyo Tech have tremendous experience working in the automotive industry before becoming professors.

In this program, the first year lecturers come from both Tokyo Tech and KMITL. In the second year, students need to do research with advisors from all 3 parties – Tokyo Tech, KMITL, and NSTDA. There is no internship in this program, but students need to work with NSTDA. The research topic can be anything related to the automotive industry, which is very broad and includes almost all functions such as materials science, industrial engineering, mechanical engineering, energy, electrical and electronics, and communication.

The first group of students started their program in 2007. However, many students dropped out during the first year due to KMITL's management system and the English language barrier. KMITL solved the language barrier problem by requiring that students must be able to communicate in English in order to be eligible to enter into the program. This greatly reduced the English problems of new students.

KMITL also wants to expand the program into PhD degrees, but the interviewee from KMITL believed that it is hardly possible for this to happen because from this master's degree program, Tokyo Tech gain benefits because they can cream off top students to study for PhDs with them in Japan.

7.3. Resources

Currently, there are around 30 – 40 students in the program. There are only around 10 graduates as yet but this number is expected to increase significantly this year because the first year will reach the deadline of its 4-year study time limit. KMITL assigns professors from mechanical engineering to teach this program, involving around 20 people.

7.4. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

The linkage between this program and the industry are mainly through the theses that students have to do in their 2nd year. The topic of the research usually comes from projects that NSTDA researchers are working on. Currently, most students are working in topics related to materials science with researchers in National Metal and Materials Technology Center (MTEC). Another group is working on engine tests, and alternative fuels such as ethanol. A final group is working with National Electronics and Computer Technology Center (NECTEC) on control systems. An example of the research is the design of component parts and interior parts. However, the direction of NSTDA's research has recently shifted to electronics and electrics so the researches of new groups of students will focus more on electrical and electronic systems and related projects.

Graduates from this program usually work in the automotive industry, research institutes or pursue a higher degree. Examples of positions and employers of the graduate are as follow:

1. Mr. KeerasutSuttanarak. Currently working in Engineering IT, DENSO Insternational Asia Co., Ltd.
2. Mr. SakdaThongchai. Currently working as a coordinator/assistant researcher at The Joint Graduate School of Energy and Environment (JGSEE), King Mongkut's University of Technology Thonburi
3. Mr. YokNusom. Currently working as an engineer at ECO-Products Development Laboratory, MTEC
4. Mr. ManopMasomtob. plans to study for a doctoral degree in Germany
5. Mr. WatcharapongSirikul. Currently working as an engineer at Kijjak Co., Ltd.

7.5. Results of Linkages

The result of the linkage from this program is in the form of the research. Because the thesis topic comes from the projects that researchers at NSTDA are working on, the result of the linkage is in the form of the progress of the research. But the effect on the automotive industry is dependent on how NSTDA researchers utilize these results.

7.6. Obstacles to Linkages

The problem that this program is facing is that most projects are problem solving, not pure research projects. Therefore, it is hard for students to use it as a master degree thesis. Therefore, the first group of students had to direct their research into the energy field, instead of direct automotive engineering.

The second problem is that this program requires students to have published something in order to graduate. However, the professors from Tokyo Tech are not available all the time. They only come to Thailand for about 2 weeks, which makes it hard for students to get in-depth advice. Moreover, the research projects that are mainly problem solving projects are hard to turn into the publications due to the characteristics of the research and the need for confidentiality.

Another problem is that the funding from NSTDA to provide scholarships to students is drying up. Based on the plan, the responsibility to fund this program will be shifted from NSTDA to National Science, Technology, and Innovation Policy Office (STI) but STI has no interest in automotive engineering and mainly prefers to collaborate with France and Germany. The change may affect this project as well as the relationship between Thailand and Japan. Tokyo Tech has also changed their president and if the financial results are poor, Tokyo Tech may decide to change their direction.

7.7. Policy Related Issues

1. Continuous government financial support for such a good program which has enabled Thai universities to leverage the knowledge of a leading Japanese counterpart should be institutionalized.
2. Apart from the thesis, there should be an independent-study option for master's students focusing on problem solving for Thai automotive suppliers. Of course the study must make an academic contribution to meet the requirements of a master's degree.

8. National Science and Technology Development Agency

8.1. Background

National Science and Technology Development Agency (NSTDA) was created by the Science and Technology Development Act of 1991 to conduct, support, coordinate, and promote efforts in scientific and technological development in the public and private sectors. NSTDA consists of 5 centers – the National Center for Genetic Engineering and Biotechnology (BIOTECH), the National Metal and Materials Technology Center (MTEC), the National Electronics and Computer Technology Center (NECTEC), the National Nanotechnology Center (NANOTEC), and the Technology Management Center (TMC). One sector that is in the focus of NSTDA is the automotive sector.

8.2. Development of NSTDA's Automotive Cluster Program

The Automotive Cluster Program at NSTDA was initiated in 2003 as a top-down policy of the Thaksin administration. It aimed to enhance the competitiveness of Thailand in certain sectors such as food, fashion, medical services, and automotive engineering, along with the capability to develop the industry. At that time, design was perceived as the weak point of the Thai automotive industry. Considering its resources, NSTDA and its network had the potential to research and improve the capability of the firms in finite element design, casting, stress treatment, spray hardening, etc., thereby improving the Thai automotive industry. The private sector also played a role in development of the automotive cluster program at NSTDA, through the Thai Automotive Institute.

8.3. Resources

The automotive cluster program has around 30 full-time equivalent employees. Most full time staff are engineers with a bachelor's and/or master's degree, mainly in mechanical engineering. The automotive sector of NSTDA also has fewer than 10 PhD employees, who are mainly in middle and top management positions. However, if all partners and all nodes are included, there are more than 100 people involved in the automotive sectors. Partners mentioned here consist of employees of the Thailand Automotive Institute and professors from universities such as Chulalongkorn University, Thammasat University, King Mongkut's University of Technology, North Bangkok, King Mongkut's University of Technology, Thonburi, and King Mongkut's Institute of Technology, Ladkrabang

8.4. Mechanisms and Strength of Knowledge/Technology Linkages with Firms

At the time when the automotive cluster program was set up, NSTDA provided training in basic finite elements to new employees of the Toyota Technical Center Asia Pacific (TTCAP), before they went for training in Japan. However, this training was only a one-time event because after that Toyota conducted its own in-house training based on this course. After that, this finite element team has spun off to become an "incubating" profit center under the name "Design and Engineering Consulting Center (DECC)" to provide finite element consulting and training to all industries, not specifically to the automotive industry. Their main income comes from consulting projects. For the automotive industry, DECC mainly provides services to local firms, mostly in the 2nd and 3rd tiers. NSTDA has provided about 20 million Baht (or around 1.3 Million US$) as a seeding fund for DECC. Currently, DECC is still under incubation due to financial constraints. One reason that DECC is still under the care of NSTDA is that the head of DECC is a professor, and does not fully push the organization as a for-profit business.

Besides DECC and finite elements, NSTDA have also done research in control systems and Electronics Control Unit in NECTEC and also the Intelligent Traffic System (ITS) which aims to increase driving safety and make driving more efficient. One example of the products coming from these labs is the Governor Box (G-Box) that records the speed and the location of the vehicle, and which can be used in a gasoline tanker, for example, to track if the drivers drive off their route and sell gas to other people.

Recently, NSTDA was awarded a contract by TTCAP to carry out research on making interior parts from natural products and used tires. NSTDA got the contract because of its infrastructure, such as labs. TTCAP provides all the funding and NSTDA provides the labour. This project just started last year and is still active.

Even though there are many projects with Japanese car makers the relationships are not going as well as they might because NSTDA does not serve them well enough and also cannot meet their needs in every aspect. However, the relationship between NSTDA and Thai SMEs is much better and the relationship is a long-term one because the local firms have to rely on the ability and infrastructures that NSTDA has. Additionally, the local firms and NSTDA have complementary knowledge. Local firms have years of experience based on trial and error, while NSTDA has in depth knowledge of theory. Based on previous projects with local firms, the absorptive capability of the local firms is not a constraint for the firms to improve their technology.

Beside the direct relationship that NSTDA has with the firms, it also has an indirect relationship with the firms through universities. NSTDA provides scholarships and funding to universities, if the universities have consulting projects with firms. However, not many projects have been submitted for this funding because professors have to rely heavily on the number of their publications for their career progress.

Additionally NSTDA also tries to develop the capability of universities to help the automotive industry. Besides funding, NSTDA tries to develop each university to become a center of excellence in specific areas to assist with particular problems such as Kasertsart University for tires, King Mongkut's University of Technology North Bangkok for molding, and Chulalongkorn University for surface treatment through the Thai-German Institute (TGI). Based on this plan, each university not only knows their own specialty well, but can also refer to other centers when their customers have problems.

8.5. Results of Linkages

The results from the consulting projects that NSTDA and universities provide for firms include lunching new products, reducing defects and costs and increasing productivity. Many firms have been able to move from no tier to 3rd or 2nd tier because they could improve their quality to the level of the firms in the tier.

An example of product improvement from the consulting projects done by NSTDA is the work that NSTDA has done with Thai Rung, a local 1st tier firm. NSTDA has worked on projects with Thai Rung to develop a limousine and also an armoured car as a future project.

8.6. Obstacles to Linkages

The first obstacle that NSTDA faced during the start-up period was the unclear mission of its automotive cluster program. At that time, NSTDA was asked (by government) to strengthen the automotive sector, with no clue on how to start or what could be improved. NSTDA solved this problem by consulting with the Thailand Automotive Industry Association and firms in the industry.

Currently, one key obstacle is that Japanese carmakers do not want to do research with NSTDA. NSTDA have tried to deal through the Thai management team of those companies but this did not work because the Thai management team of a Japanese car company is not a prime decision maker. The management team also does not know the details of research and design. They just know the broad picture. When talking with the employees in the plants, employees said that design is done from headquarters in Japan. The R&D department in Thailand is only responsible for fine-tuning and problem solving projects, not the core design of the part or the car.

Although NSTDA had many projects with Toyota in the past, the relationship between NSTDA and Japanese carmakers worsened because NSTDA did not treated them well enough and could not serve their needs. For example, Japanese carmakers asked NSTDA to do quality checks when there was a quality problem in the R&D process but NSTDA ignored them. These issues significantly affect the trust that

Japanese firms have in NSTDA. As a result, Honda does not want to deal with NSTDA and Toyota barely has business with NSTDA at present.

The NSTDA's project to provide funding to universities to support the firms also has problems. First, not many projects have been submitted for this funding because this research cannot be used to show the academic progress of the professors. In Thailand, professors' progress is measured through the number of their publications. However, these firm-supporting projects are hard to turn into publications due to the characteristics of the research and to its confidentiality. Additionally, when the funding is withdrawn, all projects and initiatives of the universities are stopped. This year NSTDA has a limited budget so it has decided to provide funding to only internal researchers.

Intellectual Property Rights (IPR) are also a problem. NSTDA prefers to have a co-research project with a firm because it measures its performance by using the number of patents filed, but the firms prefer to keep new ideas as trade secrets. Moreover, the patent application process is also slow.

The last problem is an internal problem of NSTDA. The direction of NSTDA lies in the person, not the institution. Recently, there has been a change in the organization structure of NSTDA, eliminating the automotive sector. The automotive industry reacted strongly toward this issue and it is still under discussion.

8.7. Policy related Issues

1. The mindset of the management team of NSTDA need to be changed in order to make them interested in the automotive industry. This can be done if the government sends a signal to NSTDA that the automotive industry is still a focus industry. Government might also make the National Science, Technology and Innovation Policy Office, the supra-ministerial body responsible for science, technology and innovation issues, focus more on the automotive industry. In addition, because the government structure in Thailand is a "silo" structure, the information flow between each government organization (for example between the Ministry of Industry which is responsible for automotive sector development and NSTDA) is very difficult.

2. To the performance measure for professors in the universities should be changed. Instead of measuring the number of publications, the measurement should e also take account of the impacts they can create in the industry.

9. Thai Auto-Parts Manufacturers Association

9.1. Background

The Thai Auto-Parts Manufacturers Association (TAPMA) was created with approval from the Ministry of Commerce on June 29, 1978. It is an association of auto parts manufacturing companies from the private sector, and aims to serve as the central voice for auto parts industrialists in the country in order to protect, support and develop Thai industries. TAPMA was also created to detect and address problems that hinder the automobile industry's development in terms of production technology efficiencies, raw material import difficulties and workforce challenges, especially attracting and developing skilled labourers and engineers.

9.2. Purpose of TAPMA

1. Support production enterprises in the automobile parts, components and tools industries, by partnering with the government for support
2. Support members by tackling problems and negotiating on behalf of members to establish common benefits for their enterprises and the sector as a whole. Monitor and follow the movement of the parts, equipment, tools and accessory markets, domestically and abroad, for the benefit of the country's economy and finances
3. Research the latest technical and production developments for parts, equipment, tools and accessory enterprises, and exchange and publicize this knowledge and news to members

4. Request from members statistics, documents or information concerning their enterprises, including parts, equipment and accessory projects with explicit permission from individual members
5. Support members in producing quality auto parts, equipment, tools and accessories that meet or exceed international standards and support production of these components to fulfill market demand. Also support research into and improvements in production and marketing processes
6. Enter into agreements for members detailing their roles (including do's and don'ts) in operating smooth and problem-free manufacturing plants for parts, equipment, tools and accessories
7. Negotiate and resolve conflicts between members, and between members and outside parties
8. Promote occasional harmonious and non-political sporting and social events
9. Engage in charitable activities for society and support members with welfare within the parameters of Act 22 under the 1966 Commercial Association Decree

9.3. Resources

Currently TAPMA has 528 companies on its membership list. Its members consist of all firms in the automotive parts and related industries, from 3rd tier to 1st tier.

9.4. Mechanisms and Strength of Knowledge/Technology Linkages

TAPMA is more like a lobbyist group, seeking favor from government. Its role as intermediary, connecting members to other actors in the automotive sectors, is rather limited. However, the association recognizes three major challenges that Thai automotive part manufacturers are facing. In the short term, reducing weight and reducing cost of their products is the key. In the medium term, the focus is on CO_2 emission and carbon footprint. In the long term, the automotive parts industry needs to adjust themselves for the new technology car such as electric and Hybrid cars. TAPMA and all its members need to carry out continuous R&D in order to cope with these challenges. Their linkages with universities or government organizations are effected by each individual member, not by TAPMA, except on those issues related to government policy and government intervention. TAPMA also links with international automotive-related organizations in order to initiate projects or create trust in the Thai automotive parts industry. An example is setting international standards for automotive parts.

Another project is to increase the competitiveness of the Thai automotive parts industry. The current project is to set up product/process champions. At present the Thai automotive parts industry produces almost every part, and has used all processes, without a clear understanding of which products or processes the industry is good at. It is essential to identify special advantages and then ask for help from the government to initiate a policy of supporting this process/product champion.

9.5. Results of Linkages

The result of TAPMA's linkages with government bodies should be seen in terms of government policy to support the Thai automotive parts industry, rather than directly in the increasing technological capabilities of its members. An example of a result of the linkage is the setting of a domestic and international standard for automotive parts.

9.6. Obstacles to Linkages

There are some uncomfortable feelings between TAPMA and TAI (The Thailand Automotive Institute). Sometimes TAI does not like TAPMA's direct engagement in government projects, bypassing TAI. In terms of the relationships with universities that members of TAPMA have, the key obstacle is the different perception of the level of service that each party expects and receives. The industry wants universities to be total solution providers, while the universities limit their roles only to testing (of automotive parts sent by parts manufacturers) and providing services under limited scope.

9.7. Policy related Issues

These policy issues are mainly developed from what members of TAPMA say about what they expect the government to do.

1. Universities and government organizations should become solution providers or problem solvers, not only test and service providers because that is what the industries need and the universities and government organizations have better knowledge and infrastructure than the firms.
2. Each university should have an area of expertise, and someone should map the various areas of expertise to show which organization is an expert in each process or product. Currently the firms do not know who to go to when they have a problem.
3. The implementation of the tax reduction policy should be improved. Even though the government provides tax incentives for R&D projects done with or by the universities, the process of proving that this expense is for R&D is very difficult, and takes a very long time.

There is also an issue of the division of labour, and collaboration between a public intermediary like the Thailand Automotive Institute (TAI) and a private intermediary like TAPMA

10. The Somboon Group

10.1. Background

The Somboon Group is one of the biggest 1st and 2nd –tier automotive parts suppliers in Thailand. It was established in 1975 and aims to be to be a leader in automotive parts manufacturing in the ASEAN region, providing end-to-end services, and growing alongside its customers. 2007 sales were almost 6 billion Baht (or 200 million US$) and sales grew by more than 10% in every year since 2003. The Somboon Group consists of 4 companies; Somboon Advance Technology Plc (SAT), Bangkok Spring Industrial Co., Ltd. (BSK), Somboon Malleable Iron Industrial Co., Ltd. (SBM) and International Casting Products Co., Ltd. (ICP). Examples of major customers are Auto Alliance, Dana, GM, Hino, Honda, Isuzu, Kubota, Mitsubishi Motors, Nissan, Toyota, and Yongkee.

SAT is a leader in drive shaft production in Southeast Asia, with factories in Samutprakarn and Rayong. Both factories are equipped with fully automated robots and advanced computer numerical control (CNC) machine lines and simulation systems software for bending fatigue testing in product development. SAT also has advanced testing machines, such as Static Torsion Testers, Rotation Bending Testers, and Fatigue Testers. The products that SAT produces include rear axle shafts, and inner shafts. Production in 2007 was almost 2.5 million pieces.

BSK has been operating for more than 45 years and produces leaf springs, coil springs, and stabilizer bars. BSK has the equipment with the latest technology for the production of high stressed and side force, left/right turn, high quality coil springs to serve all customers. BSK also produces high stressed solid stabilizer bars using fully functioning automatic hydraulic bending machines.

SBM and ICP have long experience as a ductile and grey iron casting foundry. Their main products are brake drums, brake discs, hubs, exhaust manifolds, flywheels and brackets. Their products are tested by full inspection in/out process lines, X-Ray, chemical composition evaluations, tensile strength testing, dimensioning by coordinate measuring machine (CMM) equipment, finishing surface, and roundness checking of parts surfaces.

10.2. Resources

As of 2007, the Somboon Group had more than 2000 employees. Almost 700 employees worked for SAT, 450 for BSK, 750 for SBM, and 250 for ICP. Sales in 2007 were almost 6 billion Baht (or 200 million US$) of which the majority share came from SAT and SBM.

10.3. Technology Linkage with Suppliers and Customers

The Somboon Group outsources around 10-15% of its work to 3rd tier suppliers in order not to have to invest in some processes. In general, the suppliers have a quality and delivery problem. When the quality is not available, their products cannot be delivered. The Somboon Group helps these suppliers by sending engineering teams to their factories to help them find and fix their problems, such as with moulding or surface hardening. Overall, about half of the suppliers need this type of help from the Somboon Group.

The Somboon Group also helps its customers with technical problems. It aims to be a solution provider for customers. An example case involves brakes. Recently, there were more claims from the end users to the carmaker that their car was shaking when the brakes were used. The manufacturers of all parts of the brake system said that they had produced according to the blueprint. The car makers who assembled the brake by themselves, such as Mitsubishi and Honda, told the suppliers to figure out what the root of the problem was. The Somboon Group did the testing and provided a solution to their customers.

10.4. Mechanisms and Strength of Knowledge/Technology Linkage with Universities

The Somboon Group has many kinds of linkage with the universities and government organizations. One approach they have used is to hire a professor from a university as a consultant in a particular topic, such as mechanical design. The firm can gain knowledge through both the consulting and from the provision of training by the professor.

In terms of institutional relationships, most of the linkage projects are in testing and services where the relationship is loose and is conducted on a point-by-point, project-by-project basis without follow-up projects. An example is sending products to MTEC for testing. A better example is the case where the Somboon Group hired a professor at KMUTT to do research on surface hardening and casting of the mixture of aluminium and other metal to produce disc brakes. The best example, which is rare, is the relationship with Chulalongkorn University (CU). At that time, the firm imported the first low-pressure wheel-making machine into Thailand but no one knew how to make the moulds for low-pressure machines. A CU professor engaged fully in this project and the result was very successful.

The university network is also not formed. Most of the time, the consulting and service projects are one-time projects. Even though the firm may have another associated problem, there is no reference from one professor to another. Such a referral has happened only once but this was based on a personal contact that that professor had.

Measuring in terms of budget, only around 1-2% of the R&D budget that the Somboon Group spends annually is on relationships with universities and government organizations.

The Somboon Group also has technical relationships with international organizations. There are three cases of international technical linkages. The first case was about a couple years ago when a Japanese partner recommended that the firm conduct training using one professor from Osaka University. Another case was when the firm used a consulting service from an international organization. The consulting service was mainly in the form of email communication, and sending products for testing. The other type of relationship is hiring other firms for their technical advice

(TA), such as asking for help when the firm was developing a new process. However, these relationships are only advisory, not doing joint research. The TA relationship is, however, a long-term relationship. The Somboon Group has set up a team just to work with this TA in order to maximize knowledge transfer. However, the knowledge transfer method is mainly through on-the-job training, which is mainly an experience transfer.

Around 2 years ago, the Somboon Group decided to stop using TA and invested in spring design and production by themselves because the TA service was not satisfactory. At that time, customers worried about whether the Somboon Group could succeed or not. At the end, they succeeded, and now plan to provide TA to other firms in other countries who used the TA services from the same firm as the Somboon Group used before. However, since they stopped using the TA service, the linkage that the Somboon Group had with their Japanese customers has also gone. Therefore, the Somboon Group is planning to set up an office in Japan to develop closer relationships with the customers.

10.5. Results of Linkages

Because most of the linkage the Somboon Group has with universities and government organizations are in the term of testing services, their results are the testing results. However, there are some projects where the group contracts out research to universities, and obtains new processes that can solve existing problems.

10.6. Obstacles to Linkages

With its suppliers, there are no major problems, since Somboon normally outsources to long-term and trusted suppliers. If new processes are required and problems arise, Somboon can send in its engineering teams.

With universities, the key obstacle is that the firm and the universities do not understand each other. The Somboon Group believes that the professors in the universities have the knowledge and capability to do more than just the provide a testing service, and are eager to have long-term relationships with the universities to do research, such as modifying processes when using the metal from India which has a different composition, or design the processes and products for cost and weight reduction. But usually the universities do not know what the firm wants, and the firm does not know what level of service the universities and government organizations want to offer.

Frequently recommendations from the professors cannot solve actual problems. This is because professors provide upstream, purely theoretical, knowledge, and do not know how to apply it to industry. A middleman is needed who can transform the upstream knowledge into an industrial application. Also, most professors only want to disseminate their existing knowledge, but do not want to fully participate in problem solving with the firm.

Finally, the firm does not know who to go to for each type of problem. All universities have broad knowledge and overlap with each other, and only some organizations are clear about what they are good at such as MTEC or DECC.

10.7. Policy related Issues

1. Universities and government organizations should consider becoming solution providers or problem solvers, not only providing testing and services. This is what the industry needs, and the universities and government organizations have better knowledge and infrastructure than the firms.
2. Each university should have an area of expertise, and someone should make an expertise mapping to show which organization is the expert in each process or product. Currently the firms do not know who to go to when they have a problem.
3. Thai industry needs more metallurgists. Currently it is hard to find metallurgists, especially those able to do process design. Even someone who knows the process usually knows only the injection process, not all processes. If we look at global trends, there is a move toward polymers. However, Thai industries are not there yet, and metallurgists are still needed. Therefore, the universities should develop more metallurgists to serve the industry.

4. Industries in Thailand usually talk about the broad picture, and want to do everything, but do not focus on any particular process. If there were a focus on a product champion, a process champion, or even a raw material champion and all parties agreed, relationships would be better.
5. A training center should be set up as a joint effort by the universities and the machine producers. Such a project has happened in Japan. In one area, where there is no machining, the universities set up a training center and the machine manufacturers provide machines for the center. The firms in that area can train in the new technology and new machines, and the machine manufacturers can sell their machines to these firms.
6. Thai universities should focus more on research that applicable to industry. The Japanese model can be used here. The Japanese public universities get funding only if they do research with industry.
7. Implementation of the tax reduction policy should be improved. Even though the government provides tax incentives for R&D projects done with or by the universities, the government's process for proving whether the expense of the firm really was for R&D is very difficult and time consuming.

11. Policy Recommendations

To strengthen the linkage among the industrial communities, universities, and agencies supporting the automotive industry in Thailand, policy recommendations can be integrated addressing the strategic issues for agency and institutional context development.

The policy recommendations supporting agency development can be emphasized in three areas as described below:

a. Awareness and Commitment: there should be a central agency playing strong roles as a conductor or intermediary, to link all parties representing industrial communities, universities, and research institutes together. This agency should be able to rally support and engagement from the members. The strategic objectives and actions of this agency should focus on mission-driven rather than activity-driven work.

b. Capability: the authority of the central agency should be clearly defined and funding should be sufficient to support the mission. This would allow the agency to take the initiative and lead the industry instead of simply proposing ideas, then seeking financial support before starting work. As a result, the agency could maintain its leadership position. Where the agency may lack expertise or resource, it should seek cooperation with other private agencies.

c. Incentive: to effectively utilize this policy, incentives should be provided to encourage an individual to actively engage in industry development as well as to promote collaboration among the members. For example, the performance of a researcher or university faculty member should be measured with proper key performance indicators (KPIs) and the incentive should be set based on the practicality of knowledge uses rather than academic output. Moreover, special tax benefits should be provided for the case where more than one party is involved in the activities.

The policy recommendations supporting institutional context development can be emphasized in two areas as described below:

a. Trust: this is the fundamental element needed for all parties to work together. To strengthen trust, the role and authority of the central agency should be clearly defined, and the agency must actively engage in driving the mission to lead capability development in the industry. Trust between or among party members should also be developed. The basic understanding of the priorities and limitations of each party is very important. For example, universities should be aware that "delivery time" is a critical factor for an industry. On the other hand, industry should also be aware that, in many cases, the limitation for universities is "resource mobility and funding". To avoid misunderstandings and conflicts between the parties, more opportunities for personal exchange should be initiated, so that members of each party can learn from each other from the direct experience being a part of one another.
b. Regulation: it is critical that regulations should be flexible and rapidly adjustable to match industrial and technological changes. The roles of an agency in charge of implementing regulations should shift from solely being a regulator to becoming both a regulator and promoter. The effectiveness of regulation implementation should be measured from result-based rather than activity-based indicators.

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CHAPTER 2

Innovation in the Indian Automotive Industry: Role of Academic and Public Research Institutions

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While the story of India's economic growth over the last twenty years is well known, it is often explained as a services-driven phenomenon. However, some manufacturing sectors have played an important role in this economic growth, and the automotive sector is prominent among them.

The automotive sector's contribution is not only in terms of revenues, profits, taxes and employment, but more importantly in quality processes, efficiency improvements, and product innovation. This dynamism has been seen across the sector – in the commercial vehicles, utility vehicles, cars, two-wheelers and automobile component industries. According to a study by the Confederation of Indian Industry, quality defect rates in manufacturing dropped from as high as 12% in 1998 to 100 ppm in 2008[i] *– the Indian automotive sector which was at the vanguard of the quality movement can legitimately take credit for this substantial improvement. Companies across the automotive sector spectrum have won prestigious Deming and JQM awards.*[ii] *The automotive sector is the most prominent location of product innovation in Indian manufacturing. It accounts for the second highest aggregate spending by industry on research and development, following only the pharmaceutical industry.*[iii]

In this paper we seek to understand the drivers of innovation, corporate innovation strategies, and more specifically, the role of academic and public research institutions in the innovation profile of this sector.

Indian Automotive Sector: A Historical Perspective[iv]

In the early years after India's independence in 1947, the government of India under Prime Minister Jawaharlal Nehru adopted a strategy of creating heavy industry under a planned economic development process. While the automobile industry was already recognized by that time as a mother industry that could create positive externalities across the economy, India deliberately under-emphasized the car industry (which was seen as providing private transportation for the rich) and instead encouraged the creation of manufacturing capacity in trucks and buses. Two important companies that are prominent players to this day – Ashok Leyland and Tata Motors (then Tata Engineering and Locomotive Company Ltd. – Telco) were set up in the 1950s with collaborations with Leyland and Mercedes Benz respectively to create the beginnings of a medium/heavy commercial vehicle industry. A limited car production capacity was also set up subsequently by two companies – Premier Automobiles and Hindustan Motors. Ancillarisation was encouraged in the 1960s and a number of companies producing automobile components were set up at this time, usually through foreign collaboration. Under the then industrial policy, foreign players could not enter the Indian market on their own in either the end product or the intermediate stages – hence they were willing to provide technical collaboration and assistance to Indian players.

The automobile industry grew slowly in tune with the "Hindu rate of growth" of the economy. Lack of competition (the government did not encourage the entry of new players), foreign exchange controls, industrial licensing, and the Monopolies and Restrictive Trade Practices Act together removed any incentive or pressure to improve either operational efficiency or do much product-related innovation. The most visible form of this was the Ambassador car model of Hindustan Motors that remained largely unchanged for almost 30 years.

The Indian automotive sector came to life only after the entry of Maruti Suzuki Ltd. with its small car Maruti-800 model in 1983. Maruti Suzuki came about as a joint venture between Suzuki Motor Company of Japan and the Government of India. Maruti Suzuki was started as a means to fulfill the dream of Sanjay Gandhi, son of then Prime Minister Indira Gandhi, to build a people's car. After his sudden death in an air crash, the government decided to enter the automobile business in the form of what became

Maruti Suzuki. While the excitement at that time was around the fuel efficiency, low cost and aesthetic looks of Maruti's small car product, looking back from the vantage point of 2011 it is clear that the entry of Maruti transformed the Indian automotive sector.

Maruti not only brought in better manufacturing practices in its plant, it also ushered in Japanese quality management systems. While Suzuki brought in some of its own vendors to supply components for the Maruti car, existing component manufacturers in India had to upgrade their manufacturing processes, improve efficiency, lower costs, absorb new technologies and put in place systems for continuous improvement if they wanted to do business with Maruti Suzuki. The success of Maruti's products in terms of reliability and re-sale value reinforced the importance of quality and, by the late 1980s, India's most prominent industry association, the Confederation of Indian Industry (CII), initiated the quality movement in India.

The automobile industry soon became the arena for the first significant steps in deregulating the Indian economy with the government deciding to allow broad banding of industrial licenses (companies could now decide their product mix within the overall quantities they were permitted to produce) in the automotive sector. In parallel, the government encouraged the entry of new technology and new players into the two-wheeler and light commercial vehicle industries. Thus, in the 1980s, Honda, Suzuki, Yamaha and Kawasaki got involved in the Indian 2-wheeler industry, and Toyota, Mazda, Nissan and Mitsubishi entered the light commercial vehicle (LCV) industry through joint ventures.

The entry of these new players galvanized these industries, but not necessarily in favour of the new entrants. In the light commercial vehicle industry the eventual winner was the incumbent Telco, which used the broadband policy to enter the light commercial vehicle business, and then came up with products that were much more suited to the Indian environment in terms of ruggedness and serviceability. The Indo-Japanese LCV players lost out as their products became more expensive due to progressive hardening of the Yen vs. the Rupee and their failure to rapidly indigenize their products. In the motorcycle industry, one player, Hero Honda (a joint venture between Hero Cycles and Honda Motor) became, over time, the winner of the mass market, while, an incumbent, Bajaj Auto, came back into reckoning in the executive segment post 2000. Most noteworthy about Bajaj Auto's performance was that its most successful motorcycles were designed not by its technology partner Kawasaki, but by the Bajaj Auto team itself.

The car industry changed after the economic liberalization process gathered momentum in the early 1990s. Ford was the first to enter through a joint venture with Mahindra & Mahindra, but the Escort model they launched was already being phased out of other markets, and it did not make much of a mark in the Indian market. General Motors suffered a similar fate with its Opel Astra. The first international player to make a mark in the "new" Indian car market was Hyundai which designed a car especially for the Indian market. The Santro, launched in 1998, had quick acceleration, the ability to turn around in small spaces, good fuel efficiency, and, with its tall boy design, was differentiated from the existing cars in the market. Over the last ten years, almost all the major automobile companies have entered the Indian market – Toyota, Honda, Skoda, Volkswagen, Nissan, Fiat and Renault are all present in India in addition to Ford, GM, Hyundai and, of course, Suzuki which was the first to enter, and continues to dominate the Indian car market thanks to its strong presence in the lower end of a price sensitive car market. Several manufacturers including Toyota (with the Etios), Ford and Volkswagen have introduced cars which are specially designed or adapted to the Indian market.

In this congested market space, Indian automobile companies have managed to stake out a space for themselves. Tata Motors first entered the car market by building passenger vehicles on a light commercial vehicle platform. Later, with the in-house development of the Indica, they built their first ground-up car. The success of the Indica (initially launched in 1998, and later re-launched in an improved version in 2001) and a low end light-commercial vehicle, the Ace, in 2005, emboldened Tata to enter the car market with a disruptive innovation, the Nano, in 2008.

Similarly, in the utility vehicle space, another Indian company, Mahindra & Mahindra (M&M) first upgraded its existing jeep-like product and then launched its first successful in-house developed Sports Utility Vehicle, the Scorpio, in August 2002.[v] Subsequently, it launched another Multi Utility Vehicle based on in-house development, the Xylo, in 2009.

Another important part of the Indian automotive sector is the automobile component industry. In recent years, it has grown in size, and thanks to is enhanced quality of output, cost competitiveness, and design skills, it has become prominent in the global automobile component industry as well. Forging manufacturer Bharat Forge is a good example of this trend. In the last 20 years, Bharat Forge has grown from a small domestically focused player to become the second largest forging manufacturer in the world after Thyssen Krupp. The important steps in this transition were (1) setting up a large automated forging capacity to meet any need from any customer at high quality; (2) renewal of the workforce by inducting graduates on the shop floor; (3) building computer-aided design skills, first at the level of the dies for forgings and later in the final product; (4) implementing various efficiency-enhancing and cost-reduction processes across the company; (5) exploiting windows of opportunity in key external markets including China; (5) adding on machining skills so as to enhance value addition; and (6) gaining technological capabilities and proximity to auto OEMs by strategic acquisitions in Europe.[vi]

From the above, it is quite evident that some Indian companies across the automotive industry spectrum have enhanced their innovation capabilities considerably during the last two decades. What role has academia and public research institutions played in this? And what role will they play in the future? What can the government do to enhance such collaboration? These are the questions we seek to answer in the rest of the paper.

Methodology & Structure of the Paper

To answer these questions, we decided to study some of the prominent organizations from across the automotive sector. We have chosen 2 automobile component companies; 5 automotive companies with different strategies, business models and segments; and 3 research groups from academia that have been closely involved in research and development work related to the automotive industry.

We have built a case study around each of these companies/research groups using diverse sources of data: annual reports, case studies, data submitted to the government as per statutory requirements, and interviews with key managers/researchers. For each company, we look at the company's history, its product and innovation strategy, and the role played by academia and public research institutions. For each academic research group, we look at the expertise and background of the group and the nature of their interaction with industry.

Building these case studies allows us to build a snapshot picture of the sectoral innovation system.[vii]

After the presentation of these case studies, we identify the emerging trends in terms of the priorities of the companies related to innovation, what role academia is playing in helping the companies innovate, the role of the government, and identify possible avenues for joint working in the future.

Innovation in the Indian Automobile Component Industry: Two Cases

The Indian Automotive Component Industry has emerged as one of the most dynamic, export-oriented industries in India. It is often mentioned as one of the industries with the best export and growth potential. Both domestic sales and exports have been growing at a rapid pace as shown in Table 1:

Table 1: Indian Automobile Component Industry Sales & Exports 2000-2011 (USD Billion)

	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Turnover Growth Rate					8.70 29%	12.00 38%	15.00 25%	18.00 20%	18.40 2%	22.00 20%	26.00 18%
Export Growth Rate	0.63 37%	0.58 -8%	0.76 31%	1.27 68%	1.69 33%	2.47 46%	2.87 16%	3.62 26%	3.80 5%	3.80 0%	5.00 32%

Source: Auto-Component Manufacturers Association http://www.acmainfo.com

1. Case 1: Tube Products of India

1.1. Company Profile & Brief History[viii]

Tube Products of India (TPI) is a constituent of Tube Investments of India (TII) Ltd., a leading engineering company with bicycle, metal forming and other related business. TII is a part of the large south Indian conglomerate, the Murugappa Group.

TPI was set up in the year 1955 in collaboration with Tube Products (Old Bury) Limited, UK to produce Electric Resistance Welded (ERW) and Cold Drawn Welded (CDW) tubes. This business was set up primarily to meet the needs of the parent company's bicycle business. However, today, TPI manufactures Precision Welded tubes for several major automotive companies in India and abroad. It has also diversified beyond automotive into other user segments.

TPI is well known for the wide variety of Precision Welded ERW and CDW steel tube in terms of size as well as material grades offered. Though it started with a plant near Chennai in south India, today it has manufacturing facilities in the north and west as well to meet the needs of its customers. TPI has also set up an exclusive export oriented unit.

1.2. Product & Innovation Strategy[ix]

Like many other engineering companies, TPI has a long history of focusing on quality and process improvements with a view to improving efficiency and productivity. However, in recent years, there is also a major emphasis on innovation, particularly development of tubes for new applications, and using new/alternate materials.

The automobile sector is looking to lower weights – "light weighting" – to enhance fuel efficiency and lower emissions (meet tighter emission norms). At the same time, safety is an important consideration for the sector. "Light weighting" means using alternate materials. But it's usually not enough to just substitute materials. There is often a need for re-design. Safety concerns focus on eliminating weldments, and looking at joinery issues. Vehicles have to be crashworthy.

TPI addresses the passenger car and light motor vehicle markets. “Light weighting” here involves bringing in materials with high strength but at the same time not losing out on shaping properties / ductility, etc.

TPI is working with auto companies on drive line and body / suspension components. One obvious area of interest is substituting tubes for rods. Tubes are lighter, but stiffness is important. Substituting a rod by a tube changes the moments of inertia. So there is a need for re-design of the components.

TPI has been working primarily with leading Indian manufacturers like Tata Motors and Mahindra, and not with multinational auto majors. To get the back-end knowledge, TPI has joined a US-based steel processing consortium, ASPPRC (Advanced Steel Processing and Products Research Center) since the last 6-7 years. ASPPRC has close links with the Colorado School of Mines. Membership of this consortium has helped learn about processing steel in a more comprehensive manner. Leading global steel makers and automobile companies are a part of this consortium, and this helps TPI get a clear product perspective.

TPI works closely with the R&D and Product Development departments at Tata Motors and Mahindra to understand their needs and co-develop alternate components. They also keep the customer’s vendor development department in the loop so as to avoid any procurement issues later on. TPI has found no difficulty in working with Indian companies like Tata and Mahindra, where there are like-minded people. However, it has not been easy to get entry into MNCs.

1.3. Collaboration with Academia / Public Research Institutions

In terms of links with institutions, TPI has contractual relationships with a number of institutions. For testing methods, they work with the Automobile Research Association of India (ARAI), jointly with Tata/Mahindra or a Tier I vendor like Spicer. They also use the testing services of organizations like Structural Engineering Research Centre (a government-funded R&D institution that specializes in testing structures) and the National Automotive Testing & R&D Infrastructure Project (NATRIP), a new government sponsored programme that is setting up a national network of testing centres with industry participation.

TPI's relationship with the Indian Institute of Technology (IIT) Madras[x] is strong. The interaction is more on fundamental problems that are well suited to the competence of the faculty at the institute. TPI has 5 employees currently in the MS programme at IIT Madras. They work in areas like crack propagation. The learning of these employees from IIT Madras helps build the research capabilities within TPI.

Similarly, TPI has worked with IIT Bombay, again on a contractual basis. This is primarily in the areas of Metal Forming (working with a Professor who is part of the government-funded CAR programme) and Hydroforming. They have also worked with another professor on aluminium welding and friction welding (this is in anticipation of user shifts from steel tubes to aluminium tubes).

In the past, TPI worked with the Indian Institute of Science as well, primarily with the Prototyping Centre (APDAC) for areas like Finite Element Modeling (FEM). This was at a time when TPI's own Technology Centre's design capabilities were in infancy.

The relationship with IIT Madras (IITM) is excellent. IITM readily accepts TII/TPI people for their research programmes. Murugappa group has been a major sponsor of the IITM nano-tech centre [Rs. 30 million out of Rs. 250 million]. IITM has also helped build a Technology Appreciation programme for shop floor employees of TII/TPI. TPI's learning from this interaction is that while IITM does not have solutions to all problems, the key is to go with them for what they are good at doing.

2. Case 2: Rane Group

2.1. Company Profile & Brief History[xi]

The Rane group was founded in 1929 as a trading house. Through strategic technical alliances and access to the best technology, they have today grown into one of the important players in the automobile components industry in India.

The main companies in the group are Rane (Madras) Limited (Manual Steering & Suspension Systems), Rane Engine Valve Limited (Engine Valves, Valve Guides, Tappets), Rane Brake Lining Limited (Brake Linings, Disc Pads, Clutch Facings, Composite Brake Blocks, CV Brake Pads & Sintered Brake Pads), Rane TRW Steering Systems Limited (Power Steering Systems, Seat Belt Systems), Rane NSK Steering Systems Limited (Steering Columns & Electric Power Steering) and Rane Diecast Limited (High Pressure Die Casting Products).

Between them, these companies serve almost all the major segments of the automotive industry in India. The group turnover was USD 375 million in 2009-10.

2.2. Product & Innovation Strategy[xii]

2.2.1. Process Innovation

Rane Group has been following Total Quality Management (TQM) aggressively. Four companies in the group have received the Deming award and one is now aiming for the JQM award.

Process improvements at Rane group have been made for the last 10 years under the umbrella of TQM. Total Preventive Maintenance (TPM) has been in place since the last 5 years and there is a major thrust on lean manufacturing since the last 3-4 years. Both process improvement and equipment improvement are being pursued. Multiple Japanese advisers have been advising Rane on the implementation of these methodologies. Efficiency improvements through the identification of Mudas (source of waste) in the factory have been brought about. The company seeks to optimize movement in the factory and thereby reduce waste of men and materials. This process goes on continuously, leading to re-alignment of the factory.

2.2.2. Product Innovation

The Rane group already has a focus on products and designs. There is an awareness of the importance of new technologies and products. There is consciousness of Intellectual Property Rights and an environment for the creation of new processes and designs is already there. Innovations are being protected in a systematic manner.

For those companies in the Rane group that are Joint Ventures (JVs), the main technology source is the JV partner. Others like Rane Madras and Rane EV are standalone companies and depend on their own technology development efforts. The latter companies have their own R&D and/or engineering departments. On a case-to-case basis they acquire technologies from other sources as well. The R&D departments are also involved in improvements to existing products and have used existing technologies to develop adjacent products.

Rane does benchmarking with collaborators. They also have technical partnerships with Japanese partners for competency development.

The Rane group is active in application engineering and component-level new design. Adapting existing products to other requirements through component design is one of their core areas. In terms of such application engineering innovation projects, they have achieved proficiency at the component level. Work at the sub-assembly level is in progress, and the product level is the next frontier.

In one case, a component innovation done in a Rane group company has been accepted by the collaborator (who has a large innovation laboratory in China) for inclusion in their final product. This is in the area of occupant safety systems.

Rane group started looking at innovation as a distinct activity only recently. As a part of their leadership development activities, a professor from IIM Bangalore gave lectures to the senior management team and they are now moving forward on this. The group plans to integrate the innovation activity with their group-wide TQM approach during the coming years. A couple of senior managers have been identified to lead this focus on innovation.

The Rane group has been in touch with leaders in innovation such as the Tata group companies to learn about their innovation processes. They plan to benchmark against Tata group companies including Tata Consultancy Services and Titan Industries (jewellery division).

2.3. Collaboration with Academia / Public Research Institutions

Rane group has interactions with IITs (mainly Madras), Anna University and PSG Tech, (a leading engineering institution in Coimbatore). The PSG Tech relationship is strong because of the Rane group founders' links to Coimbatore. PSG Tech has small R&D laboratory specific projects that are undertaken as student project work.

The Rane group chairman has put together cross-functional and cross-company groups that interact with PSG in specific areas. They identify areas of possible collaboration. After that it is left to individual companies to pursue the matter.

One of the group companies, Rane TRW, is in the seat belt business. An important arena for Rane TRW is plastic reservoirs for steering systems. They have done some work on development of new reservoirs to meet emerging global standards. IIT Madras has been involved in testing and validation of NVH (noise vibration harshness) characteristics. They also have (often informal) interaction with various experts in the area of plastic components. These experts may be from CIPET (a publicly-funded institution), ex-CIPET or consultants from the industry. Areas of interest include process engineering, alternate materials, lightweighting and strength of materials (allowing lighter structures).

2.4. Innovation in the Automotive Industry: Five Cases

Like the automobile component industry, the automotive industry itself has been growing at an aggressive pace. The growth figures for the domestic market and exports are given in the following tables:

Table 2: The Indian Automobile Industry Automobile Sales (No. of vehicles)

Category	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Passenger vehicles	902,096	1,061,572	1,143,076	1,379,979	1,549,882	1,552,703	1,949,776
Commercial vehicles	260,114	318,430	351,041	467,765	490,494	384,194	531,395
Three wheelers	284,078	307,862	359,920	403,910	364,781	349,727	440,368
Two wheelers	5,364,249	6,209,765	7,052,391	7,872,334	7,249,278	7,437,619	9,371,231
Grand total	6,810,57	7,897,629	8,906,428	10,123,988	9,654,435	9,724,243	12,292,770

Source: Society of Indian Automobile Manufacturers http://www.siamindia.com

Domestically, the passenger vehicles industry displayed the highest compound annual growth rate of 13.7% over the period 2003-2010.

Table 3: Indian Automobile Industry Automobile Exports (No. of vehicles)

Category	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Passenger vehicles	129,291	166,402	175,572	198,452	218,401	335,729	446,146
Commercial vehicles	17,432	29,940	40,600	49,537	58,994	42,625	45,007
Three wheelers	68,144	66,795	76,881	143,896	141,225	148,066	173,282
Two wheelers	265,052	366,407	513,169	619,644	819,713	1,004,174	1,140,184
Grand total	479,919	629,544	806,222	1,011,529	1,238,333	1,530,594	1,804,619

Source: Society of Indian Automobile Manufacturers http://www.siamindia.com

In exports, two wheelers were the fastest growing industry segment with a compound annual growth rate of 27.5%.

3. Case 3: Ashok Leyland Ltd.[xiii]

3.1. Company Profile & Brief History[xiv]

In keeping with India's post-independence philosophy of self-reliance, what is today Ashok Leyland was first set up in 1948 as Ashok Motors to assemble cars. Consequent to equity participation from Leyland UK, the company actually started manufacturing trucks and buses since 1955.

Ashok Leyland prides itself on a tradition of technological leadership, earlier through technological collaboration, and now, increasingly through internal product development. A pioneer in truck technologies such as full air brakes and power steering, today Ashok Leyland is known for its rugged products suited to Indian conditions. More than 500,000 vehicles manufactured by the company have been used on Indian roads.

Ashok Leyland has been most successful in the public bus segment of large cities. 80% of buses used in India's metropolitan cities for public transport have been manufactured by the company.

In 1987, the control of the company came into the hands of the prominent non-resident Indian business group, the Hindujas, consequent to their taking over the overseas holding and IVECO, a multinational truck company. IVECO subsequently sold out its stake to the Hindujas in 2006. Ashok Leyland was the first Indian automobile company to be awarded ISO 9002 certification (1993) and also the first Indian automobile company to be awarded the ISO/TS 16949 corporate certification (2006). It has achieved many other certification landmarks as well.

Over time, Ashok Leyland has shifted from chassis based vehicles to (next generation) fully built solutions; many of these are the result of in-house development. In the last decade, new facilities created include an engine R&D facility at Hosur and a Technology Centre at Chennai. The number of people involved in R&D / product development has gone up from about 80 to over 1,000 during the same time frame.

In fiscal 2009-10, Ashok Leyland had sales of Rs. 73 Billion.

3.2. Product & Innovation Strategy

As in many other parts of the Indian automobile industry, innovation in the commercial vehicle (truck) segments of the Indian history has been driven by the increasing stringency of pollution control norms and enhanced competition. At the same time, demand for commercial vehicles has generally been on a growth path for the last several years except for the year 2008-09 when the market contacted due to the effects of global recession. In the commercial vehicle segments, growth has been healthy in the bottom and top weight segments as India moves towards the hub-and-spoke model of logistics that characterizes much of the developed world. Growth has also been driven by regulatory efforts to curb the practice of overloading trucks and the upgradation of bus services in metropolitan cities through the introduction of low-floor city buses.

Ashok Leyland's focus has been on providing the best "value-to-cost" equation for customers. Following the withdrawal of IVECO from the controlling structure of Ashok Leyland, the company is now aggressively creating its own technological capabilities to meet this goal. This is reflected in the increase in R&D intensity from 1.7% in 2005-06 to almost 3% in 2009-10 (see Table 4 below). The objective is to ramp-up capabilities to be self-sufficient in creating technologies for the global market. This is already visible in near-term products. In addition, technology adjacencies are being pursued such as next generation technologies, electronics, telematics, etc.

Table 4: Ashok Leyland Ltd. Expenditure on R&D (Rs. Million) During Last 5 Years

Year	Capital Expenditure on R&D	Recurring Expenditure on R&D	Total Expenditure on R&D	R&D Expenditure as a % of Sales
2005-06	485.55	563.85	1049.40	1.70
2006-07	778.78	785.24	1564.02	1.90
2007-08	954.39	1068.84	2023.23	2.30
2008-09	1500.15	1153.66	2653.82	3.98
2009-10	1024.92	1315.89	2340.82	2.97

Source: Company Annual Reports of Respective Years

Two new centres/groups have been set up – one for Advanced Engineering, and the other called Mission Summit (this group links technology to market – basically, it looks at how technology can improve the operating economics of trucks both in terms of operating costs, and usage of the asset across the life cycle).

Till 2007-08, the emphasis was on development of engines ("H" series) with common rail injection systems to meet the needs of Bharat Stage III (similar to Euro III) emission norms. In 2007-08, the company decided to launch a "Future Vehicle Development Programme" and create a "New Engine Platform "to prepare itself for even higher emission norms as well as emerging customer needs. These culminated in the UNITRUCK truck platform announced in 2008-09, a modular truck range covering the 16-49 Ton segments. This modular range is expected to help both customers (easier fleet management) and Ashok Leyland (lower number of parts, and improved supply chain management). The company also started development of a new modular "NEXTGEN" cabin and a new engine series, "NEPTUNE."

Besides increasing plant capacities to meet future needs, Ashok Leyland has sought to move away from its traditional reliance on medium and heavy commercial vehicles to form a Joint Venture for Light Commercial Vehicles with Nissan (announced in 2006-07; first vehicle expected to be on the road in 2011), move into construction equipment through a joint venture with John Deere (announced in 2008-09), and diversify into automotive electronics through a joint venture with Continental AG (the company by the name of Automotive Infotronics was formed in 2007-08). In 2007-08, Ashok Leyland also invested in a company called Albonair in Germany to develop vehicle emission treatment/control systems and products.

Ashok Leyland's innovation activities are driven by a number of recent process initiatives. A team of young employees from different functional areas was brought together as a task force to develop the business plan for 2007-08 which set more challenging targets than the traditional top-down business plans.[xv] Through a collaborative "voice of the customer" process, Ashok Leyland built a special semi low floor, front engine bus for the city of Mumbai that retained a low price but offered improved ventilation for the driver and a simple electronic management system among other improved features besides the mandatory Bharat Stage III engine. This resulted in the largest ever order of 644 buses from Mumbai's local public transport utility company, BEST.[xvi] A "Mission Gemba"[xvii] team from Ashok Leyland worked closely with a supplier of fuel tanks to optimize his plant layout and operations so that he could double his productivity and thereby meet Ashok Leyland's enhanced requirements with minimal investments.[xviii] Suggestions submitted by employees were used to lower the "Effort & Ergonomy Index" across the plant.[xix] Another company-wide team project contest titled "Improve" based on innovation by teams/quality circles resulted in 946 projects in 2005 with a benefit to the company of Rs. 32.9 million. The following year saw a doubling of the number of implemented projects and a participation rate of 40% of the company's employees.[xx] Young engineers in the company's Advanced Engineering Group are encouraged to present papers at international conferences such as the annual Society for Automotive Engineers (SAE) conference.[xxi]

Other processes in use include a "Mission Summit" programme (launched in 2007) for breakthrough innovation that resulted in the innovative IBus demonstrated in the Auto Expo of January 2008, a Six Sigma programme extended company-wide in 2007-08, a "GENMOD" process to capture the voice of the customer launched in 2008-09 and a Lean Development Process launched in 2009-10.[xxii] The Hibus, a plug in hybrid bus developed by Ashok Leyland, was demonstrated at Auto Expo 2010. A variety of consultants are involved in these process initiatives.

3.3. Collaboration with Academia / Public Research Institutions

During 2006-07, Ashok Leyland and Bosch jointly endowed a Centre for Excellence in Engineering Design at the Indian Institute of Technology Madras. This Centre was set up to offer an integrated dual degree programme in Engineering Design – a B.Tech in Engineering Design + an M.Tech with specialization in Automobile Engineering - that would improve the availability of design engineers with a practical orientation.[xxiii] Ashok Leyland and Bosch each contributed Rs. 40 Million (about USD 0.9 million) for the creation of this Centre.

Ashok Leyland has tied up with Indian research centres and laboratories for internal competence building. There are programmes with IITs as well as the Indian Institute of Science at Bangalore (e.g.in the area of Noise Vibration Harshness).

The Collaborative Automotive R&D Programme (CAR) launched by the government in 2004-05 provided a good platform for collaboration with academia. A CAR project in which Ashok Leyland participated (integrated telematics project for Koyambedu) has been scaled up and is quite successful even though it was delayed by a few years. All important stakeholders – central government, state government, International Institute of Information Technology Bangalore, Siemens VDO (now Continental) - came together on this project. Ashok Leyland's learning from this project was that the challenge is to use the right technology for Indian conditions. A new company started by Ashok Leyland in a joint venture with Continental (Automotive Informatics) will play an important role in this field of automotive electronics in the future.

Forums like SAE and SIAM have brought together automobile industry people through a Mobility Industry Group to work on competence ramp-up.

Ashok Leyland has interacted with international academics as well. They invited Prof Clayton Christensen to advise them on how to create disruptive technologies. Using that methodology, a novel concrete cement mixer was developed and displayed at the Auto Expo. This is a vehicle with a smaller footprint than traditional concrete mixers. Similarly, the eminent Japanese scholar Prof. Shoji Sheba was invited to advise on Lean 6 Sigma.

The Indian Statistical Institute, a prominent research and education institution specializing in Statistics has been involved for training and certification in Six Sigma – a number of green and black belts have been trained. This collaboration helps in terms of improvement of processes, certification, etc.

4. Case 4: Mahindra & Mahindra

4.1. Company Profile & Brief History[xxiv]

Mahindra & Mahindra Ltd. (M&M) is today a diversified Indian corporation with interests in automobiles, farm equipment, financial services, hospitality and information technology. In the financial year ending March 2010, M&M had a sales turnover of Rs. 205.95 Billion and a net profit of Rs. 20.88 Billion.

M&M entered the automobile manufacturing business in 1945 through an arrangement with Willys jeeps to import and assemble their product from kits. In 1954, they started manufacturing utility vehicles. M&M has over time become a major player in the farm equipment and tractor business, and, since 1983, has been India's largest tractor company.

In the automobile industry, M&M's traditional focus was on soft-top and hard-top utility vehicles, primarily for rural markets. In 1995, they entered the motorcar segment through a Joint Venture with Ford. However, this JV was short-lived and was dissolved in 1999, with Ford continuing the business on its own.

M&M entered the urban market for Sports Utility Vehicles (SUVs) through the launch of a new product, the Scorpio, in 2002. Prior to the launch of the Scorpio, M&M launched an upgraded version of one of its existing hard-top utility vehicles, the Armada, as the Bolero, at the upper end of the low-priced utility vehicle segment. The Bolero was quite successful.

However, M&M's major makeover came from the launch of the Scorpio. The Scorpio was first conceived in 1997 as a part of a new Integrated Design and Manufacturing (IDAM) initiative launched by M&M under the leadership of Dr. Pawan Goenka, a former General Motors executive. Originally conceptualized as a rural vehicle, the Scorpio was finally positioned as an urban vehicle when M&M management realized the potential of the product.

M&M also has a presence in Light Commercial Vehicles. It is now entering the Medium and Heavy Commercial Vehicles businesses through a Joint Venture. M&M acquired the two-wheeler business of Kinetic Motors to enter the two-wheeler industry. In 2010, M&M also acquired a controlling stake in Reva Electric Car Company, India's pioneering electric car manufacturer. M&M entered a joint venture with Nissan/Renault to manufacture the Logan passenger car for the Indian market; however M&M and Nissan/Renault have now decided to go their own ways.

4.2. Product & Innovation Strategy

The Scorpio project signified the entry of M&M into the complete end-to-end design and manufacture of an automobile for the first time. It was developed with a small team by international standards – just 120 people – but the smallness of the team also meant that it was close knit and effective. The IDAM team collaborated with a number of external agencies for the design and engineering of the Scorpio. For example, the engine was developed in collaboration with AVL, an Austrian company. The design of the Scorpio incorporated a lot of input from the increasingly sophisticated Indian consumer. While the diesel version of Scorpio was designed to meet Indian emission norms (at that time equivalent to Euro II), another petrol version compliant to Euro III standards was also developed.

Since M&M lacked resources and experience, M&M used the black box development approach and got major sub-systems developed by vendors. Most of these vendors were international suppliers, but often not the leading ones. Instead, M&M chose to work with Korean companies that had the expertise but not much prior experience. This brought costs to a level that M&M could afford. M&M has made concerted efforts to absorb most of the technologies sourced from external vendors.[xxv]

Similarly, in setting up the plant, M&M worked with relatively less known suppliers to keep costs under control. As a result, M&M was able to keep the cost of setting up a plant with a 45,000 car capacity to only USD 120 million.

Scorpio was a successful vehicle, selling nearly 35,000 vehicles in the first 18 months after launch, and winning the CNBC Autocar "Car of the Year" award in January 2003. More than that, it established M&M as an important player in the Indian automobile market capable of innovative designs and features. M&M claimed that Scorpio offered "45 new features provided through systematic capture of customer feedback."[xxvi]

The Bolero and Scorpio also formed the basis for M&M's internationalization strategy with the Bolero being launched as the Mahindra Cimarron in Uruguay (with a focus on the South American market) and the Scorpio being launched as the Mahindra Goa in Europe. M&M entered the South African market in 2004, and in 2005-06 launched a pick-up variant of the Scorpio in that country – the first time an Indian automobile company launched a new product in an international market.[xxvii]

Since then, several variants of the Bolero and Scorpio have been launched, both domestically, and internationally.

In 2008-09, M&M launched the Xylo, a bigger multi utility vehicle for urban customers. Like the Scorpio, the Xylo was received well in the market and was seen as an important alternative to established products like the Toyota Innova, the leader in that segment.

The investment in research and development at M&M shows an increasing trend

(Table 5):

Table 5: Mahindra & Mahindra Ltd. R&D Expenditure in the Last 5 Years

	2005-06	2006-07	2007-08	2008-09	2009-10
Cap Ex on R&D (Rs million)	NA	NA	538.1	2768.7	3907.2
Total Exp on R&D (Rs million)	1265.9 (rounded)	1700	2453.3	5156.5	6648.6
R&D as a % of Sales	1.33%	1.46%	1.85%	3.44%	3.23%

Source: Company Annual Reports

Note: This is the total R&D expenditure of the company and included R&D expenditure on tractors and farm equipment.

In the last three years the priorities of R&D at M&M have been evolving from an emphasis on engine development to meet regulatory norms (2007-08) to the development of alternate fuels (2008-09) and sustainable movement solutions (2009-10).[xxviii]

Representing the importance of R&D and product development to M&M, it has a board-level committee focused on research and development since 1998. Also, the head of the team that developed the Scorpio, Dr. Pawan Goenka, is today the head of the automotive business of M&M.

4.3. Collaboration with Academia / Public Research Institutions[xxix]

M&M takes special interest in collaboration with academia. The company's collaboration with academia takes 3 forms:

- Technology Development
- Fundamental Research
- Training / knowledge development

M&M has relationships with four of the Indian Institutes of Technology.

In the technology development arena, M&M gives projects to academic institutions when analytical investigation is required as they believe academics are better placed to do such work. Areas in which projects are given out include vibration analysis, combustion analysis, fluid dynamics, wave analysis, etc. This activity supplements the in-house product development undertaken by the company.

M&M has given projects to the Indian Institute of Science in the areas of vehicle aerodynamics, Computational Fluid Dynamics calculations, and simulation studies.

M&M has worked with Indian academic institutions on research projects such as hydrogen technology for engines (IIT Delhi) and biofuels (IIT Kanpur)

M&M's experience has been that the gap between academia and industry is more on non-technical issues like focus and time, not because of capabilities or competence. This gap can be bridged once there are more people with experience on both sides.

M&M works extensively with_academia for training. Their Graduate Engineer Trainees undergo a one-year training programme developed and taught by professors from different institutions. M&M prepares the outline of a training module and academia builds on this. Partners include MS Ramaiah College, VIT and College of Engineering, Pune.

Modules for existing staff are being prepared with IITs, and deemed universities that have the expertise. M&M personnel have been deputed to VJTI (a leading engineering institution in Mumbai) for MTech in Powertrain engineering. Earlier, some M&M personnel attended Masters programmes at IIT Madras.

M&M also has some international collaborative R&D projects / programmes with organizations like SRC Canada for Hydrogen diesel dual development (sponsored by Ministry of Renewable Energy), Southwest Research Institute USA and TUV from the Netherlands.

5. Case 5: Tata Motors[xxx]

5.1. Company Profile & Brief History

Tata Motors is one of the flagship companies of the globally renowned Tata conglomerate. Tata Motors sprung to international attention with the announcement of the Tata Nano, the world's lowest priced car, in January 2008.

Tata Motors was founded as the Tata Engineering & Locomotive Company Ltd. (Telco) in 1945. Telco commenced the production of trucks through a technical collaboration with Mercedes Benz in 1954. After the expiry of this collaboration agreement in 1969, Telco started designing, developing and manufacturing trucks on its own.

While Telco's technological capabilities improved over time, its ability to expand its range and capacity was constrained by the licensing regime of the government. The broad banding policy for the automobile sector announced in the mid-1980s freed Telco from this constraint. Telco was able to compete successfully with Indo-Japanese ventures such as Swaraj Mazda, Allwyn Nissan and DCM Toyota in the newly emerging Light Commercial Vehicle segment thanks to its rugged products, simple technology and strong service network.

Following the liberalization of the Indian economy in 1991, Telco entered the car and utility segments as well with products such as the Estate (a station wagon), Sierra, and Sumo (a very successful utility vehicle used in both urban and rural India for multi-passenger transportation). These products built on the capabilities Telco had built in the light commercial vehicle arena. For example, the Estate and Sierra were built on the chassis of the 207 light truck.

However, Telco's first ground-up entry into the passenger car market was through the Indica, launched in 1998 based on a decision taken in 1995. The Indica, a sturdy diesel "small" car emerged as an important competitor in the entry level market thanks to its low operating costs. It was particularly successful with taxi operators. Telco subsequently launched petrol versions of the Indica targeted at individual consumers. The Indica V2 launched in 2001 overcame many of the niggling problems that plagued the original Indica model. Later, a sedan variant on the same platform called the Indigo was launched in 2002.

Telco changed its name to Tata Motors in 2003. Subsequent significant events were:

- Acquisition of Daewoo's heavy commercial vehicle business in South Korea in 2004 (this gave Tata Motors access to advanced engine technologies for developed markets);
- A strategic alliance with Fiat was announced in 2006 to cover technology, sales and marketing;
- Launch of the Tata Ace, a one tonne, "last mile" delivery vehicle in May 2005 (more than 500,000 vehicles built on the Ace platform were sold between 2005 and 2010. This product won BBC Top Gear's Best Commercial Vehicle Design Award in January 2006);
- Launch of the Tata Nano in 2008;
- Acquisition of a controlling stake in Jaguar Land Rover in 2008.

Tata Motors reported a top line of Rs. 381.44 Billion in 2009-10 with a net profit of Rs. 22.4 Billion on a standalone basis in FY 2009-10.[xxxi]

5.2. Product & Innovation Strategy

Tata Motors has a long heritage as an engineering company. Telco set up its research and development centre as long back as 1959. Under its legendary chairman, Suman Moolgaonkar, Telco built strong engineering capabilities even though these could often not be satisfactorily exploited.

Telco's first successful internally developed product was the Tata 407 light commercial vehicle launched in the late 1980s.

The Indica was developed at a cost of Rs. 17 Billion (USD 378 million) and gave Tata Motors the confidence to build other new products. In the Indica project, Tata Motors managed the product development at a system design and integration level and involved a number of international vendors and partners in the project. These included partners / consultants for styling, body, engine design, etc. As the company's first major clean sheet car design and development project, the Indica was an important learning ground for Tata Motors' engineers.

Tata Motors has two research centres in India – one at Jamshedpur that focuses on the improvement of components and aggregates and an Engineering Research Centre at Pune set up in 1966. Work done by the Pune Centre resulted in Telco getting the DSIR National Award for R&D Effort in Industry in 1999 and the National Award for Successful Commercialization of Indigenous Technology for the Indica in 2000.

In terms of internal development processes, the Ace constituted an important step and was the precursor to the Nano. Some of the significant decisions in the Nano project were:

- Choice of a 30-year old engineer, Girish Wagh to head the development team (this was a major departure from the traditional practice at Tata Motors)
- Use of cross-functional teams in product development
- Use of the "Production-Preparation-Process (3P) in the development process
- Strict cost control through a "Design-to-cost" approach (the development budget was pegged at Rs. 2.2 billion ($49 million)).

Reflecting Tata Motors' successful use of "frugal innovation" techniques, consulting firm Booz rated Tata Motors as a highly effective innovator in its 2006-07 study of innovative companies.[xxxii]

Given the aggressive cost targets of the Nano, Tata Motors worked closely with a variety of suppliers, both Indian and foreign, to design components, sub-assemblies and assemblies that would meet very tight cost targets. Some of these capabilities were built during the Ace development process.

5.3. Collaboration with Academia / Public Research Institutions

Tata Motors has been at the forefront of developing capabilities indigenously. Towards this end it collaborates actively with institutions, firms, and consultants.

Tata Motors has been an active participant in the CAR project on Tailor-welded Blank and Hydroforming Technology for Automotive Weight Reduction being led by the Advanced Research Centre for Metallurgy and Advanced Materials (ARCI) at Hyderabad. They have also been actively involved in sponsoring projects at the Indian Institute of Science, Bangalore (see Case 10 on Centre for Product Design and Manufacturing at Indian Institute of Science).

6. Case 6: TVS Motor Company[xxxiii]

6.1. Company Profile & Brief History

TVS Motor is the third major player in the Indian motorcycle industry. TVS Motor is part of the TVS Group, a well-established industrial conglomerate in south India with a strong presence in the automobile component industry. In fiscal 2009-10, TVS Motor Company had sales of Rs. 44.2 Billion.

TVS Motor entered the two-wheeler industry through mopeds. The flagship moped *TVS50* was developed and launched in 1980 by Sundaram Clayton, a TVS group company. Numerous models and variants launched over the years helped TVS dominate the moped segment. TVS-Suzuki was formed as a joint venture between Sundaram Clayton and Suzuki Motors in 1982 to develop and launch motorcycles. The company went public in 1984, with Suzuki owning 33.7% of equity, TVS and its associates 16.7%, and general public the rest.[xxxiv] TVS's stake increased to nearly 50% in 1986 when the moped division was transferred from Sundaram Clayton to TVS-Suzuki.

The TVS-Suzuki joint venture launched the first-ever 100cc motorcycle in India in 1984. While this was markedly superior to existing products, Hero Honda soon launched four-stroke motorcycles with Honda's technology, which delivered superior fuel efficiency. TVS's in-house R&D efforts became focused on tweaking Suzuki's existing two-stroke engines to generate greater mileage.

Lacking a four-stroke model, TVS continued to be at a distinct disadvantage in the market. TVS-Suzuki launched its four-stroke model only in 1997 by which time Hero Honda had a stranglehold on the market. Difficulties in accessing Suzuki's technology and the cost of indigenizing the technology, among other issues, contributed to the split of the TVS-Suzuki joint venture in 2000.

6.2. Product & Innovation Strategy

TVS started to develop independent in-house product development capabilities even before the split with Suzuki. TVS launched *Scooty* in 1994, which quickly became the leading scooterette, and various motorcycle models throughout the late 1990s. The four-stroke motorcycle *Victor*, launched in 2001 was also an in-house effort, and gained TVS significant market share in motorcycles.[xxxv] TVS saw success with the launch of this product, resulting in their motorcycle market share zooming up to 19% in 2002-03. TVS continued to focus on fuel economies and emission controls and followed up with the launches of *Centra* and *Star* (both 100cc) in 2004. The success of *Victor*, however, could not be replicated, and Hero Honda continued to be strong in the economy segment.

While TVS continued to develop and launch new products, none of them could emulate the success of *Victor*. The surfeit of models in the economy segment from TVS and Bajaj led to the leader - Hero Honda launching a price war. As a result, TVS decided to focus on the newly emerging 125cc segment. To enter this segment, TVS licensed engine technology from AVL – an Austrian engine technology house, to be used in the new bike that was to be launched in 2007 – the 125cc *Flame*. The engine used Controlled Combustion – Variable Timing Intelligent (CC-VTi) technology. TVS claimed that the engine generated 10% more power and 10% greater fuel economy than regular engines. To protect their technology, TVS and AVL filed a patent on 23rd August, 2007 in the Indian Patent Office at Chennai.

On 30th August 2007, TVS unveiled the 125-cc *Flame*, based on CC-VTi. TVS had already started a new manufacturing facility with a capacity of 400,000 units in 2007 to capitalize on the expected success of the new bike.[xxxvi] Further fuelling TVS's expectations, *Flame* received rave previews.

However, Bajaj Auto succeeded in obtaining an injunction against the launch of *Flame*. This meant that the launch of *Flame* was delayed, and TVS finally had to launch *Flame* without the CC-VTi technology. Though the injunction was subsequently lifted by a higher court, the basic patent dispute is still pending a decision with India's Intellectual Property Appellate Board as of January 2011.

TVS Motor has been continuing an active innovation programme over the years. The company's investment in research and development has been rising steadily in the last three years. The spending on R&D is given in Table 6 below:

Table 6: R&D Expenditure by TVS Motor Company

	2005-06	2006-07	2007-08	2008-09	2009-10
Cap. Ex. on R&D (Rs million)	128.2	372.8	155.3	142.9	111.2
Revenue Exp on R&D (Rs million)	548.7	477.5	548.2	634.2	724.3
Unallocated Exp on R&D (Rs million)	83.9	175.1	-	-	-
Total Exp on R&D (Rs million)	760.8	1025.4	703.5	777.1	835.5
R&D as a % of Sales	2.3%	2.61%	2.12%	2.08%	1.86%

6.3. Collaboration with Academia / Public Research Institutions

TVS Motors is reputed to be a company with strong engineering expertise and has been committed to develop a strong technological capability of its own. While this effort is driven primarily through the company's internal efforts, the company uses collaboration with a variety of external partners to complement its internal capabilities.

As a philosophy, TVS Motors is strongly committed to the Japanese Total Quality Control (TQC) framework, and most significant internal processes are aligned with TQC. To this end, TVS Motors works closely with Japanese quality gurus to continuously enhance its quality processes. These efforts have borne fruit as reflected in several prestigious quality awards including the Deming Prize (the only 2-wheeler company in the world to have received this award) and the TPM Excellence Award 2008. TVS Motors also has one of the most effective employee suggestion schemes in the country.

TVS has worked closely with the Warwick Manufacturing Group to enhance its internal engineering and technology management capabilities. Several senior engineers in the company have been deputed to attend the Masters programme at Warwick University or the programmes offered by Warwick in India in collaboration with the Confederation of Indian Industry.

TVS has been an enthusiastic supporter of the Collaborative R&D Programme (CAR) launched by the Government of India through the Technology Information, Forecasting and Assessment Council (see Case 12). TVS has been a member of the consortium of 4 of the 10 CAR projects (the highest for any automotive company):

1. Engine Management System for Petrol Powered Small Vehicles (led by IIT Bombay)
2. Acoustics Diagnostics for 2-Wheeler Engine Assembly Line (led by IIT Kanpur)
3. Low-cost Flexible Automation using Robotic Arms (led by IIT Madras)
4. Process Development in Semisolid Forming and Squeeze Casting of Aluminium Alloy Components for Automobiles (led by Indian Institute of Science, Bangalore)

Of these, the second project listed above, viz. "Acoustics Diagnostics for 2-Wheeler Engine Assembly Line" has been installed and demonstrated at TVS Motors. This project has resulted in the development of a PC-based system for quality testing of single cylinder engines at the end of the assembly line using acoustic and vibration inputs. "Good" and "bad" engines can be distinguished based on the audio and vibration data collected from running the engine at different speeds. This helps smoothen the assembly line by matching the speed of engine testing to the production off the line.[xxxvii]

TVS Motor has been working with academic institutions at different levels to identify faculty and programmes that can help the company and the industry build basic competencies used in the automotive industry. For example, the company has identified the Welding Research Institute at Bharat Heavy Electricals Ltd., Trichy, to develop 5 basic courses on welding. With each of these partners, the company is focused on using the principles of Instructional Design to develop modules with clear goals, exercises and measurement. This effort is based on the philosophy that there is little point in talking about research and development if basic skills and competencies are not available.

7. Case 7: Bajaj Auto

7.1. Company Profile & Brief History

Bajaj Auto started with a focus on scooters, selling scooters from 1945 and manufacturing them from 1959. Bajaj entered motorcycles in collaboration with Kawasaki, but focused on motorcycles only when the scooter market started declining in the 1990s. *Caliber,* launched in 1998 was Bajaj's first success in motorcycles, and *Pulsar,* launched in 2001, the first blockbuster.

Bajaj concentrated on the 150cc+ segment (*Pulsar*, *Avenger,* etc.), and led the executive segment with nearly 60% market share. Bajaj made large investments in R&D resulting in strong new product development capabilities and innovative features like Digital Twin Sparkplug Ignition (DTS-i).

Bajaj Auto was the second largest two-wheeler company in India in financial year 2009-10 and had sales of Rs. 119 Billion during this year.

7.2. Product & Innovation Strategy

Bajaj historically dominated scooters, a fact that remained constant even with the entry of LML Piaggio and Kinetic Honda post deregulation in the mid-80s. Even till the mid-90s, the mainstay of Bajaj was the long running *Chetak*, which was based on a 25-year old *Vespa* model. In the scooter segment, Bajaj focused on adaptive changes to *Chetak*, e.g., developing a 150cc engine which was more suitable to Indian conditions. Bajaj's reputation for 'value for money' and reliability, built over the years, led to continued domination in the scooter market.

Bajaj entered motorcycles in 1985, having signed a technical collaboration agreement with Kawasaki of Japan to produce 100-cc two-stroke motorcycles. Unlike Hero Honda, the Bajaj-Kawasaki alliance was not a joint venture, and involved no equity participation from Kawasaki. The first product was the *KB 100* launched in 1986, which performed poorly in the market. The "KB" design was found to be ill-suited to Indian conditions. A modified version was soon launched in the market, which had a better sales performance.

Bajaj soon realized that Hero Honda had succeeded in moving the market to four-stroke vehicles. Bajaj's first four-stroke bike was launched in 1991 – the *Kawasaki Bajaj 4S Champion.* This was a 100cc bike, and took Hero Honda's existing *CD-100*'s value proposition head-on, with a fuel economy of 87 kmpl (against *CD-100*'s 80kmpl). Bajaj's advantage was short lived as Hero Honda again changed the shape of the market with *Splendor*. The *Splendor* was a 'modernized' design, but with the same engine as the *CD-100*, making style a major selling factor, in addition to fuel economy.

The Bajaj Kawasaki partnership continued to design and launch new motorcycles throughout the second half of the 1990s – the 100cc *Boxer*, the 111cc *Caliber*, etc., but made only a minor dent in Hero Honda's domination.

In 1999, Bajaj launched a greenfield manufacturing facility, incorporating principles from the Toyota production system. The team setting up the new facility also launched a fresh product development effort in competition with the Kawasaki-Bajaj collaboration. While the collaboration team was working on the 175cc *Kawasaki Bajaj Eliminator*, the internal Bajaj team concurrently developed the 150cc and 180cc *Pulsar.*

Pulsar was developed in collaboration with Tokyo R&D, a design studio specializing in automotive R&D. The team also created and commercialized Digital Twin-Spark Ignition (DTS-i) technology, which incorporated two spark plugs in the combustion chamber. This generates two points of combustion in the engine, and allows quicker and more efficient combustion, and hence better power, fuel efficiency and lower emissions. Bajaj applied for, and was granted a patent by the Indian Patent Office for the DTSi technology.

Eliminator was launched in January 2001 but proved too expensive for the Indian market, and failed to make a dent. *Pulsar* was launched in November 2001, at much more competitive prices, and received rave reviews from auto magazines.

Bajaj soon launched the 175cc *Avenger*, which was the Kawasaki Bajaj *Eliminator* fitted with the cheaper, more powerful and more fuel efficient Bajaj DTS-i engine. The dual success of *Pulsar* and *Avenger* made the executive segment a stronghold of Bajaj.

Bajaj continued its collaboration with Kawasaki, with Bajaj having developed competencies complementary to Kawasaki's. Kawasaki was strong in higher-end bikes (>250 cc), and Bajaj developed the capability to design and manufacture lower-end bikes cheaply. Bajaj acquired a stake in Kawasaki's operations in the Philippines and Thailand, and manufactured Bajaj vehicles for local consumption. Bajaj later moved into other developing markets, acquiring facilities in Colombia, Indonesia and Brazil. The R&D on the lower-end bikes continued, with Bajaj developing new features such as ExhausTEC a modification to the exhaust pipe that improves low/mid-range torque.

Bajaj's investment in Research and Development is given in the following table:

Table 7: Bajaj Auto Ltd. Expenditure on Research & Development

	2005-06	2006-07	2007-08	2008-09	2009-10
Cap Ex on R&D (Rs million)	263.0	473.4	481.4	310.8	312.3
Recurring Exp on R&D (Rs million)	504.4	676.9	706.0	837.9	1035.3
Total Exp on R&D (Rs million)	767.4	1150.3	1187.4	1148.7	1347.6
R&D as a % of Sales	1.03%	1,24%	1.37%	1.36%	1.17%

Source: Company Annual Reports

In 2005-06, Bajaj developed and launched a new CT 100 and Discover 110. Another newly developed motorcycle, Platina, was launched in April 2006. During this same year the following new technologies were developed: SNS suspension and a new generation DTS-I engine (with intelligent control of spark timing). The R&D infrastructure was upgraded in the areas of design, CAE, prototype and testing

In 2006-07, Bajaj launched a third upgrade of Pulsar (150 and 180cc). The upgrade included LED taillights, digital LCD speedometers, non-contact and backlit switches. The company launched the oil cooled Pulsar 200cc and a new Pulsar 220cc DTS-Fi – first fuel injected bike from Bajaj (features: port fuel injection, fixed fairing with stacked head lamps, diagnostic functions which are displayed on the speedometer, front and back disc brakes, high rigidity frame and a high performance front and back suspension system). Bajaj also introduced the Kristal-automatic scooter with fuel efficient DTS-I engine.

In 2007-08, Bajaj launched the XCD 125 DTS -Si motorcycle and the three-wheeler Gasoline Direct Injected auto rickshaw. The XCD 125 DTS -Si was engineered to cut down weight, while incorporating advanced features like LCD speedometer, LED tail lamps and tank spoilers. The 3-wheeler direct gasoline injected has a new 2-stroke engine-reduced emissions and a lighter weight.

In 2008-09, Bajaj launched the Platina 125 cc DTS-si and XCD135cc DTS-si motorcycles. The R&D department focused on expanding its design and testing teams. It enhanced its digital computational capabilities along with the ability to prototype and test the products to even higher standards. This enabled Bajaj Auto to design and produce "ready-to manufacture" prototypes for the new generation products.

In 2009-10, Bajaj launched the following new products: Pulsar 220 F, Pulsar 180 UG, Pulsar 150 UG, Pulsar 135 LS and Discover DTS-si. During this year, Bajaj's R&D completed development of the 4V DTS-I technology for outstanding engine performance. Design optimisation enabled it to be used on the Pulsar 135 LS, which competes at a lower price point. The DTS-i is controlled by a new generation CDI (Capacitor Discharge Ignition), which takes continuous load and temperature inputs to compute the optimum timing of each spark plug. In the same year, Bajaj enhanced its design, computing and test facilities. A notable addition was the commissioning of a world class NVH (Noise, Vibration and Harshness) laboratory. Bajaj Auto believed that this would give the company the ability to make even more refined products. The R&D team size in areas of design, analysis and validation was expanded.

7.3. Academic Research Groups Involved in Automotive Innovation: Three Cases

India has a large higher education system. The country produces more than 500,000 engineers every year. Though the quality of the education system is highly heterogeneous, there are several highly rated institutions like the Indian Institutes of Technology and the Indian Institutes of Science.

An initiative by the Government of India provided a conducive context for collaboration with industry in the automotive sector. The Principal Scientific Adviser

(PSA) to the Government of India mooted a programme for support of consortium-based R&D called CAR in 2003. Senior members of Indian automotive companies were enthusiastic about such a programme.

Six panels of industry and academic experts were formed, resulting in a 2005 Road Map covering 30 areas. These six panels had about 12 people each (that became the nucleus for a future network). During one year they met three times each culminating in a meeting at IIT Madras where the topics were narrowed down. The consensus was that the government should support the industry and bring in academia and research institutions to undertake pre-competitive research through a consortium approach.

The hope was that this consortium based approach would obviate the need for the complexities of technology transfer. The project is itself the transfer process – companies imbibe as much as they can through their association during the project. Given government audit regulations and problems encountered in earlier programmes, TIFAC (the managing agency) decided to make all government contributions through the institutions and as grants. The PSA believed that funding innovation in the automotive sector would have good results because being a growing industry, there was a greater likelihood of technology getting commercialized.

Finally four areas were narrowed down. The common demand driver for technology underlying these themes was fuel-saving. Various dimensions of fuel-saving were identified – size (smaller cars); light-weighting (could give up to 20% reduction in fuel consumption) with a focus on new materials and processes in steel and aluminium, not magnesium; engine improvement; electronics; fleet management; alternate fuels (including electric drive vehicles and hybrids but not hydrogen or fuel cells that were seen as too far out).

One of the challenges faced was that in many emerging technology areas of automobiles, standards were set not by the vehicle manufacturers but by their Tier 1 suppliers (such as the AUTOSAR standard of Bosch). These Tier 1 suppliers had old loyalties to specific manufacturers, but the other tiers aligned with the stand taken by the Tier 1 supplier. The Tier 1 suppliers controlled the intellectual property. So, if for example Tata Motors wanted to use the electronics covered by one of these Tier 1 supplier standards it would have to shell out high costs/royalties. An attempt would be made to create alternatives for Indian manufacturers. In some areas the contrast was stark – e.g. in electronics, a high-end foreign car would have 70 microprocessors whereas in India there would be only 4 or 5. The areas of microprocessor use would also be different. Software standards would help Indian players. In spite of the existence of a large Indian software industry, this is of not much help to auto companies because the software companies lack domain knowledge. The fear was that Indian component vendors may get locked out one day because of lack of software / electronics expertise.

A total of about Rs. 0.35 Billion has been spent on 10 consortium projects since the inception of the CAR programme. About one fourth to one third of the project budget goes to the lead institution; but the lead institution is the conduit for the funding of other dimensions of the project. The institution can commission work at the companies and pay for this e.g. prototypes, machinery, etc.

The 10 consortium projects funded were as follows:

Table 8. List of Collaborative R&D Projects under CAR Programme

	Project Title	Partners
1	Engine Management System for Petrol Powered Small Vehicles	IIT Bombay, IIT Madras, TVS Motor Company, Ucal Car Fuel Systems
2	Vehicle Tracking and Control Systems using GPS/GSM Technologies	IIIT Bangalore, Ashok Leyland, Lattice Bridge, Bharat Electronics, Pallavan Transport Corporation Consultancy Services
3	Wi-FI Based Vehicle Tracking	Amrita Vishwa Vidyapeeth
4	Development of Tailor Welded Blank and Hydroforming Technology for Automotive Weight Reduction	ARCI Hyderabad, IIT Bombay, Tata Motors, Mahindra & Mahindra, Tata Steel, ProSim
5	Acoustic Diagnostics for 2-wheeler Engine Assembly Line	IIT Kanpur, IIT Delhi, IIIT Allahabad, Kritikal, Knowledge Online and TVS Motor Company
6	Low cost Flexible Automation using Robotic Arms	IIT Madras, Systemantics, IIT Bombay, Magstorq, TVS Motor Company, Mahindra & Mahindra, Sona Koyo Steering Systems, TVS Lucas, Bosch
7	Process Development in Semisolid Forming and Squeeze Casting of Aluminium Alloy Components for Automobiles	IISc Bangalore, Sundaram Clayton, TVS Motor Company, Mahindra & Mahindra
8	Use of Straight Vegetable Oils in IC	ICAT/NATRIP, IISc Bangalore, IIT

	Engines	Madras
9	Ultracapacitor for Electric & Hybrid Vehicles	IISc Bangalore, IIT Kharagpur, NCL Pune, CECRI Karaikudi, Kaptrinics, NED Energy
10	Development of Automobile Components through Electromagnetic Forming Process	Bhabha Atomic Research Centre, Advanced Materials and Processes Research Institute, IIT Bombay, IIT Delhi, Fleur-de-lis Technologies, + Automotive Companies

8. Case 8: National Facility for Semisolid Forming, Indian Institute of Science, Bangalore

8.1. Profile & Brief History (Incl. Areas of Expertise & Infrastructure)

National Facility for Semisolid Forming (NFSSF) at IISc, Bangalore, is a research and development centre focused on new aluminium casting technologies for the automobile industry. It was set up by faculty in the Materials & Manufacturing and Thermal Sciences and Fluid Mechanics Groups in the Mechanical Engineering Department of the Indian Institute of Science at Bangalore.

According to the *Indian Foundry Journal*, NFSSF produced the first ever semi solid casting in India – an auto component in A356.2 alloy. The SSF billet used for the casting was made using an Electromagnetic Stirrer designed and fabricated by NFSSF. The special feature of the casting so produced is its excellent surface finish, the absence of porosity and the presence of the desired microstructure (dendritic globular).[xxxviii]

The NFSSF itself was originally set up by the Ministry of Mines of the Government of India to explore alternate uses for non-ferrous metals. Subsequently other government departments such as the Department of Science & Technology, and the Defence Research and Development Organisation have been involved in supporting the NFSSF.

8.2. Collaboration with Automotive Industry[xxxix]

8.2.1. Long-term Research

One of the co-founders of the NFSSF, Prof. Pradip Dutta, joined IISc in 1996. In the first few years, he did not come across many opportunities for collaborative research with industry. The situation changed after 2000 when General Electric set up its multi-disciplinary research centre at Bangalore.

In 2000, a team from General Motors visited IISc. This team was from the Materials and Processes group within GM R&D. They were looking for processes that could help them create components and structural elements with lower weight ("lightweighting") and good material properties.

GM R&D works with academic institutions in two modes: (1) a project mode where they give contracts/purchase orders with fixed deliverables and well-defined delivery periods; and (2) a long term collaborative mode. The latter is managed through a Collaborative Research Lab (CRL), a group from within the GM R&D organization. These long term collaborative projects are managed under a Master agreement (MOU). In Phase 1, the long term collaborative programme involved 5 -10 umbrella projects. The themes of these projects are inter-linked. These long term collaborative projects are usually centered on fundamental studies and publication is encouraged. GM has more than 100 years of experience in figuring out how these projects fit in with their own requirements, and also how to ultimately dovetail these with commercial developments. The long-term collaborative projects also have the flexibility to change direction if some new insight emerges and they can even allocate more money if necessary.

Prof. Dutta's group has completed two phases of the long term collaborative programme with GM and moves into its 3rd phase in 2011.

Though the MoU with GM contains an IP sharing agreement, most of the project work is in the knowledge generation mode. Publication is encouraged though prior permission of GM is required. Students are encouraged to spend their summers at GM labs. Faculty also visit GM, and sometimes collaborate with others in the US. The major learning from interaction with GM has been in terms of where technology is moving.

Other institutions like IIT Kharagpur have similar arrangements with GM.

8.2.2. Process Development

Since 2002, Professor Dutta has also been involved in the Collaborative Automotive Research Programme (CAR) of TIFAC. This is in the area of Development of Processes for Lightweighting.

The first phase of this programme was the creation of the NFSSF. This was initially set up with bulk funding from the Ministry of Mining which was looking to promote the use of non-ferrous metals in the automotive sector. This facility has been focused on the development of technology and machines for semi solid forming. This technology was first invented at MIT in the late 1970s. Some metals when stirred before solidification display a globular structure. Morten Flemings found that when reheated, these could be cast in a semi-solid form with interesting properties – basically, porosity is eliminated, thus enabling thin-walled structures with high strength.[xl] The overall process involves semi-solid forming and advanced die casting.

The patents for the original development of this technology were bought by Toyota and other high-end automotive companies. However, these companies did not exploit the technology much because of the high costs involved (3X cost of ordinary materials) and used it only in a limited set in components for high end automobiles. In the late 1990s, the patents expired, and external interest revived. The Chinese have a major interest in this area, while the Europeans are well ahead in theory.

The development of indigenous technology was completed in 2006-07 with the implementation of an electromagnetic stirring process. However, this had a relatively narrow range of success.

In 2007, as a part of the CAR programme, TIFAC asked why this technology could not be commercialized with a consortium of auto companies, with the help of SIAM. Six companies came together – Sundaram Clayton, Mahindra, Tata Motors, TVS, Bajaj and Hindalco (for making the billets). The objective was to establish the feasibility of the component technology and to make billets of the new material. Early on, Hindalco decided not to make the large capital expenditure involved, and instead IISc took up the task of making the billets itself.

The next phase will start in June 2011 with an emphasis on billet making. The Automobile Research Association of India (ARAI) will be involved because there will be a major testing component. A simplified billet making process that uses gravity will be used. This process was instigated by a small scale entrepreneur who thought that the original process of IISc was too complex and involved too much deviation from existing practice. As a result of this simplified process, the cost of the billet will be only 10% more than the normal billet.

8.2.3. Experience of Collaborating with Industry

Programmes like CAR pose the challenge of using government money effectively. Generally, industry's contribution is in kind and time rather than money. The experience of this group is that to make industry and academia work together someone has to walk the extra mile. In this programme IISc had to go into some non-research activities like getting dies made in order to make the project move ahead. Such activities involve tendering and take a long time, and institutions like IISc are not ideally geared towards such activities.

9. Case 9: Professor Shashikanth Suryanarayanan's Laboratory, IIT Bombay

9.1. Profile & Brief History (Incl. Areas of Expertise & Infrastructure)[xli]

Professor Shashikanth Suryanarayanan (Shashi) is an Assistant Professor in the Design Engineering group of the Mechanical Engineering Department of the Indian Institute of Technology Bombay (IITB). IITB is one of the Indian Institutes of Technology set up as part of a far-sighted initiative by the government of India over 50 years ago.

Prof. Shashi did his Ph.D. at the University of California at Berkeley.

Prof. Shashi's research interests are in the areas of Control Systems Design and Mechatronics. He seeks to use the tools provided by systems/control theory in the development of disruptive technologies for intelligent/clean transportation.

According to Prof. Shashi, the philosophy is as follows: "Over the years, automobile subsystems have evolved into highly complex mechanical entities. The trend today is to replace mechanical complexity with intelligent mechatronics. Mechatronic systems promise to provide the benefits of cheaper costs, better vehicle handling performance, cleaner engines, lighter vehicles, reconfigurability etc."

Prof. Shashi's group has initiated projects in automotive controls with Indian companies in pursuance of this broad trend. His group has worked on the following projects:

- Development of a low-cost Engine Management System for Petrol-powered Small Vehicles Funded By: Technology Information Forecasting and Assessment Council & Office of the Principal Scientific Advisor, Govt of India. Participating partners: IIT Bombay, IIT Madras, TVS Motor Company Ltd, UCal Fuel Systems Ltd and TIFAC.
- Development of a Steer-by-Wire Prototype Funded By: Sona Koyo Steering Systems Ltd.

9.2. Collaboration with Automotive Industry[xlii]

CAR was initiated by the PSA based on a similar programme of Collaborative Auto R&D in the US involving US auto majors like Ford and GM. The US government funded universities in this programme. The programme itself had a broad mandate – technology development, prototyping, standard development, building testing infrastructure.

CAR programme was intended to support projects done by universities of a pre-competitive nature. These projects were expected to have medium term relevance.

For Prof. Shashi, it was natural to get involved with CAR. He had a background in controls and had just returned to India. He was idealistic, and this seemed to be an interesting opportunity to work with industry. Proposals were invited by the government (TIFAC). By the rules of the programme, a consortium was to be formed. The role of the consortium was largely to validate ideas.

The project had several useful outcomes. A number of people got trained on emerging technologies. They were able to build something that no Indian group has been able to do - a fuel injection system for small engines that matches the best of international giants. This was implemented and demonstrated in a real vehicle. It exceeded expectations. It became the setting for a new company set up by Prof. Shashi. However the prototype developed under the CAR programme was not commercialized.

Prof. Shashi was not surprised that the prototype was not commercialized because there is a big gap between building a prototype and commercializing it – you need to understand technology, market, pricing; organizational priorities also come in the picture. There has to be enough time, and the top leadership of the concerned companies has to be interested.

10. Case 10: Centre for Product Design & Manufacturing, IISc, Bangalore

10.1. Profile & Brief History (Incl. Areas of Expertise & Infrastructure)

The Centre for Product Design and Manufacturing (CPDM) is a Centre of Excellence at the prestigious Indian Institute of Science (IISc), Bangalore. IISc is arguably India's top science and technology university.

The CPDM focuses its research on the areas of Design Theory and Methodology, Human Factors in Design, PLM and, Vehicle Design, Simulation and Testing. It offers courses at the Masters and Doctoral levels.

CPDM advocates a synthesis of research in design and design in practice based on a belief that product designers and design researchers are complementary to each other. "While designers create products to improve the society, design researchers develop effective design methods and techniques for better design."[xliii]

10.2. Collaboration with Automotive Industry[xliv]

10.2.1. Research Projects

CPDM faculty have been receiving funding from automobile companies for open-ended research. For example, General Motors has funded faculty on more abstract research projects which do not have immediate applications. Professor Deb of CPDM is working on modeling dynamics. Prof Gurumoorthy of CPDM is working on Large Assembly dealing with design changes. These are 3-year research projects without the immediate prospect of commercial outcomes. Research papers and some algorithms are the principal outcome of these projects. While these projects have been completed, a new project on more sustainable drivetrain for 3 wheelers is under discussion.

10.2.2. Design & Development Projects

CPDM is involved in several projects related to design of automotive systems. The main areas of work are:

1. Safety issues, crash resistance, passenger and pedestrian safety
2. Joining materials and processes for crash resistant structures
3. Electric mobility, electric vehicles

CPDM has had interaction with large Indian automotive companies such as Tata Motors, Mahindra & Mahindra and Ashok Leyland.

CPDM's most intense relationship has been with Tata Motors on joining techniques for non ferrous alloys with a particular emphasis on strength and durability. Tata Motors was seriously involved in this project and even took a space in the facility of the Society for Industrial Development (SID – the arm of IISc that facilitates industry collaboration) at IISc to be close to the project. One employee of Tata Motors registered in the PhD programme. Though technically successful, it is not known to what extent Tata Motors has used this technology / development in its own facilities.

Mahindra & Mahindra used the services of CPDM for a crash analysis project. However, there has not been any significant repeat interaction.

Ashok Leyland has also been involved in a one-off exercise on crash evaluation. However, the Ashok Leyland connection also led to IISc offering three workshops for SAE on noise & vibration, design and crash and safety.

CPDM faculty also work through the APDAP (Advanced Product Design and Prototyping) Centre at IISc. Faculty bid for participation in external projects through the ADPAP. Through this channel, they have done projects for several companies including TVS, Pricol (an instrument and dashboard manufacturer), Minda (an Indian company involved in the manufacture of automobile components), IFB Autolive, Ford, etc. These design projects are not blue sky projects. They are reasonably known technologies. To bring in an element of novelty, CPDM tries to do the design from scratch.

The project for Pricol was on instrument clustering. It involved value engineering to reduce cycle time for manufacturing and reduction of cost. The design was supplied to Pricol but was perhaps not implemented because of some unrelated issues at Pricol. The project for Minda was of a similar nature and involved value engineering for 2-wheeler instrument panel.

The project for IFB Autolive involved the design of a passenger restraining system under very tight and increasingly stringent weight constraints. The solution was technically very good, but not accepted/implemented by the client due to changing priorities. The faculty involved are now trying to retrieve the product to pursue other possibilities.

A current project is for a cycle manufacturer to develop an all composite (high end) bicycle. The project involves material selection and characterization.

A roofrail for a new car was developed for Ford. This is likely to be used on international models of Ford.

10.2.3. Experience working with Companies

CPDM's experience has been that, relatively speaking, Indian manufacturers have less patience to work with academic institutions. Almost all companies (Indian or foreign) negotiate hard and seek to squeeze costs out of the project even though they change the specifications often. Indian companies expect complete solutions while MNCs are relatively happy with lab prototypes. From CPDM's perspective, the biggest challenge has been in completing projects on time.

10.3. Synthesizing Across the Cases: Innovation Trends & Role of Academia / Public Research Institutions

Innovation in the Indian automotive sector is broadly driven by the following:

1. Emission Norms: The increasing stringency of pollution control/emission norms has been perhaps the single biggest driver of innovation in the automotive industry. Their continuing impact is very visible in the innovation priorities of Ashok Leyland, M&M and TVS Motor Company.

2. Competition: The need to differentiate products from existing products has been another driver of innovation. This includes creation of new segments (M&M Scorpio, Bajaj Pulsar, Tata Ace) and the development of disruptive products (Tata Nano). Another result of competition is changes in styling, appearance, etc. (particularly visible in Bajaj and M&M).
3. Fuel efficiency / cost of use: Indian consumers are price and value conscious. They are constantly seeking a better value proposition. They want lower costs but don't want to give up features or benefits. Volatile and increasing fuel prices continue to induce companies to look for options that enhance fuel efficiency. This is particularly evident in the 2-wheeler industry where consumers want fuel efficiency, styling and power. The emphasis on lightweighting as seen in the case of tube supplier TPI and more complete combustion (multiple spark plugs used by Bajaj and TVS) are specific examples of this trend. Cost reduction is also a major driver of the Government's Collaborative R&D Programme.
4. Alternate Fuels: Rise in fuel prices and their volatility has drawn attention to alternate fuels, electric cars and hybrids. This trend is in its infancy, but there are signs of Indian companies (e.g. M&M) paying more attention to this in their most recent R&D and strategic (e.g. acquisition of Reva) plans.

Before we investigate the implications of these trends for industry-academia relationships in the future, it is useful to reflect on what role industry-academia links have played in the last few years as covered by these case studies.

1. By and large, there have been limited links between automotive companies and academic institutions in the automotive sector.
2. In the absence of the CAR programme, these links would have been even weaker.
3. The most prevalent role of academia is in competency development and training. Other major activities include analytical studies and testing.
4. Academic institutions can provide some services needed by automotive companies (e.g. the design services provided by CPDM at IISc) but academic institutions may not have a distinctive advantage in providing these. They will have to be cost competitive with other providers to win such projects. And the research content will typically be low.

5. Since most Indian companies start from a small resource base, they are very demanding on what they get from institutions and what tangible results are obtained. This is in contrast to the long term research programmes being funded at the Indian Institute of Science by General Motors.
6. However, some companies have been willing to support long term education / research initiatives of academic institutes in the larger social interest e.g. Ashok Leyland's sponsorship of the Design Engineering programme at IIT Madras.

From our discussions with the CAR programme officials and the academics involved, we learnt that this programme was very useful in terms of creating a network of people in the broader automotive innovation system. We also learnt that:

1. Not too many Indian companies were keen to join the CAR programme consortia even though there was no financial commitment expected.
2. There is an inadequate number of mature engineers in the country. As a result, the companies find it difficult to evaluate new technologies or innovations. Things are changing slowly as more and more people with experience and expertise are coming in (often returning from the developed world).
3. Corporate partners provide support only in kind. Often, the firm's support is constrained by its own priorities, and the institution undertaking a project gets only the residual time or capacity available.

One of our respondents tried to explain that the limited interest of companies is natural:

> "The role of academia in innovation has to be understood in the context of the automotive industry. The industry is very consolidated and typically not more than 5 – 10 companies dominate every space. Decisions regarding technology are not really made in India. Local decision makers only decide on timing – the development happens elsewhere. Local innovation – in terms of features – does not involve the kind of technology where academics can participate. Hence the role of academics is limited.
>
> "In India, technology is more an adaptation story, driven by the process of homologation or localization.
>
> "Academics here can at best put out ideas or prototypes that have promise. The Indian environment has some shortcomings – you need someone listening to you who can do something beyond patting your back. Whatever contribution is

made is in spite of the system. This is not because of any sinister design on the part of the companies; it is because not enough work is done here, there is no critical mass of expertise, no broader ecosystem, no confidence and credibility that something worthwhile will emerge. The level of expectations from academia is low. At best, companies hope to get some trained manpower out of the projects. These employees can manage the acquisition of technology from outside.

"The big challenge in the automobile industry is that quality and reliability is essential. No idea can go into a product without extensive testing. The overall process involves a long cycle time. Unless you have gone through this cycle a few times, you won't have confidence about how it works."

Indian automotive companies have been steadily increasing their outlays on research and development. For many companies, it is now in a healthy range of 2-3% of sales. Their ability to find companies or consultants who can fill in their gaps, particularly from outside India, is well developed (e.g. development of Tata Indica and M&M Scorpio). They have a good ability to integrate across vendors and across technologies; they also appear to have learnt how to absorb technology within a short timeframe.

What is not as clear is how they will manage emerging technologies like hybrids and alternate fuels. These are areas in which consultants will be difficult to come by. And the expertise available with the employees of Indian companies, even those who have had extended stints with global auto companies, would be limited.

10.4. Policy Implications

Before we make recommendations for polices that could enhance the innovation ecosystem in the Indian automotive sector, its useful to summarise the existing policy framework that supports innovation.

10.4.1. Current Policy Support for Innovation[xlv]

India already has several policy measures in place to support innovation.

Support for Academic Research: Academic institutions can apply for project-specific research grants from the Department of Science & Technology (DST), Government of India, under the SERC programme. This programme is being upgraded into a full-fledged National Science & Engineering Foundation that will enhance autonomy of the grant programme as well as the quantum of support for academic research. The DST administers joint R&D programmes with other countries that offer support for basic research. Apart from the DST, other ministries of the Government also have support programmes for scientific research.

Support for Industrial Research & Development: From a taxation perspective, India already has a supportive environment for innovation. Tax breaks are available for R&D spending. Automobiles and automobile components are already included in a special set of industries that have a higher (i.e. 150%) deduction of R&D. Payments for R&D to designated academic institutions and national laboratories are also entitled to a higher level of write-offs. Besides taxation benefits, the government offers excise duty concessions for locally developed technologies that are covered by patents in two or more specified countries. Under its Technology Development and Demonstration Programme (TDDP), the Department of Scientific & Industrial Research offers low-cost loans for technology development. The Technology Development Board (TDB) offers low cost loans for technology commercialization.

Support for Collaborative Programmes: The New Millennium India Technological Leadership Initiative (NMITLI) of CSIR supports joint R&D programmes in emerging areas between companies, R&D institutions and academic institutions by providing grants for the portion of work undertaken by public R&D / academic institutions. Another collaborative initiative supported by the government is a scheme to support the creation of Centres of Research Excellence (COREs) in engineering institutions; under this scheme managed by TIFAC, the government provides a matching grant to the contribution of industry and the institution.

Sector-specific Programmes: The CAR programme, discussed above, was one of India's first consortium R&D programmes. The Government has other sector-specific support programmes for innovation such as the Small Business Innovation Research Initiative (SBIRI) of the Department of Biotechnology that offers research grants to small biotech companies and loans to larger companies. The Drug Development Programme of the DST supports joint R&D projects between pharmaceutical companies and research institutions by underwriting the work undertaken by the R&D institution.

Support for Technology-driven Entrepreneurship: The Government of India has two main programmes. The National Science & Technology Entrepreneurship Development Board supports the creation of incubators in technology and management institutions, and provides seed funding for some of the enterprises housed in these incubators. The Technopreneur Promotion Programme (TePP) provide grants and loans to entrepreneurs who are trying to scale up their innovations.

It is clear that India has a plethora of programmes designed to strengthen academic research, collaborative R&D programmes, and R&D by industry. We now identify gaps and propose additional policy measures.

10.4.2. Strengthening the Role of Academic & Research Institutions in Automotive Innovation

Our earlier discussion identified the following roles played by academic research and research institutions in automotive innovation:

- Teaching / training / capability development
- Long-term research
- Analytical, design and testing services
- Pre-competitive R&D (such as in the projects of the CAR programme)

In addition to the existing policies of the government, some policy measures that would help enhance these roles are:

Creation of Centres of Excellence in Areas related to the Automotive Industry: There are a number of emerging areas in automotive technology including new materials, alternate fuels, and electric and hybrid vehicles. These will be the areas of the future, and in many cases there are no established technologies. Firms will be seeking to learn and develop capabilities in these areas. The government would do well to give grants to the leading educational institutions to create centres of excellence in these areas.

Institute Challenges/Contests at the National Level: Another way of creating deep yet relevant capabilities in academia is by throwing challenges to university teams of professors and students to develop new technologies. The DARPA in the US has used this method very effectively to create capabilities for the development of unmanned and remotely controlled vehicles that work reliably on non-uniform terrain.

Mandate Practical / Design Projects for Engineering Students: Another useful way to enhance innovation and design capabilities among students and in academic institutions is to require all graduating engineering students to complete a working design prototype before they graduate.

Simplify Administrative Functioning / Rules for Commercial Activities by Educational Institutions: Academic institutions face many bureaucratic and administrative challenges in executing large collaborative projects (such as the CAR programme) or participating in consulting and design projects. Academic institutions should be not only permitted but encouraged to set up non-profit corporate entities that can perform commercial activities on behalf of the university / academic institution in a more effective manner.

Facilitate Boundary Spanners between Academia and Industry: Industry and Academia often speak in different languages, and one of the challenges in promoting academia-industry collaboration is having people on both sides who understand each others' language. Enhanced mobility between academia and industry would help such boundary spanning activity. The government, industry, and academic institutions should get together to create innovative programmes to enhance such mobility.

Allow faculty to start and participate in new ventures: Service rules often prevent faculty members from participating in new ventures as investors or promoters. But, we have seen in Case 9 how it is sometimes necessary for a new venture to be started to take a new technology to market when existing players are unable or unwilling to commercialise the technology. Government should proactively amend service conditions to allow such ventures to be created, and support the ventures through incubators and seed-funding schemes.

10.4.3. Other Policy Implications

In the Indian case, we have seen one set of companies actively engaged with Indian educational institutions in the context of innovation is the Indian companies such as Tata Motors, M&M, Ashok Leyland and TVS Motor Company. While direct support for the development of local firms may conflict with WTO rules, there is a case for support of a local automotive industry to enhance domestic innovation efforts.

The Collaborative Automotive Research (CAR) Programme has been quite successful. Apart from creating a large network of people with automotive expertise, the CAR programme has resulted in specific outcomes such as the demonstration of semisolid forming for the first time in India. There is general agreement that a success rate of 20-30% is a good rate to achieve for such a programme, and by this measure the CAR programme has been successful. Government should therefore continue to support such collaborative research programmes in specific areas which are relevant to the future development of the Indian automotive sector.

But there are some learnings from the CAR programme as well that could be applied to future consortium-based programmes:[xlvi]

1. Such programmes should insist on high quality standards and focus on attracting really committed applicants.
2. There needs to be a strong review process. Since new technology development has to be globally competitive, the government should not hesitate to call in the best people in the world to do reviews if there is inadequate expertise available locally.
3. Companies should be encouraged to play an active role in such pre-competitive collaborative programmes. But they should not have the final word on deciding the continuation of such projects because they may lack the expertise or they might stop the project due to extraneous considerations.

Acknowledgements

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[xii] This section and the next are based on an interview with Mr. S. Mohan, one of the leaders of the Rane group's innovation initiatives on January 13, 2011.

[xiii] This case has been written based on information in the public domain (primarily from the company's annual reports) and an interview with Dr. Aravind Bharadwaj, CEO, Automotive Informatics (a joint Venture of Ashok Leyland). Dr. Bharadwaj was earlier the head of the Advanced Engineering Group at Ashok Leyland. He was one of the

founders of the Collaborative Automotive R&D Programme of TIFAC, Government of India.

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[xv] Ashok Leyland Ltd., Annual Report 2006-07, pp. 6-7.

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[xviii] Ashok Leyland Ltd., Annual Report 2006-07, p. 12.

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[xlvi] These recommendations came from one of our interview respondents.

CHAPTER 3

Resources of Innovation in Indonesian Automotive Industry the Role of University and Public Research Institution (PRI)

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The study attempts to reveal external resource of innovation in Indonesian automotive industry. More specifically, the study tries: i) to identify the variation of innovation sources in the company's innovation process, ii) to differentiate types of innovation within the company based on internal and external resources; and iii) to find the role of university and public research institution as the external resource of company innovation. Data and information were mapped and analyzed by using the framework of sectoral innovation system (SIS).

The study found that: first, the resource of innovation in Indonesian automotive industry diverged from individual and organization actors both from internal and external resource. The innovation resource mostly came from the internal organization of company. Second, the external resource of innovation in Indonesian automotive industry mainly came from company's competitor that stimulates the creation of new product in sharp market competition. Third, the roles of university and PRI as external resources of innovation in Indonesia were very small. Fourth innovative PRI has shown the potency to be the external resources of innovation for local automotive companies. Fifth, innovation cooperation between industry and PRI was linked by R&D matching grant provided by the government. Sixth, The PRI's support to innovative industry occurred in the form of technical assistance.

The study proposes some policy implications for the development of Indonesian automotive industry. With regard to the role of university and PRI in the future, the study implies that: i) university needs to improve the graduates quality in automotive engineering and perform the industrial application of research output, ii) innovative PRI should be promoted to commercialize its product innovation, and iii), Innovation cooperation between local automotive industry and PRI should be strengthened and the PRI's support to locally innovative industry should be expanded in the future.

Key words: Sectoral, innovation system, automotive, knowledge source, policy

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1. Introduction

1.1. Background and Objective

In the era of globalization, R&D activities inside company itself have shifted toward the utilization of external resources. The success of corporate innovation is determined by the use of the best knowledge comes from both internal and external resources. Such a drifting has been driven by the fact that source and flow of knowledge and skill are becoming available from outside, whether from individual and organization. The company has adapted to see and find new product and also ways to increase efficiency and effectiveness through inter-company collaboration, cooperation with supplier, and alliances with competitor. The collaboration becomes an imperative step to create profit in the paradigm the so-called open innovation. (Chesbrough 2006)

The utilization of external knowledge source occurs through interaction among business, university and other organizations such as customer, supplier, university researcher, and competitor. Through such an interaction the company imports the best knowledge with lower cost and faster process from the best resources in the world, rather than by generating and creating within their own company. However, the utilization of external knowledge source through collaboration can leak key technology to competitors. This is one of the reasons for the company's slow interest in collaborating on innovation. Generally, big companies supported by advanced technology research tend to collaborate with university and research institution as their source of external knowledge, while small and medium companies doing innovation for minor and gradual improvement generally rely on business services as their source of external knowledge. The utilization of external knowledge has become indicator of company's innovative performance. Chen's research finding confirmed that the higher the openness to collaborate the better the innovative performance of Chinese firms (Chen *et al.* 2008)

Other important reasons for the utilization of external knowledge in innovation are as follows: i) the company can focus on innovation activities in areas where they have a clear competitive advantage; ii) the use of R&D funds will increase in the most promising innovation activities; iii) the capacity of R & D will improve through investment in R&D cooperation, without sacrificing their own innovation and technology products; and iv) the culture of collaboration with external innovators in developing the joint technology will improve.

Furthermore, the benefits of company’s openness as the source of external knowledge for other companies are as follows: i) the company’s profit will rise by giving a license or develop spin-off companies; ii) overhead and the additional cost of HRD will reduce, i.e. the recruitment and training for business expansion, so that company personnel can focus on the higher value of innovation activities; and iii) the culture of knowledge sharing through cooperation with other companies will enhance, and technology commercialization cost and risk will reduce.

This study is concerning the external resource of innovation in Indonesian automotive industry. The study will assess the state of knowledge resources from companies, universities, and research institutions. There were several previous studies on innovation in Indonesian automotive sector. However, these studies did not focus on the external resources of innovation viewed from innovation system and evolution perspective. The states of studies related to innovation in the automotive industry in Indonesia are excerpted as follows.

Aswicahyono & Kartika (2009) revealed the importance of Japanese investment in the development of Indonesia's automotive industry. Large shareholding of principals play important role to develop the automotive industry investment in Indonesia. Hiring local engineers have important function to improve technology learning to enhance local capability. Viewed from value chain, Indonesia should strive to be the attractive location of investment activities that generate high value of the Japanese automotive industry. Indonesia should attempts to shift from mere assembly to become either the regional research center or logistics service center in the global production of MNCs. Indonesia should: i) create high-quality of R&D personnel graduates from world-class university in engineering field, and ii) improve the quality of transportation and telecommunications services, those are functional to support the MNC's global production network.

Layton (2007) found out the importance of Indonesian automotive component industry to improve its quality of non-OEM component. The automotive component industry should: i) apply the industry standard-based brands and seals of quality; ii) increase the downstream technology transfer to upgrade the product of component industries; iii) promote the selected high value of component products into the new mid-market. The application of high value standards and market based products will effectively integrate the non Original Equipment manufacture (OEM) automotive component industry from second and third tier to the higher tier. It is because the Indonesia products may not compete in price, the standardization of non-OEM product quality is a justified strategy in facing of cheaper imported products in the expanded Indonesian market.

Ricardo & Hastuti (2009) showed the results of survey on the Indonesian automotive component industry that generally performs medium level of innovation activities, namely tooling-up (improving the equipment's technological performance) and industrial engineering (making some changes and engineering on existing machinery equipments). Only certain medium scale industry performs high-level innovations such as experimental research and development, including purchasing (acquisition) of machinery with improved technological performance. There are some constraints of innovation activities in component industry namely: lack of personnel knowledge to conduct innovation activities, lack of fund to finance the expensive innovation, and risk of low sales because of loosing in price competition with imported non-OEM component products.

Riyanto, *et.al.* (2009) revealed the patterns of innovation in automotive component SMEs including product, process and organizational innovation. Product innovation tends to occur at the local small and medium enterprises (SMEs) that produces component to fulfill the demand for after-market parts. The companies exploit their creativity to meet the needs of after-market parts. Process innovation tends to occur in the SMEs by joint venture, which manufactures OEM parts according to designs and specifications determined by principals. The companies practice the innovation process such as designing process technology and shortening production process (time line) for the increase of productivity and competitiveness. Organizational innovation also tends to occur in the SME by joint venture which obtains technology management transferred from the principal. The company acquires knowledge through training on the implementation of JIT and TQM concepts to enhance efficiency and competitiveness. The joint venture SMEs works in vertical specialization of production that is integrated with the principal, in which the key inputs of production such as trademarks, designs and specifications are defined and owned by the principal.

Dhewanto & Umam (2009) claimed that the public research institution (PRI) in Indonesia has not succeeded to commercialize automotive technology products due to low in quality and standard demanded by market. The LIPI research center for electricity and mechatronic has build and produced "electric car" the so called "Marlip", resulted from extensive research since 1998. The car has 80% local content and being available in 8 variants. The car commercialization has to find the industry for mass production. Industry has not seen PRI as external resources to acquire technology. It is therefore, government stimulus is needed to encourage industrial willingness to realize industry-university partnership.

The objective of study is to reveal external resource of innovation in Indonesian automotive industry, with special attention to the role of university and PRI. The study will answer three questions: i) what are the variations of innovation sources in the company's innovation process; ii) what are the types of innovation within the company based on internal and external resources, and; iii) how are the role of university and PRI as the external resource of company innovation. Data and information will be mapped and analyzed by using the framework of sectoral innovation system (SIS). The findings will contribute to enrich empirical evidence of the theory of innovation systems and evolution as the foundation of sectoral innovation system.

1.2. Analytical Framework

This study uses the analytical framework of sectoral innovation system (SIS) developed by Malerba (2004). Viewed from system perspective, SIS emphasizes the processes of relation, interrelation, interaction, interconnection in the system evolution. Seen from time horizon, the evolution in SIS explains how: i) the process of variation and selection inside the system occurs in the mid-term, ii) the process of adaptation in developing system capability takes place in the long term. The strength of SIS model lies in its ability to explain how and why the innovation process occurs in one sector.

How and why the processes of creation, absorption, distribution and utilization of knowledge and innovation occur in one sector or company. SIS model explains the differences between sectors or companies based on differences in the accumulation of knowledge and innovation capabilities in each sector or company. Theoretically, the SIS model is an analytical tool derived from the theory of innovation systems and system evolution.[3]

SIS model contains three main components namely: i) knowledge and technology, ii) actor and network, iii) institutional and demand. The interaction of three components in the system is exhibited in diagram below. The learning process in accumulating knowledge and technology is formed by two "learning loops", namely learning from external and internal resources. The actors, both individual and organization are external as well as internal resources in learning to accumulate knowledge and technology. Meanwhile, demand is the resources of external learning to accumulate knowledge and technology. The interaction among actors of individual and organization occur through networks, those are market and non market networks. The relations in the network are created and influenced by institution, namely market and non-market institution. The whole processes of innovation in SIS always consider and analyze the influence of actors, networks and institutions. See Figure 1.

First, knowledge and technology are the essence as well as boundary of SIS. The boundary of SIS covers the area of knowledge, technology, engineering, design, and operation. Knowledge in SIS is viewed from access and accumulation of knowledge. The access of knowledge can occur toward internal and from external sector. The access of knowledge toward internal resource (i.e. it is accessed by a competitor) will reduce the appropriateness. Access of knowledge and technological advancement from the external resources (i.e. universities, research institutions, suppliers, users) affect the sector's opportunities in innovation. Meanwhile, the accumulation of knowledge and technological capability are the results of knowledge creation and acquisition of

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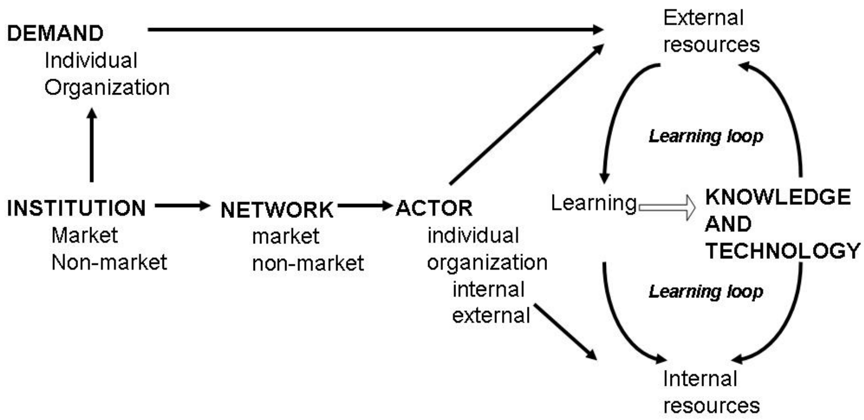
[3] About the integration of these two theories into a model of SIS see Malerba (2004:11-15). It is important to note that the SIS model is not relevant to explain the cluster and strategies of each sectors or companies, because the SIS does not analyze external conditions and others combinations of input factors in producing outputs such as products, productivity and competiveness derived from theories of economics and management.

knowledge in long run that comes from the whole process of innovation. The mechanism of knowledge accumulation occurs through the process of creation, absorption, acquisition and utilization of knowledge. Then, the accumulation of technological capability is the results of learning in internal resources (learning by doing, using, and searching) and learning from external resources (learning from the progress of S&T, actors' interaction, and technology spillover).

Figure 1. Sectoral Innovation System Interaction



Source: Malerba (2004)

Second, actor and network are the elements and structure of SIS. The actor is the agents of systems those compose of individual and organization. Individual actor includes consumers, businessmen, and scientists. The actor of organization comprises of companies with their internal units (i.e. R&D, production, and marketing) and external organs (i.e. users, suppliers, universities, research institutions, financial institutions, government agencies, business associations, business principal). While the network describes the ways of various actors connected in the system. The network provides road to access knowledge and technology in the system. The variations of access are characterized by market and non-market relationship. The relationships through market can be occurred through licensing, joint venture, contract, subcontract, integration, acquisition, alliances, collaboration, cooperation, competition. While non-market relationships can be taken place through consultation, dispatching of personnel to learn, training, meeting, service, lobbying, information exchange, command, collective action, partnership.

Institution and demand are the *third* component. Institution is the law, rule, standard, norm, tradition and convention that shapes interaction and influence the actors' action in the system. The interaction of actors in the system occurs through binding contract and non-binding agreement. The binding contract can be formed by formal law (IPR, patent, trademark) and government regulation (incentive, procurement, preference, deregulation, and facility), then non-binding agreement form such as convention. Besides, market institutions such as monopoly, oligopoly and competition, furthermore non-market institutions comprises of the sociopolitical factors i.e. political guidance, collusion, and nepotism that could affect the action of actors in the system. The national institution may influence the patterns of sectoral development in a country (i.e. sectoral shift of national planning and policy directed by national agency). Furthermore, demand is an agent that interacts with producers. The agents are represented by consumers, corporations, and government sector. The interaction of agents with producer is formed and influenced by both market and non-market institutions. The demand has function as the pull factor of innovation, especially innovation for solving the problem of demand (i.e., innovation based on input from users and suppliers).

The application of SIS framework in this study has some advantages to achieve the objective of studies. i) it facilitates to indentify the variations of elements combination in the company's innovation based on interactions in the system; ii) it assists to categorize the type of innovation within the company based on internal and external resource, and; iii) it makes the ways to analyze the role of university and PRI as external resources of innovation for automotive industry. The analysis based on information from interviews and secondary data of ten companies, universities, PRI, business association, and government agency.

1.3. The Structure of Report

This report is structured as follows. The second section will explain past trends and current developments in Indonesian automotive industry. The description focuses on mapping the main factors that has shaped the dynamics of the Indonesian automotive industry in the long run. The third section will explain the evolution of Indonesian automotive industry, viewed from dynamic capability. The patterns of evolution will be explained by the dynamic of company's ability in absorbing knowledge, developing network and capacity building. This section becomes the foundation of innovation sources that will be described in next section. The fourth section will elaborate the findings of study; focus on the combination of system elements (both internal and external resources) that have contributed to innovation in the Indonesian automotive industry. The fifth section will analyze the findings emphasize on the role of university and PRI as an external resource of innovation in the Indonesian automotive industry. Then the sixth section contains conclusion especially about the role of university and PRI as external resource of innovation in automotive innovation. And lastly, the report will be ended up with policy implication as the ways forward to strengthen the role of university and PRI as external resource of innovation in the future.

2. Overview of Indonesian Automotive Industry

2.1. General Trend

In the long run, the general trend of automotive production in Indonesia showed three patterns, which associated with national economic growth in the year 1976-2010. *First*, car production rose slowly from about 100 thousand to the stable number at around 150 thousand per year in 1976-88. This situation was consistent with stable economic growth of 5-6% in that period. *Second*, car production increased rapidly from around 100 thousand to the peak number about 400 thousand in 1989-1997. This condition was coherent with high economic growth of 7-8% in that period. Then production dropped drastically to around 50 thousand due to economic crisis with negative growth of -13% in 1998. *Third*, car production rose again from about 50 thousand to around 600 thousand per year in 2000-2008. This condition was in line with economic growth constantly increased after recovery in the early 2000 toward a stable growth between 5-6% in last five year.[4]

In the short run, the fluctuations of car production related to the impact of government policies towards economic development and automotive industry. In the 1970s, the policy of prohibiting car import in form of complete build up (CBU) encouraged the establishment of assembling company to assemble complete knock down (CKD) components. The CKD components were imported by the sole agent of brand holder (ATPM). In the 1970's, there were 20 assemblers producing more than 50 brands. Three major assemblers groups were TAM, IM and KTM. Then in 1976, government policy, that was called deletion program, encouraged the use of local components by applying high tariff to imported components. Production of car increased, although local companies were only able to produce simple components, but the main component and the complex one was still remain imported. The car production depressed due to the expensive price of imported components, which were triggered by the devaluation of rupiah exchange rate policy in 1983 (27%) and 1986 (31%).

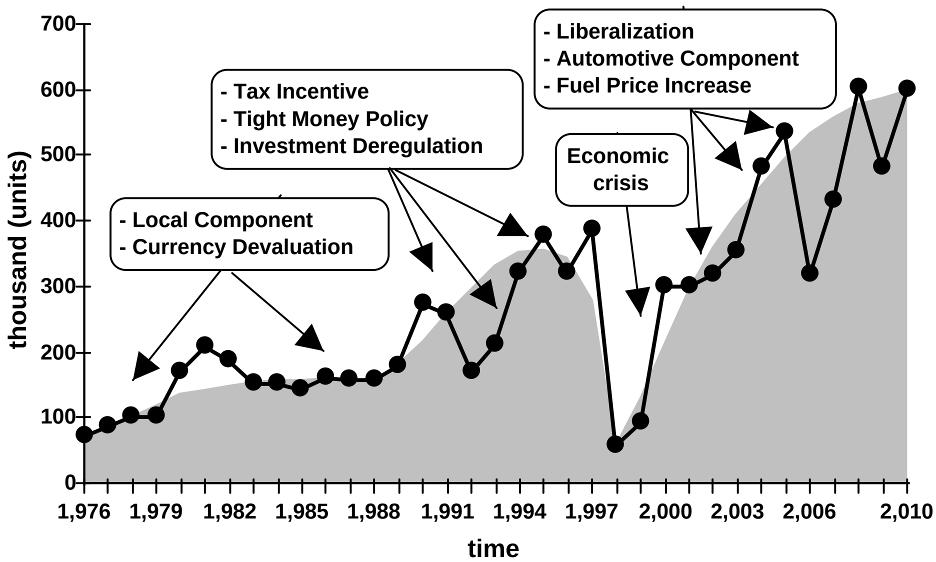
In the 1990s, car production increased rapidly, although it was temporarily depressed by tight monetary policy in the early 1990s. There were several policies that had encouraged automotive production. *First*, automotive policy package of 1993, namely the reduction of import tariff and providing the incentives associated with the use of local content. The higher the local content becomes the lower the tariff of the residual imported content. *Second,* the package of investment policy of 1995, namely the deregulation of automotive investment to produce a new car and setting the year of 2003 as the time limit of import tariff reduction. This policy encouraged the emergence of ideas, such as: i) designing a new car by own creation (Maleo sedan), ii) producing a new car (car people) with high local content, and, iii) producing a new car (national car) with Indonesian brand (Timor). The designated company was able to produce Timor

[4] About factors that influence the dynamic growth of Indonesian economy in the long run, see also Aminullah (2007)

brand supported by providing import tax exemption associated with company planning (it was not realized) to fully use the local content in stages within certain period. This special incentive in automotive policy was questioned by others car producers.

In 1997, economic crisis hit production car to the bottom line. Due to economic crisis, the idea of producing the new car's by self creation was no longer relevant. The national car production was unable to compete and terminated according to the recommendations of WTO body on dispute settlement. After the economic crisis of 1997, Indonesia's automotive production again rose sharply as the impact of liberalization policy in automotive sector by non-tariff barriers removal and tariff reduction. The increasing trend of automotive production since the 2000s has been supported by government policy to encourage exports, strengthen the domestic market, and improve the industrial structure by developing automotive component industry. While a temporary declining production occurred in 2005-2006 was suppressed by the increase of fuel price at that time. See Figure 2.

Figure 2. Trend of Automotive Production in Indonesia (1976-2010)

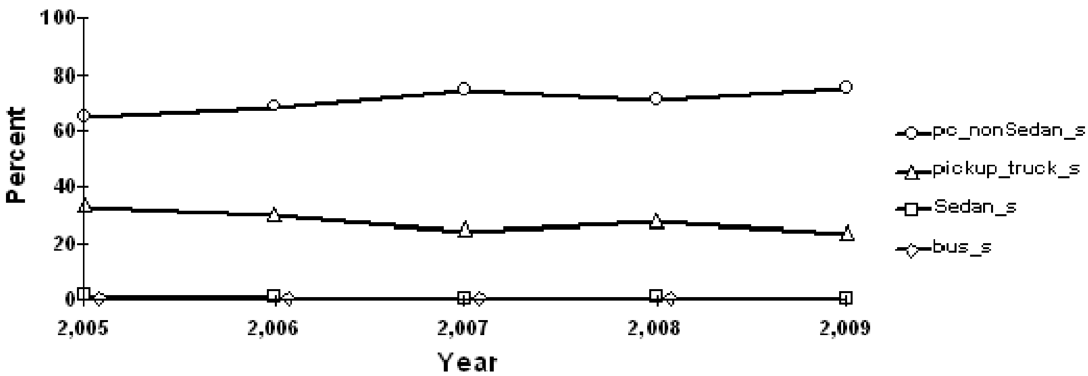


Source: The Association of Indonesian Autonotive Industries (Gaikindo)

2.2. Recent Situation

The recent situation was the latest trend from 2005-2009, the automotive industry in Indonesia was still very dependent on the production of passenger car non-sedan, which was referred as car category I generally used as commercial car as well as multi-function passenger car (MPV). The production share of passenger car category I was around 68%, subsequently followed car category III (pickup and trucks) about 30%, and the remaining was car category II and IV (sedan and bus) around 2%. The production of commercial car tended to increase in the last five years. The commercial car was designed solely to meet Indonesia's domestic market, making it difficult to export. See Figure 3.

Figure 3. Automotive Production Share by Category in Indonesia (2005-2009)



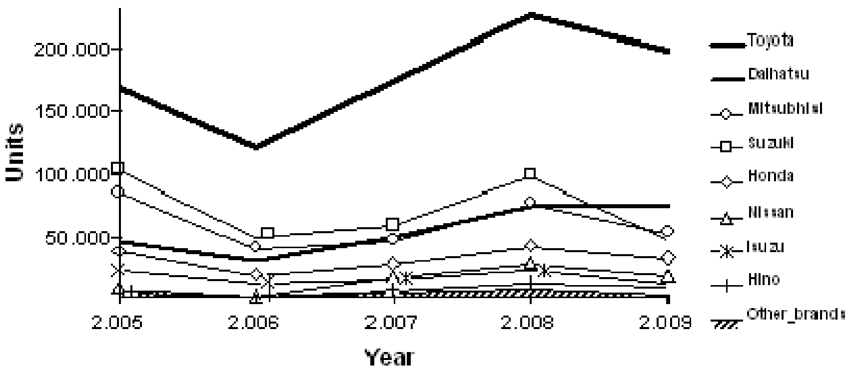
Automotive Production by Category in Indonesia (2005-2009)
in units

Time	pc_nonSedan	pickup_truck	Sedan	bus	Total__production
2,005	326362	165691	6228	2429	500710
2,006	204313	88433	2008	1254	296008
2,007	307638	100754	1570	1676	411638
2,008	425500	166249	5923	2956	600628
2,009	349805	110316	2367	2328	464816

Source: The Association of Indonesian Automotive Industries (Gaikindo)

Car production in Indonesia was almost absolutely controlled by Japanese brand around 98.5%. Toyota dominated the Japanese car production in Indonesia. The share of Toyota rose from 33% (2005) to 43% (2009) after taking the share of Suzuki and Mitsubishi, which decreased respectively 10% and 5% in the same period. The second place was Daihatsu. The Daihatsu share increased from 10% (2005) to 16% (2009) also by taking the share of Suzuki and Mitsubishi. While the Honda managed to defend its stable market share of 7%. Top five brands of Toyota, Daihatsu, Suzuki and Mitsubishi hold 87 of Indonesia's automotive production. The remaining 13% are shared by the three Japanese brands (Nissan, Isuzu, and Hino) and nine other brands (Mercedes, Nissan Diesel, Hyundai, BMW, Cheri, Mazda, Peugeot, and Chevrolet). See Figure 4.

Figure 4. Automotive Production by Brand in Indonesia (2005-2009)



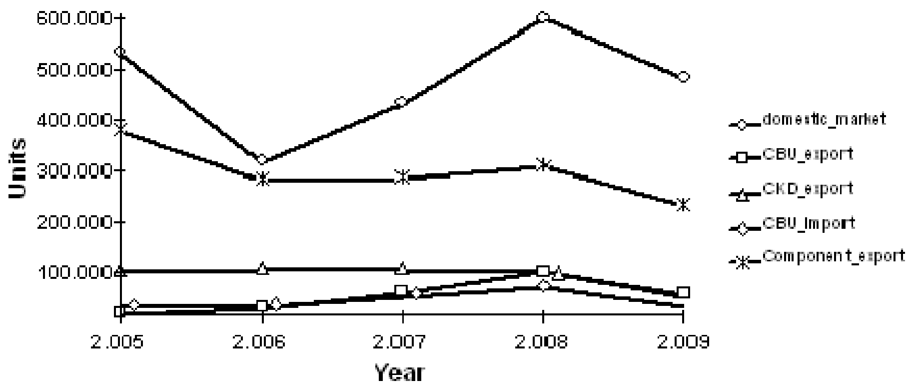
Automotive Production Share by Brand In Indonesia (2005-2009)

Brand	2.005	2.006	2.007	2.008	2.009
Toyota_	33,79	41,29	41,89	37,61	42,61
Daihatsu_	9,73	11,17	12,24	12,69	16,58
Mitsubhisi_	17,23	14,18	11,70	12,97	11,56
Suzuki_	20,74	17,53	14,58	16,36	10,70
Honda_	7,91	7,11	7,16	7,27	7,41
Nissan_	2,15	1,14	4,50	5,04	4,31
isuzu_	4,90	5,14	4,26	4,07	3,19
Hino_	1,44	1,09	1,99	2,39	2,50
Japan_brands	97,89	98,65	98,31	98,41	98,86
Other_brands	2,11	1,35	1,69	1,59	1,14

Source: The Association of Indonesian Automotive Industries (Gaikindo)

The sales of car in Indonesian domestic market in the last 5 years reached to 500 to 600 thousand per year. The CBU car export from and also import to Indonesia have showed the trend of positive growth. While, the CKD car and the auto components that export from Indonesia have showed the trend of negative growth. The declining trend in the competitiveness of automotive component was shown by negative growth of -10% in the period 2005-2009. Due to lack of competitiveness in export markets, resulting in the Indonesian automotive market was still dependent on the domestic market. This is confirmed by the facts that car production for the domestic market was much larger than for export, both CBU car and automotive components. Then, seen from the CBU car trade balance, the pattern and volume of CBU car import was not much different from CBU car export. See Figure 5.

Figure 5. Automotive Trade in Indonesia (2005-2009)



Automotive Trade Growth in Indonesia (2005-2009)

Time	r_domestic_market	r_CBU_import	r_CBU_export	r_CKD_export	r_Component_expor
2.005					
2.006	-40,27	5,99	73,96	2,46	-25,04
2.007	35,88	63,72	94,57	-0,26	1,88
2.008	39,33	31,82	67,56	-1,83	7,09
2.009	-19,91	-55,02	-43,88	-48,76	-25,21

Source: The Association of Indonesian Automotive Industries (Gaikindo)

Indonesian domestic market is fragmented into 30 car brands and dozens of models. See Table 1. Five top brands (Toyota, Daihatsu, Mitsubishi, Suzuki and Honda) controlled 85% of the domestic market. The remaining 15% was shared by the brands of the Japanese car (Mazda, Nissan Diesel, Subaru, and Lexus), the European car (Mercedes, BMW, Volkswagen, Audi Peugeot, Renault, Land Rover, Jaguar and Volvo), the Chinese car (Photon, Cherry), brand from Korea (KIA, Hyundai, Timor, Ssangyong), the American car (Chevrolet) and the brand of Malaysian car (Proton). Among those brands there were five top models (the Toyota Avanza, Toyota Kijang, Daihatsu Xenia, Suzuki Carry/Futura, Honda Jazz) dominating the domestic car sales. The models changed rapidly in accordance with the dynamic of market demand. The fragmentation of market by several models to meet the low demand was supported by easing the import of CBU and OEM parts to update the model. Consequently, the domestic components industry was less developed, except to produce non-OEM parts, ancillary parts of low value and generally produced by labor-intensive to meet the demand of after-market.

Table 1. Domestic Market Share by Brands in Indonesia (2005-2009)

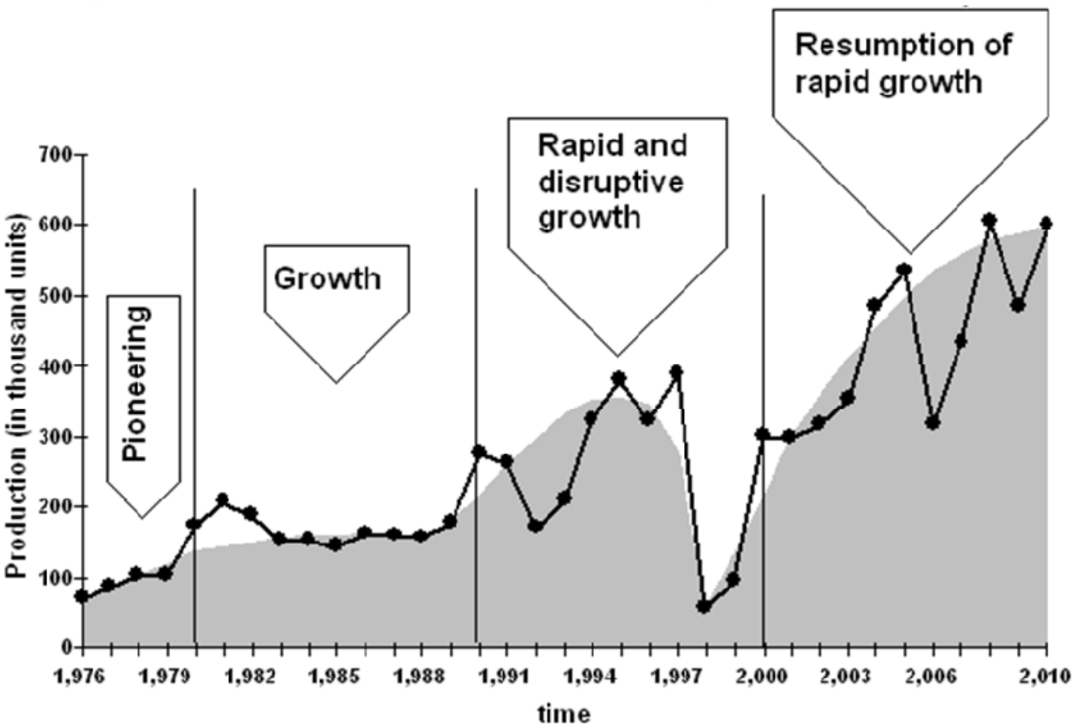
Brand	2,005	2,006	2,007	2,008	2,009
Toyota	34.23	38.79	34.76	35.10	38.61
Daihatsu	8.76	10.35	11.99	12.93	16.03
Mitsubishi	16.70	14.75	14.20	14.50	12.77
Suzuki	16.35	14.04	13.41	12.10	9.24
Honda	10.07	9.41	9.23	8.70	8.18
Top_five	86.10	87.33	83.59	83.32	84.83

Source: The Association of Indonesian Automotive Industries (Gaikindo)

3. Evolution of Indonesian Automotive Industry Viewed from Dynamic Capability

Evolution as shown in the company's life cycle explains the dynamics of company's ability in absorbing knowledge, developing the network and capacity building. The dynamic capabilities play important role in explaining the different patterns of long-term corporate performance. It is become the foundation of innovation resources that will be described in section IV. These capabilities are integrated in the phases of evolution that is reflected by industrial growth in the long run. There are four phases of evolution based on production growth in Indonesian automotive industry in the period of 1970s-2000s, namely pioneering (1970-1980), growth (1980-1990), rapid and disruptive growth (1990-200), and resumption of rapid growth (2000 - present). See Figure 6.

Figure 6. The Stages of Growth in Indonesian Automotive Industry (1976-2010)



There are three types of capabilities that functionally describe the phase of company's evolution. *First,* absorptive capacity is the ability of company to absorb, understand and exploit external knowledge. The variations in absorptive capacities explain the differences in the patterns of company evolution. *Second,* the ability to positioning the network will determine the stability and strength of networks in exploiting external knowledge sources. The more unstable the network is the greater the intensity of interaction and the opportunity to access external knowledge source. *Third,* the company's ability to develop, expand, diversify i.e. to serve new markets. The dissimilarity in companies' expansion creates the diversity among companies and it adds the differences in company evolution. (terWal, *et al.* 2007)

3.1. Pioneering Phase (1970-1980)

In the pioneering phase, the formation of dynamic capabilities in Indonesian automotive industry relies on the inter-firm network relationships with partners, both domestically and internationally. Companies that have stable business network tend to have the support from partners in developing their business. The success of selecting partners is determined by social networks (the role of influential actors) in the network.[5] The dynamics of company's ability to build and strengthen its networks in the pioneering phase is determined also by factors such as opportunity, stimulus and protection from the government's role.

3.1.1. The emergence of automotive industry network

Historically, there are three groups of business that control the production of automotive industry and car market in Indonesia, namely KTM, IM, and TAM. The emergence of three business groups occurred in 1970s.

KTM was founded in 1969 as the agent and assembler of Mitsubishi car, then become the agent of Nissan car. Meanwhile, IM began with Volvo dealer in 1973, and then IM produced Suzuki ST20 in 1978. Furthermore, TAM was established in 1971. TAM was a joint venture of AI and TMC with shares of 51% and 49%, where the AI was the sole agent of Toyota car in 1969 and the dealer of Honda motorcycle in 1970.

The new automotive industry emerged in several ways, namely: *First*, the development of business agent, i.e. MF formerly was controlled by AI then became the agents of Peugeot and Renault. *Second*, the acquisition of weak company was to strengthen the business position. i.e. AI took over GM automotive factory in 1968. *Third*, the development of partnerships with foreign company, i.e. UDT made agreement with GMH to assemble Holden from imported CKD in Surabaya factory in the 1970s. (Chalmers 1996)

In the pioneering phase, the development of business occasionally required the support of social networks mainly the influential actor, both from government or private sector. The success of AI as the sole agent and assembler of Toyota was through

[5] The role of influence actors in changing the government-business network was confirmed by the findings of Adnan. For more details, see Adnan (2010)

personal networks with actor (former economic minister 1950-s) who had a close relationship with Toyota. Thus, AI became the partner of Toyota expansion in Indonesia, by positioning the GM that was controlled by AI as the Toyota assembly plant.

The development of TAM in pioneering phase was recognized by its products such as Toyota Hi-Ace, Toyota Dyna L, T Daihatsu V22 V23 RH and RT. The availability of these products in the market indicated the ability of corporate networks to develop, expand, and diversify. The expansion of company networks created the company's business diversity. TAM imported Toyota Car in CKD and re-assembled in a factory assembly line in 1972. In 1973, TAM played as the dialer of Daihatsu car and Komatsu heavy equipment. TAM built MA as car assembling factory in 1974. Then, in 1976, TAM built MBD an iron processing factory.

Furthermore, KTM business activity in pioneering phase was initially considered as a determinant toward full manufacturing process in Indonesia. KTM focused on the production of commercial car, with production quantity amount to 20,000 in 1977. The KTM's product the so called Colt T-100 pick-up was in the frontrunner, and then it was developed into minibus and car station, namely: Mitsubishi Colt T-120. Besides, KTM also produced Mitsubishi FE101 or FE111 and Datsun 1N-20. While, at that time the IM was still producing motorcycle Suzuki with 2 stroke engine.

3.1.2. Government role

There are some factors including opportunity, support and protection, which were provided through government regulations that had influenced the emergence and development of automotive industry in Indonesia. The first regulation in 1969 was about i) setting the location for the dispersion of assembling companies, ii) the recognition requirements for companies as the general assembler and local assembler, and iii) the obligation of imported commercial cars in CKD form.

In 1972 the government issued some regulations concerning: i) the sole agent company, car and heavy equipment assembling were not allowed to foreign companies, and ii) all activities of sole agent and car assembling need to be united, so that import and car assembling were done by one company. As the result of grouping since then there were 20 groups of sole agent-assembler. Furthermore, in 1974 the government set the level of CKD provision for commercial car, sedans and station wagons.

Before government enforcing the mandatory use of local components in 1976, the used of local components actually occurred in car category I, there were 6 of the 14 brands used local components. In category II, 5 of 8 brands, used local components. In category III, 9 of 19 brands used local components. In order to speed up the use of local component, government restricted car import by encouraging the use of local components. In 1976 government set 100% in the tariff of import duty and domestic sales tax for sedan, 50% for components and 0% for commercial cars. Furthermore, the government obliged (if it does not comply with then the sanctions imposed), the assembler, and its car agent is within the same group, to use local components in doing car assembling. The government stimulated the growth of local component assembling in Indonesia, by raising CKD sedan tax 200% of the import price, plus 10% import duty, plus 30% luxury tax of the sales price and plus10% user's name customs of the sales price.

In 1977 the government enforced import ban for certain products, although without a clear sanction, including the simple products (paint, batteries and tires) and gave a deadline of universal products (such as shock absorber, window, exhaust, radiator and chassis) within 3 years in 1980, and special products (like wheel drive, clutch and axle) until 1984. In 1978, the government implemented the deletion program of replacement of imported components with the local component, which was associated with import tax. If a certain number of local components did not meet, then a penalty in the form of tax increase was imposed. The purpose of deletion program was also to reduce the number of brands and models of car in the fragmented market. The reality shown the opposite event, in 1974 there were total 12 brands and 21 types, then in 1976 it increased to 42 brands and 130 types, then before the year 1980 it again increased to 51 brands and 147 models.

3.2. Growth Phase (1980-1980)

The growth phase in Indonesian automotive industry is characterized by some following phenomena. The emergence of new car designs is pulled by market demand for new products. The company's ability to absorb, understand and exploit external knowledge in developing new designs increases significantly. The number of brands and models of car become more varied and growing rapidly. Marketing network and service grow and compete tightly. The competition among companies in design, price and service become tensely to get a central position in the market. The ability in doing expansion, acquisitions, diversification, and spin-offs become the indicator of company position. Inter-companies network in a business group is becoming more integrated and stable.

3.2.1. Design and brand competition

Until the early 1980s, the market of commercial car in Indonesia was dominated by KTM products mainly Mitsubishi Colt T-120. Furthermore, IM was initially producing Suzuki motorcycle ST 20 with 2-stroke engine. In 1982, under the license of Suzuki Japan, then IM developed the 4-stroke engine, IM modified the engine to produce Suzuki car ST100, the car successfully occupied the top place after beating Colt T-120. Then, the position of Suzuki ST100 was taken over by Daihatsu Hi-jet and Zebra produced by TAM.

The competition in commercial car occurred among the brands of Toyota Kijang, Suzuki Carry and Daihatsu Zebra. As for sedan, the competition occurred in the brands of Honda Civic, Toyota Corolla, Mazda 323 and Nissan Sunny. They compete on price, incentives and service delivery. Suzuki Carry brand that occupied the top place in 1986 then shifted down in 1987 after the appearance of Toyota Kijang and Daihatsu Zebra.

The sharp competition in design and brand was driven by the imperative use of local components as well as by the support of principal. The high usage of local components was encouraged by incentive in form of tax deduction that resulted in creating some Indonesian version of car designs such as the Toyota Kijang, Daihatsu Hi-jet Zebra, Mitsubishi Colt, and the Suzuki Carry. In 1988 Daihatsu Hi-jet Zebra managed to use about 90 percent local components. TAM created two alternative designs to their car, that is, the Eagle Wing 1 and Venus, which used the engine Daihatsu Hi-jet. The creation of new designs happened with the support of principal. Meanwhile, for those who did not get the support of principal, including the Datsun Sena, VW Mitra and Dodge Sembrani were finally out of the market. In the late 1980s the market for commercial cars were still controlled by Mitsubishi, Daihatsu, Toyota and Suzuki. These four brands, dominated the market amount to 92.4% of total sales of commercial car (excluding Jip) in 1986.

3.2.2. Government role

The role of government in the growth phase relates to the issue of low economic of scale and dependency on imported component. The low economic of scale needs to be improved by reducing the number of car brands and models. By meeting the economic of scale it will increase investment to support the localization of automotive components.

The amount of production for every brands was low, it was because of small market contested by many brands. Only 10 of 30 brands those were able to sell more than 20,000 units per year. To achieve the economics of scale, in 1980 government announced the rationalization program of car brands and models. The number brands should be reduced from 57 to 30 and from 140 to 72 for the number of models. In 1981, the government set about rationalizing the brands and models by consolidating 22 sole agents and 20 assemblers into 8 groups. Rationalization by grouping the companies was expected to increase the efficiency of assembling that encouraged initiatives to increase local content. However, the program implementation did not work properly.

There were two important factors inhibiting the implementation of rationalization program through companies grouping. *First*, the uncertainty of deletion program implementation that was opposed by a high ranking government official, who wanted the implementation should be left to the market mechanism. *Second*, the non-consistency of policy execution dealt with the automotive actor who closed to influentially political power. For example, rationalization program failed to ban the import of Opel car because of strong reaction from Gaikindo (to protect a politically connected the license holder of Opel) that requested postponement the mandatory use of local components in a sluggish economy.

To spur the making and use of local components, in 1980 the government set the time schedule for the mandatory use of local components. The weakness was lack of policy coherence to improve the competitiveness of automotive components. For examples in 1980, import duty of spark plugs was 20 percent, import duties of raw materials for making the spark plugs from were 10 to 40 percent. With such higher import duties of raw materials, the local component became more expensive and less competitive to imported components. Besides, the number of forged components was distributed due to lack of government control. Such high government intervention led to high inefficiency (Aswicahyono, *et al*. 2000).

The deadline for the mandatory use of local components was as follows. In early 1984 the local components were wheel rim, cabin, chassis and frames for commercial cars category III and IV. In mid-July 1984 the local component comprised of a rear axle and propeller shaft for the commercial vehicle category I and IV. In early 1985 local components included engines (petrol and diesel), axle and propeller shaft for the commercial vehicle category II, III, and IV. In mid-1985 was brake system. And in early 1986, local components included transmission, steering system and clutch system.

In 1987 the government set full manufacturing program by enforcing the master list of car assembly and components. The automotive industry was forced to use 178 components for LCV (Light Car Vehicles) which was equivalent to 73% of the content of whole CKD components in a car.

3.2.3. The development of firm capacity

The ability of companies in expansion, acquisition, diversification, spin-offs reflect the differences in the evolution process of each companies group (KTM, IM, and TAM). The capacity differences among companies depend on the differences in principal support to expand the investment. The more integrated the network of group will be the greater the company capacity to invest.

KTM

In 1983/1984 KTM established CEM engine plant and managed to make some import substitution components for commercial cars. CEM as a subsidiary of Mitsubishi group was a joint venture between MC, MMC and KTM with the share of each companies 40:40:20. Then the KTM set up a second engine plant in 1985.

IM

In 1981, after the IDH Group injected fund from investor (the owner of Volvo agent company), the group turned into IM. In 1984, the IM group developed companies NM and UPM as the car assembler of Mazda, Hino, as well as Binter motorcycle. Then the IM took over the agents of Datsun, Nissan, and Volkswagen. IM was in a strong market position after the entry into IDH group in 1982. IM was a sole agent as well as assembler of some car brands with its core business as the Suzuki car assembler under the company ZIM.

TAM

TAM in the AG established the first Toyota engine plant in 1985. AG consists of AI, TAM and AHM and some companies those were included in the AI, such as AO in field of automotive component. AG built TEI a machinery manufacturing plant in 1982. Three factories MA, MBD and TEI merged into the TAM in 1988. After the merger, TAM started to build automotive machine plant. TAM continued to revitalize its product quality by building the new factory in 1989 and 1996.

3.2.4. Dynamic capability under market pressure.

The growth of Indonesian car market encouraged large investment in the early 1980's. The fall in oil price and global economic recession created market conditions that pushed companies operated far below capacity in 1985. For example GKD a producer of chassis for commercial car operated by 22% of capacity. In a car engine industry, from the existing of seven companies in engine assembler only one company was healthy, i.e. SEI, while the rest operated far below capacity. Company TEM had a total capacity of 72,000 units of machine per year and 2 shift work in 1985, operated only one shift work. Then production of engine by MDII was 30% of capacity. Such a low productivity reflected low performance of automotive industry (Okamoto & Sjoholm 2000).

Almost all car brands experienced a declining production drastically due to market pressure from the sluggish economy, except for a few car brands that were not affected by recession, i.e. the Toyota Kijang and Suzuki Jimny. In 1985 Suzuki was ranked 4th after Mitsubishi, Toyota and Daihatsu, except for the case of Jeep Suzuki brand managed to dominate the market by 50%, followed by 30% for Daihatsu Taft and the rest divided between the Toyota Landcruiser and the CJ-7. The year 1987 was Toyota Kijang first export to overseas like Brunei and Papua New Guinea. At the same time TAM also exported auto components to Taiwan and Venezuela until the late 1980s.

Among the various brands of sedan car, Honda still controlled the market in the recession with the market share about 25.4% of sedan car in Indonesia. The enforcement of sales tax for luxury goods with the average rose 10 percent, did not affect the marketing of sedan car, even some of brands and models were getting strong its market position, i.e. BMW. This was supported by the after sales excellent service of Astra that took over the sales of BMW car from company TS.

3.3. Rapid and Disruptive Growth (1990-2000)

The rapid and disruptive growth in Indonesian automotive industry showed rapid growth at the beginning (1990-1997). That was characterized by: market expansion, the increase of new entrants, the emergence of design innovations, intensified price competition, gradual deregulation to increase efficiency. But this early rapid growth followed by suddenly declining growth (1998-2000) because of the inability of company to overcome shock from the economic crisis. As the results, the demand fell drastically, the company was operating under capacity, with a very high cost, eventually went bankrupt, and industrial growth was interrupted.

3.3.1. New Entrant in Automotive Industry

In this phase, the market of automotive business was increasingly competitive with the emergence of new brands, such as taxi cab Proton imported from Malaysia. In addition, the government responded to the idea of establishing a national car industry with its own brand. The Government encouraged local entrepreneurs to find alternative principals who were willing to work together to encourage the development of the national automotive industry. In 1996 the government selected and determined that the principal from Korean automotive, namely KIA Motors. The company was provided with tax break facility to build Timor as national car brand. The tight market competition in developing new car industry was unavoidable with the entry of Hyundai brand from Korea, in cooperation with local entrepreneurs to produce Hyundai car under Indonesia brand, namely Bimantara Cakra and Bimantara Nenggala.

In 1990, new car industry ever initiated by IM that developed, produced and marketed the sedan car branded as “people car” (MR90). The new car development was supported by the principal from Japan, however it was unsuccessful in the domestic market, due to: i) the technology was regarded as absolute for the similar kinds of sedan and, ii) lack of government support for the car to compete in domestic market. The development of Indonesian branded car was not limited to sedans, but also in the truck category. The TXC a giant factory in field machinery, with the support of imported technology from Austria and England, was able to produce car truck namely Perkasa. The presence of this truck factory had the support from government procurement in the form of trucks purchasing to meet the needs of specific public sector, such as military truck and fuel tank vehicle. All new entrants in automotive industry practically went bankrupt after hitting by economic crisis 1998.

3.3.2. Technological Innovation

IM launched sedan car MR-90 that was claimed as the indigenous product of Indonesia. Furthermore, the company of Group BB designed and built its own car prototype, called Beta. Then, a consortium of government agencies consisting of BPPT, Pindad, Bappenas, Ministry of Industry and private parties of JM conducted a study and a very serious activity since 1992, and planned to launch a sedan car “Maleo” in August

1995. The technology was derived from British Leyland. The prototype in the form of clay models was successfully prepared. However in mid 1995, the government signaled that the project was temporarily postponed.

On the other hand, TAM expanded its factory in 1992 and then developed a third generation of Toyota Kijang with eight variants consisting of 2 types of chassis (long and short). In 1996, TAM also launched a fourth-generation of Toyota Kijang, features with a more aerodynamic exterior design. In 1991, KTB also launched the Mitsubishi Colt T120SS which was technologically improved from the previous model of Colt T120. Moreover, KTB had claimed that the local content of Colt T120 SS more than 80%, because the various OEM components for the car had been produced by the group of KTB. Then, IM declared that they successfully managed transfer of technology in the automotive industry because they were able to produce OEM engine blocks and cylinder head which were used in Nissan MR90, Suzuki Carry and Suzuki Jimny. In this phase, the sole agent companies applied the full pressed body technology for car assembling.

3.3.3. Government Role

The government policy in this phase could be distinguished by two types. From the early to the mid 1990's, the government tended to continue the policy of economic liberalization as it had been running since the mid-1980s. The government lifted the import ban for car in CBU form. Although, the government determined the import duty of 200% for the CBU car that has been produced in the country, but if not, then it will be subject to additional import duty of 100%. With this policy, the imported luxury CBU car such as Jaguar sedan and station wagon Ferary and the Land Cruiser, Pajero, Cherokee, Ranger Rover and Discovery in reality continued to augment car market in the country.

In 1996 the government issued a controversial policy of giving privileges to TPN company to became an assembler of Korean car and make it as a national car. The policy created criticism from automotive business in country as well as abroad especially the automotive principal from Japan. As consequence, the government eventually withdrawn the policy in the early 1998, by revoking the decision of appointing TPN as a sole producer of national car.

3.3.4. Competition and Economic Crisis

The market of commercial car for the category I was still controlled by two business groups namely TAM with Toyota Kijang and Daihatsu Zebra then IM with Suzuki Carry. As for the sedan category that had traditionally been contested by the HDI with Honda Civic, KTM with Mitsubishi Lancer, TAM with Toyota Corolla and Toyota Starlet then IM with Suzuki Baleno. These brands had been challenged by suddenly arise of sedan Timor (national car). In 1997 Timor successfully managed to dominate the sedan market around 40.8%.

The economic crisis that occurred since October 1997 had serious impact on the growth of automotive industry in 1998-1999. Car market drastically showed decreasing sales by 85% in 1997. The figure of car sales was about 15-20% of the number before the crisis, which was around 60 thousand in 1998 and 90 thousand units in 1999. The situation resulted in very inefficient production with very far below capacity, heavily indebted financing, and the downfall of stocks market value. Finally due to economic crisis all new entrants in the automotive industry pulled away and old players tried to survive with the help of its principals.

3.4. Resumption of Rapid Growth (2000-present)

The insolvent companies caused by the economic crisis went out from business. The companies that still had hope to live after the crisis were saved by fund injection from its principals. Eventually, the companies have regained their market position after changing the shareholders toward totally controlled by foreign investment (MNCs). Since the year 2000, the era of MNCs operation has developed the technology capability of Indonesian automotive parts firms (Rajah & Amin, 2010). The MNCs have worked based on the most efficient global supply chains, by managing regional automotive component supply among subsidiaries operating in several countries. The MNC tends to transfer technology with lower risk i.e. to its subsidiary rather than third parties. If the technology in form of general knowledge that is possibly accessible, then the transfer of technology is done through licensing from MNC to company subsidiaries, they are generally automotive component companies. If the technology is difficult to access due to un-codified and difficult to understand, it is still produced by the principal to prevent rapid imitation.

3.4.1. Rapid Growth and Competition

After experiencing the market fall with automotive production was only (15%) in 1998 and (20%) in 1999 of the production before the crisis. Within two years after the economic crisis, Indonesia's automotive market return exceeded 300 thousand units in 2000 and experienced a slight and consistent increase by the year 2005 to around 400 units. Towards the end of 2010, car production in Indonesia is estimated to number 700 thousand. This figure shown the automotive industry in Indonesia start to proceed a rapid growth again.

As in previous years, the market leader of automotive competition in Indonesia rotated among the giant brands originating from Japan. Throughout this phase, the production Toyota car remains the market leader with the backbone of Toyota Kijang Innova and Toyota Avanza. To better control of the market, TAM also made a joint production and marketing with its owned business group by launching twin car from Toyota Avanza namely Daihatsu Xenia. To maintain customer loyalty, TAM encouraged customers association namely AXIC (Avanza-Xenia Club). For the luxury sedan category Toyota Camry replaced the market position of Volvo as the car for high ranking government officials. Then in Van category TAM also is successfully selling luxury Toyota Alphard that that became the car some members of parliament and police.

On the other hand, IM launched its new product innovation, Suzuki APV a larger version of its minibus Suzuki Carry. Furthermore, IM also launched its new products Suzuki Aerio the sedan hatchback category. IM was also success for the SUV category with the Honda CRV. IM once ruled the market with Nissan Terano jeep category. For the sedan category with a capacity below 2000 cc engine has been controlled by Honda Jazz since the mid 2000s. In this rapid growth phase, KTM launched the Mitsubishi Kuda. As for category of sedans and jeeps KTM does not manage to repeat its success as in the 1970s and 1980s. Meanwhile, the Korean car Hyundai and KIA still survive in the market with a small segment. Then, the car from Malaysia and China are also entering the market but they have not been able to compete with Japanese car.

3.4.2. Government Role

Different from the previous phases, since 2000s the government no longer interfere substantially in the development of automotive industry. The regulations issued by the government are more related to lowering tariff, opening domestic market as well as export promotion, and then no longer regulate the use of local components.

The government's role since then has limited as a facilitator by creating the climate of healthy competition. As appeared in the 1999 automotive policy package, which aimed to encourage export of automotive products, promote the domestic market after economic crisis and strengthen the structure of automotive sector by developing the components manufacturing industry. Incentive program was abandoned and import duty was reduced by half. The car assembling company and component industry those conduct training and R&D in the field of car technology get tax facilities in accordance with law and regulation.

It is expected that through this policy the automotive industry will be highly efficient and competitive, with the focus of development on upgrading the automotive components industry, expanding the automotive industry for commercial car with capacity less than 5 tons, and building the automotive industry for sedan car with the capacity to 1500 cc. The industrial expansion was supported by progressive investment policy that since 2007 it has been no longer required local partner majority ownership and the permit of land management increased from 30 to 80 years.

The implications of this policy are: *first*, various types and brands of luxury car in CBU form re-entry into the domestic market, such as Jaguar and Lexus. *Second*, the number of CBU car importer increases and the competition becomes increasingly tight, because local products have to compete with imported products that has forced the local manufacturers to improve products quality. Furthermore, in line with post-crisis economic recovery, and followed by stable economic growth in last 5 years, the quantity of automotive production and sales has grown rapidly again as described in previous section.

4. The Resources of Innovation in Indonesian Automotive Industry

4.1. Types of Innovation and Source of Knowledge: Ten Companies

4.1.1. Company 1: TAM

i. Innovation in business organizations

TAM was established in 1971 by AI and TMC. AI previously was a trading company in the automotive business. TMC was a Japan corporation in automotive industry, which played a key role in the innovation of TAM business organization.

Business organization of TAM is integrated from upstream to downstream. Business of TAM includes production plant, component manufacturing and distribution. The products produced by TAM comprise of Toyota, Daihatsu, Isuzu, Nissan Diesel Trucks, Lexus, Peugeot, and BMW. TMC conducts technology transfer to TAM through the establishment of various plants both for body assembling and component manufacturing. MA company was an assembling plant of Toyota car established in 1974. TM company was a printing and welding plant established in 1977. TEI company produced car engine established in 1982. During the year 1980-1984, TAM managed to build eight automotive components plants such as chassis, brakes, and engine block.

TAM organization did vertical integration in 1988. Three assembling companies merged into TAM to increase efficiency and maintain quality of automotive components. TAM also conducted horizontal integration, i.e. by setting up several subsidiaries such as AIC company in the field of credit financing, then A2000, M88, and GA companies in the fields of distribution, marketing and assurance. Besides, TAM applied the strategy of cross-ownership among their companies. So that, companies under TAM get multiple benefits of product quality, cost efficiency and market control against competitors. (Sato 1996)

To meet the market demand, TAM organization has the customer division which specially serves the request from the government. Through the Government Sales Order (GSO), the special service of TAM car sales to the government will be perceived as not the same with other services of car sales agents. In short, to win the competition in automotive industries TAM is not only provided good quality, price and service but also institutionally embedded the special service in business organization.

ii. Innovation in industrial management

TAM was the pioneer in the implementation of Japanese industrial management in Indonesian automotive industry, those are quality control -- called Astra Total Quality Control (ATQC), human resources management (skill and career development system), moving inventory system (kaizen), and management system of organization (retail support system). (Nakamura 1999) The source of knowledge is obtained by TAM from its principal TMC through transfer of skill and expertise in automotive production line. The ways of knowledge transfer are through personnel dispatching to be trained in Japan and in-house training at AETC (Astra Education Training Center) owned by TAM. TAM has a series of innovation in management system of organization, i.e. innovation in the field of consumer credit, product distribution, marketing and insurance by established subsidiary companies namely AIC, A2000, M88, and GA.

Knowledge and expertise absorption through learning by doing with the assistance of principal has successfully built TAM into a learning organization. TAM always follows the progress of industrial technology through learning by using the equipments of car assembling industry as well as industrial management. Knowledge and Innovation technology acquired by TAM employees spread throughout the company that created gradual and consistent improvement of company performance.

iii. Innovation in product design (Toyata Kijang)

The success story of n product innovation is called Toyota Kijang a commercial car in Indonesia backed by its principal. TMC developed design and engineering for its partner and subsidiary in stages from the first generation (1977) to fifth generation (2004). Innovation was followed by an increase in TAM investment in Indonesia. Innovation of Kijang also had more advantages than its competitors in the same class (Daihatsu Hijet, Suzuki Carry and Mitsubishi Jetstar). In addition to its competitive advantage in price, Kijang had other advantages such bigger engine, more comfortable, and more powerful that its competitor.

TAM was a pioneer in developing innovative minibus with a bonnet (cap) by putting the engine in front. TAM produced Toyota Kijang minibus as commercial car for the first time in 1977. The early shape of Kijang as a pickup (Kijang Buaya) competed with Mitsubishi Colt which had dominated the market. Although this first generation still had weaknesses such as without glass windows and key for door lock, the market was able to accept the presence of Kijang.

Second-generation innovation of Kijang was marketed in 1981. Kijang engine capability increased from 1200 cc to 1300 cc, later to 1500 cc. The view of bonnet more attractive than before, doors fitted with glass windows and already had the key for door lock. The second generation was referred to as Kijang Doyok.

Third generation innovation of Kijang entered the market in 1986. The concept of Kijang shifted significantly from commercial car toward passenger car. TAM succeeded to export third generation of Kijang to Brunei and Papua New Guinea in 1987. TAM issued two types of Kijang in this generation called Super Kijang (1986-1992) and Grand Kijang (1992-1996). TAM provided the third generation of Kijang in several variants such as: L-types (long chassis), S-types (short chassis), LX (special type) and SX (standard Type) using 4-speed transmission and conventional dashboard.

The improved version of third generation entered the market in 1992. TAM technology introduced full pressed body. The power of 5K engine increased from 61 hp to 63 hp by using a 5 speed transmission, which previously used 4 speeds. Since 1992 TAM introduced the 7K engine with capacity of 1800 cc and Toyota original body with pressing machines and spot welding method. For the grand type, there are some changes, especially in the addition of double blower and power steering.

Fourth-generation innovation of Kijang hit the market in 1997. This model introduced the new design of more aerodynamic called "Kijang Capsule". TAM issued two types of engines, that was 7K type engine 1800cc and 2L type diesel engine 2500cc. Kijang diesel attempted to compete with Isuzu Panther that dominated the market. At the end of 2000 TAM began to market Kijang with Electronic Fuel Injection (EFI). There are two options, namely Kijang EFI, 7K-E engine and capacity 1800cc and Kijang

1RZ-E with capacity of 2000 cc. The fourth generation of Kijang induced innovation in marketing as shown by the success of Kijang entered export market in form of CBU (to Papua Nugini, South Pacific) and CKD (to South Africa, Malaysia, Philippines, and Taiwan). Kijang CKD with 7K and 5K cylinder blocks machines were exported to Japan.

Fifth-generation innovation of Kijang Innova entered into the market in 2004. The model of Toyota Kijang Innova was the project IIMV (Innovative International Multi-purpose Vehicle) TMC Japan in Indonesia. TMC reorganized the production and procurement among its subsidiaries in ASEAN region. Toyota Motor Thailand (TMT) with Vilux Vigo plays the role as the main Toyota plant, Toyota Motor Manufacturing Indonesia (TMMI) plays the role in producing engines, Toyota Autoparts Philippines produces transmission and constant velocity joint, T&K Auto Parts in Malaysia produces steering gears, Siam Manufacturing in Thailand produces diesel engine, and Toyota Motor Asia Pacific (TMAP) in Singapore plays the role in the distribution of Toyota Kijang Inova to Asia and the Middle East.

The fifth generation has several advantages: a more aerodynamic body shape, a comfort level with a luxury sedan, driving position more accurately, the location of shift knob easily grip and more user friendly of instrument panel. This generation applied VVT-i 2000 cc, with type 1TR-FE DOHC 16 valve, it has greater power 136 hp, and designed with direct ignition system (DIS). This generation also applied accelerator technology without cable or throttles control system-intelligent and supplemented by longitudinal engine with rear wheel system.

iv. Innovation in component technology

Fifth generation innovation of Kijang was supported by several key components that have undergone innovation. *First*, suspension. Innovation in the front and on the rear suspension was done to better absorb shocks so as to be more comfortable. *Second*, steering. Innovation on the steering stability is more reliable so that the car is easy to control the speed of 120 km/h at the S-shape bend and turn rotate 270 degrees. *Third*, engine. Innovation in engine with VVT-I that created the combustion process relatively more efficient and lower waste gas emission. Innovation in D4D Diesel engine with the use of common-rail injection system that produced the low level of vibration and a smoother engine sound that could be produced along with the lower level of exhaust emissions. Innovation in Engine Immobilizer System used transponder chip so that the machine will reject if the ID code key is a false key. *Fourth*, control system. Innovation in Electronics Throttle Control System (ETCS) to make this generation equipped with gas pedal sensor, which can change every motion of magnetic into electrical signals to be sent to the ECU. Therefore, in the event of malfunction in one of the sensor, the ECU will command the throttle body work on limp mode (at least) so the car can still run.

4.1.2. Company 2: DHS

Organization innovation: competitiveness by strategic alliance

DHS started entering the Indonesian market in 1976 when the AI was appointed as sole agent, importer and sole distributor of DHS car in Indonesia. The existence of DHS development is closely related to the progressive AI management. In 1978 the steel plate pressing factory was established as a joint venture AI, DHS, NC. Then the machine factory DEMI was established in 1983.

The position of AI as the sole agent and importer of DHS was replaced by NAM in 1987. Then in 1992, ADM was established as a merger of 3 companies, namely AT, BY, NAM. Aluminum casting plant KIIC was built in 1996. A product of ADM that was dominant in its class was the Daihatsu Zebra in the mid-1980s. Later, DHS became less successful in domestic market because it was perceived by the public had a lower quality than Honda, Toyota, Mitsubishi and Suzuki.

In 1998, AI bought the assembling plant of GM, ADM have four factory steel plates those are pressing plant, machinery, aluminum casting and assembling. But the economic crisis in 1998-1999 caused car price increased more than 3 times. Due to the consumer’s low purchasing power and facing the Korean car with relatively cheap price became serious challenge to AI. Given the brand of Toyota and Daihatsu held by AI, and then the principals of Toyota and Daihatsu committed a joint investment amount to 90 million to develop Avanza Xenia (AX). Both car were manufactured by the same factory, and distributed by AI since the beginning of 2004.

The strategic alliance of two carmakers contained complementary elements of organization to create company competitiveness. Toyota is strong in the efficiency of production operations (pioneering in JIT and high labor productivity), quickly and successfully in product development, and strong market domination with a broad distribution network. Meanwhile, Daihatsu has been successful in creating small-car, specialist in efficient and inexpensive car. The combination of Toyota and Daihatsu is pool of benefit the family car (relatively spacious room), and excellent after sales service with the benefits of small car (fuel efficient).

Since its launching in 2004, by 2010 domestic demand for AX car remained high, besides it was exported to neighboring countries and Africa. But the product sold in domestic market was regarded having lower quality than that of export market. After facing customer complaints for AX lower quality, in mid-2006, new AX was marketed with the latest engine versions, and new appearance. The next twin products developed by Daihatsu and Toyota in Jeep category are Daihatsu Terios and Toyota Rush which was issued in mid 2007. Similarly, the twin product Terios and Rush have been marketed under the management of AI. Overall the AX car leads car sales in 2010, while Daihatsu Terios and Toyota Rush continue to increase its market position.

4.1.3. Company 3: IM

i. Innovation in product design and engineering (Suzuki Carry)

The product innovation originated from a top management of IM in 1976 that initiated and proposed to the principal (Suzuki Motor) to assemble and sell car by expanding it from a motorcycle engine. (Pane 2005). In 1978, IM launched Suzuki ST20 a pickup car. This car had a 550 cc capacity with 3 cylinders, which was the development of Suzuki ST10 that existed in Japan. In 1975-1976, IM selected its major market segments for Suzuki ST20 in south and north Sulawesi by ignoring the market in Jakarta and Java Island that was controlled by Mitsubishi. The success of innovation Suzuki ST20 was to build brand image as a tough car after a lot of clove farmers used it to explore the mountainous terrain in Sulawesi.

After success with ST20, IM continued next product innovation by proposing to the principal in Japan to produce minibus car with a basic design similar to the ST 20. The principal finally agreed and then sent the Suzuki Carry ST 100 in CKD to be assembled by IM. Suzuki ST 100 with a 1000 cc was the improvement of Suzuki ST 80 that circulated in Japan before. In the next steps IM played its role not only as an assembler of imported component but also producing the engine of ST 100, making the car body, producing chassis and various other components such as wheel, excel and interior by using parts supplied by local companies.

The success of Suzuki ST100 was also supported by government policies that provided incentive in form of abolition of import duty for commercial car (minibus category). In this category the market of Suzuki competed with Daihatsu Zebra from TAM and Mitsubishi Colt100 from KTM. Brand image of Suzuki engine was persistent and strong that brought Suzuki dominated the segment of public transportation. This segment was the main business of Suzuki in the domestic market, as well as export market in some neighboring countries.

Further innovation in design and engineering was Suzuki ST150 developed from ST100, by upgrading the engine to be 1,500 cc and larger body size. The need to increase the engine power of ST150 came from the competition from Daihatsu Zebra. The machine of ST150 was designed by IM engineers by changing the engine block material from cast iron to aluminum casting engine. However, Suzuki ST150 or Suzuki Futura was not able to replace the position of Suzuki ST100, that is a car always searched by strong consumer interest. Consequently, to meet the needs of market, IM keep producing Suzuki ST100 in addition to ST 150. Next innovation based on good brand image of the ST100 machine, IM requested and got permission from principal to transplant the engine in Suzuki Katana jeep in 2000, later also as the car engine of Suzuki Karimun.

Next innovation of Suzuki sourced from the effect of consumer complaint. The deletion program that required car manufacturers to use local components including car body, that pushed the establishment of local car body assembling companies in several large cities such as Semarang, Solo, Malang, Palembang and Ujung Pandang. Due to consumer complaints about low quality of body car made by car body assembling, then the government approved the car manufacturer companies to take part in making the car body. Then the full pressed body was produced by subsidiaries of car manufacturers such as SMI, TEC, and MKM.

ii. Innovation in developing the new car (Mazda MR 90)

The idea to build a new car by automotive player sourced from public discourse on national car in the late 1980s. This idea was not an empty discussion but something possible to realize, especially after the government applied the deletion programs and policy instruments for supporting the localization program. Top executive of IM believed to be able to realize the idea of new car based on its success in building the Suzuki ST from motorcycle technology. Then IM decided to build the national car through Mazda brand license. Given the public's desire to have a sedan type car, IM managed to convince the principal to transfer the technology of engine making and stamp machine for car body making to IM.

Under the guidance of Japanese experts, IM engineer and technicians obtained practical training and guidance in building their own car. IM launched Mazda MR90 in 1990. This car was believed to become a national car that had local content of more than 60%. Therefore IM requested to the government support in the form sales tax exemption. Unfortunately, the government refused to grant tax exemption because the regulation on sedan car was obliged to pay the luxury sales tax.

Mazda MR90 failed to gain government support, causing the car failed to compete with other car of minibus category which obtained sales tax exemption. Meanwhile, if MR90 was regarded as sedan, its interior design was not eligible to compete with sedan generally. The unclear position of MR as the passenger car either non-sedan or sedan category, it caused MR90 was not too successful in market. Only the procurement from some government institutions facilitated the marketing of MR90 as official car. Because of production remained below capacity, in order to meet the production capacity of MR90 engine, then IM also sought permission from the principal to use the car machine in sedan Mazda van-trend.

4.1.4. Company 4: KTM

Innovation in product modification (Colt Jetstar1000)

The NMN was originated from MM which had imported Mitsubishi since 1956. KTM as the dealer of Mitsubishi managed to attract Mitsubishi to invest in building the factory in 1972 and 1974. KTM was previously the agent of Mitsubishi in Indonesia through NMN company established 1970.

KTM sent their some managers in the early 1970s to Japan to study and understand the details of automotive factory. The transfer of knowledge in that way was done every year. The more local personnel who understand the automotive factory was the better for the KTM company. In addition, Mitsubishi also put experts from Japan to guide, monitor and improve the ability of local personnel in assembling and producing Mitsubishi car in Indonesia. In 1973, KTM established KRM company to assemble Mitsubishi car that was called Colt. In the mid-1970s, KTM claimed that the Mitsubishi Colt used 51% of local content.

Mitsubishi Colt pick-up launched in the early 1970s and then developed into a minibus which was a favorite car that controlled the domestic market in 1970-s. In the year 1987-1988 KTM successfully exported Mitsubishi Colt Jet-star 1000. Besides, as an assembling company, KTM has also developed a subsidiary that manufactured automotive component to meet the Mitsubishi needs. Some OEM parts were produced, but many products were spare parts for after market needed by workshop for car maintenance. In 1983, KTM together with its principal established CEM company to manufacture car engines in Jakarta.

In Sedan category, Mitsubishi Lancer and Gallant were the favorite car in Jakarta in mid-1980s. Its design and technology was 100% from Japan, although some spare parts have been able to be assembled in the MKM a subsidiary of KTM in a joint venture with the principal.

4.1.5. Company 5: MKM

Innovation in component production (localization)

MKM was founded by KTM in 1975 and later developed MKM-2 in 1981. Both were component and auto parts manufacturer of Mitsubishi car in Indonesia. The establishment was directed by the automotive experts from Mitsubishi Japan and supported by the Indonesian personnel who obtained training in Japan. The company provided the series of training to local workers to become skillful and expert in producing various components of car that were used as OEM as well as spare parts which were used for after-market.

MKM operated as the factory of components for KTM a car producer in Indonesia. MKM produced OEM products such as engine blocks, axel, and wheel-rim with machine and printing equipment brought from Japan. Raw materials such as iron, copper, and aluminum are almost 100% imported from abroad. Based on portion of components produced locally in a car, the local content of Mitsubishi car has been able to reach 40% -60% since the 1980s, especially for non-sedan passenger car like the Mitsubishi Colt T1000. As for the sedan and Pajero jeep and Strada are almost 100% in form of CBU.

MKM provided the opportunity for local companies to produce components that were required by MKM. There were two ways of local company to become sub-contractors of MKM. *First*, the MKM actively search to find the factory readily to produce the component according to specification determined by MKM. *Second*, certain company offers its capability to produce a certain component. The production processes of complex parts use the printing machines imported by local company from MKM principal in Japan. Although the supplier of MKM were able to produce its own components, but the products were solely produced for MKM because design and specifications based on license from Mitsubishi Japan.

MKM always stimulates idea generation and creativity among workers, and it becomes the work ethic in the company group. Every person is required to submit a suggestion for performance improvement and problem solving to the management every month. This has spurred the innovation in work place by creative employee. In addition, it is related with performance evolution of employee annually. For the applicable ideas that bring brilliant improvement will be honored with incentives by the company.

4.1.6. Company 6: SSA

Innovation in marketing management (brand image)

SSA was a trading company that imported Volvo in CBU then marketed by IM. Volvo's success in the market in part was due to government support that had set Volvo as the high-ranking official car since 1974. Demand for the latest series of Volvo 740, 960 and S90 in accordance with the taste of official in every periods. This policy continued until the year 2001, since that time the provisions of official car for the high-ranking officials have converted into Toyota Camry.

Volvo car and its components for maintenance are imported goods. The transfer of technology does not occur in the car trading. Volvo technicians from the IM group only develop the skills on service and maintenance under the supervision and technical guidance from the principal. In the marketing field, Volvo kept maintaining its brand image as the car for high ranking official. In order to convince the customer, SSA management displayed the testing of car safety and comfort in Jakarta in 1980. In the event IM invited businessmen and high ranking officials to witness the safety of Volvo as the safest car despite having the hardest impact testing. The event was to attract the premium target market.

4.1.7. Company 7: JM

Innovation in marketing management (support for consumer satisfaction)

Landrover car was originally imported by ISC since 1950, later it was taken over by the HMN that had imported Morris Berenti since 1950. In the late 1980s HMN was taken over by JM. Landrover car always enters the Indonesian market in CBU form. JM as car importer and marketer needs limited transfer knowledge only such as maintenance and car service. All spare parts of Landrover are imported from the principals in the UK. Just to meet the needs of car consumers on the accessories of Landrover, then JM helps its consumers to assemble and modify the generic parts, such as car interiors including seat upholstery, door, or other accessory. Technicians of JM obtain technical expertise from UK factory in the form of in-house training for doing car maintenance and service. Furthermore, JM also has developed its subsidiary to produce certain automotive parts for after-market. While the components for OEM equipment are imported from the principal.

JM technician never involve in design and engineering, because whole design of Landrover car are determined by the principal. Since the 1970s, design of steering has been modified to the right position to meet the needs of market in Indonesia. Characteristic of this car is a 4x4 type of standard form, but provides room for creativity to modify to be the fire truck, caravan, a hunter car or off-road. The car the owners generally make modifications in their respective workshops, but the Landrover through JM facilitate various needs such as cranes and other equipments.

With its typical design and supported by the fans of Landrover from abroad that brought the Landrover owners in Indonesia established LRCI (Land Rover Club of Indonesia) in 1987 and later revitalized in 1997. This club is the association of car owners who have an agenda of social activities, support for disaster mitigation, sports, touring, and road greening to reduce global warming. For consumer satisfaction, JM supports the activities of this club by providing some facilities in form of sponsorship, funding, goods and networking

4.1.8. Company 8: IMPM

Innovation in marketing management (stimulant for consumer satisfaction)

Honda car was initially imported by IMR as the sole agent of Honda brand since 1973, then it was taken over by the PM which was a subsidiary of IMR. PM as the sole agent of Honda had assembled Honda car in its factory since 1975. PM assembled components, which was produced and imported by HM a subsidiary of Honda Japan. The components produced by HM -- to be assembled by PM -- must pass quality testing by Honda factory in Japan

To improve knowledge and skill regarding car assembly, Executives of PM and its staff interact directly by observing assembling process at the Honda factory in Japan. To ensure the quality of Honda car in Indonesia, the principal placed experts from the Japanese in Indonesia. Similarly, the CEO of IMR has representatives in the principal of Honda.

In the mid-1980s, Honda car (Civic and Accord brands) once dominated the sedan market in Indonesia. The Honda rival was the Toyota Corolla, Toyota Corona, Mitsubishi Galant and Lancer. In the early 1990s sedan market competition increasingly fragmented with increasing sales of Mazda 323 and 626. In 1990s, the sedan market competition was getting sharper with the entry of Korean car, sedan Timor (KIA) and Hyundai.

To win the sharp market competition, Honda always keeps innovating in terms of appearance such as body shape, display lights, and accessories consisting of power windows, electric mirrors and dashboards that stimulate consumer tastes. Honda continues to be advanced in the technology of brakes, steering, transmission, rust prevention systems. For each of these technological advancement, PM keep constantly updating its technology. The role of principal was crucial in the process of this technology transfer. However, the principal did not interfere in managing the marketing of Honda car in Indonesia. Combination of marketing strategy that stimulates consumer taste with a touch of information technology remains a basis of the sales of Honda sedan.

4.1.9. Company 9: TPN

Product innovation (Timor)

In 1996, the Indonesian government issued a national car policy. TPN obtained authority to realize the national car in cooperation with KIA of Korea. Government's basic policy was to accelerate the mastery of automotive technology in domestic industry. Automotive industry have to switch from merely components assembling into making own car gradually. The strategy for achieving the objective were by increasing in local content with a decreasing in imports of components as well as raw materials for components making.

The government expected TPN achieved the local content by 20% in the first year. The second year was expected to increase to 40% and in the third year by 60%. In practice there was a time delay of TPN local content targets. The target of 20% local content should had been achieved in 1997, then it was delayed until January 1998. The government also required TPN used components and equipment made in Indonesia through compensation and purchase (counter trade). The amount required was at least 25% of imported CBU car.

Complaints against the national car policy came from various parties, especially the automotive players who questioned the national car policy to the WTO. After the policy of giving special incentives was declared illegitimate in WTO fair trade regulations, the government finally terminated the national car policy (Mobnas). Consequently TPN was obligated to pay import duties and luxury tax of car sold by TPN. In short, such a hasty product innovation through shortcut to realize the idea of a national car was a thing not realistic in the global supply chain of automotive industry.

4.1.10. Company 10: GRM

Innovation in product modification (minibus Mitra)

GRM produced VW since 1971 then assembled VW181 that was the type of car known as the VW Safari for sub-districts official in Indonesia the 1970s. In the 1980s VW was ranked second best-selling car brand in Indonesia. The success of VW was concentrating on BTV (Basic Transport Vehicle). BTV was a cheap product and powerful vehicle for developing countries that was designed in 1970. BTV had the engine position in front so that the luggage space can be filled and emptied in the rear. The introduction of BTV to Indonesia took place at the initiative of the VW principal, which impressed by Morris, the modified England car, for the transport of goods and passengers in Jakarta, which was a means of public transport across Indonesia since the 1950s. Then, a prototype of BTV was exhibited in Indonesia in 1972 and received good response from the public.

Production of minibus Mitra a BTV version by GRM involved other party, namely PS, the company manufactured the panels of car body, then GM company assembled the Mitra minibus in its factory. Although minibus Mitra was frequently redesigned, finally the mitra was sold in the form of mini passenger car the so-called oplet, ambulances, police car, car carriers and pickup

4.2. Summary of Evidence from Companies Studied

The aforementioned description on the types of innovation and source of knowledge in the companies studied, can be summarized as follows: i) sources of knowledge in product innovation came from market competition (Toyota Kijang), the idea of experienced entrepreneurs (Suzuki), the principal (Mitsubishi Colt T100); ii) source of knowledge in process innovation came from advancement in automotive engineering research (fifth generation of Toyota Kijang); iii) source of knowledge in organizational innovation came from company’s needs to increase competitiveness, productivity and efficiency in market competition (alliance of Toyota- Daihatsu, and vertical integration of TAM); and iv) source of knowledge in management innovation come from principal through transfer of skill and expertise in automotive production line. The company's needs in management innovation for solving the problem that exists the production and organization by applying Total Quality Control, the system of HRD, moving inventory system (kaizen), and other management systems such as retail support system, consumer credit system .

Seen from human resource development, companies business policies in the past have successfully build personnel competency as assembling technician and product salesman in respective subsidiaries companies. The best use of knowledge acquired through in-house training was successfully implemented to develop management and organization innovation. However, the subsidiaries companies were still less successful to conduct product and process innovation, because the design and engineering research was constantly conducted and determined by principal.

The role of government in localization program by regulating the automotive component supply was less successful in the past, due to the component's low economic of scale to be produced locally. Government program to promote the production of national car through gradual increase of local component was failure due to three factors namely, less government support, less government commitment, and loss government credibility. Furthermore, less effective fiscal policy (tax deduction and exemption) is due to low economic of scale that created inefficient production in the past. Then, incentives through monetary policy (low interest rate) to create demand in the economy was driven more by investment, while at present it is driven more by consumer spending.

In the past, some of policy failures to achieve the policy objectives due to; i) policy incoherency, i.e. imposing contradictory objective of tax for similar products and its component materials, and ii) policy inconsistency, i.e. unfair preferential treatment in national car. While, the consortium of inter-government and automotive company to develop and produce national car product that reflect public-private partnership was failure due to less government commitment to continuously support it.

5. The Role of University and PRI as External Resources

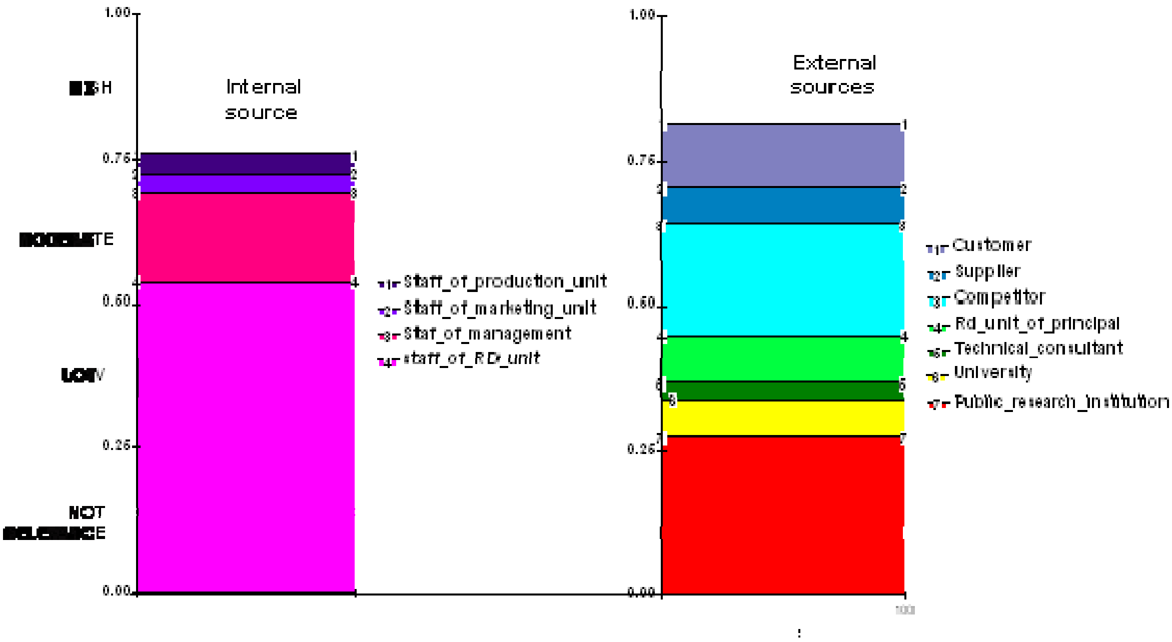
5.1. Limited Role University and PRI based on Survey Results

The previous section of IV.2 clearly explained that the role of university and PRI as external resources of innovation in Indonesia is very small (if not unavailable). This finding is also supported by the results of innovations survey in Indonesian manufacturing industry in 2009.[6] The survey revealed that: i) cooperation between universities and industry with government research institutions is very low or not relevance at all, ii). the role of university and PRI as the source of information for industrial innovation is very small. (Pappiptek LIPI, 2010: 50-51)

Furthermore, based on survey results, the situation of automotive industry sector is described as follows. The source of information for innovation in automotive industry are mostly from the staff of production and marketing units (as the internal sources) then the customers and suppliers (as the external source). Meanwhile, university and government research institution almost no relationship (and not relevance) as the source of information for innovation in automotive industry. (See Figure 7)

[6] The innovation survey collected information from 1341 medium and large enterprises as respondent. There are 46 automotive assembling factories and automotive component companies as respondent in the innovation survey.

Figure 7. The Relevance of Information Sources for Innovation in Indonesian Automotive Industry



Source: The data of Pappiptek-LIPI 2010 was re-processed by author

5.2. The Dominant Role of University

The dominant role of university is as the provider of educated people, mostly automotive engineers with bachelor degree. The educated people that enters the labor market tends to work in the sector more quickly generate revenue, such as in finance and management, due to limited job opportunities for engineers in the automotive sector. The automotive assembling and most components industries tend to use the skilled labor graduated from polytechnics or vocational training school. The low demand for automotive engineers due to several reasons: job availability in assembling line is generally enough by employing technician and mechanics, the more high value job such as design and engineering are already done by principals abroad, most of engineering job in the MNC subsidiaries are handled by foreign engineers, and local engineers who worked in the automotive industry tends to pursue careers in non-automotive areas such as marketing, distribution and other business divisions to increase sales value MNC companies.

The relationship between automotive industry and university generally occur through industrial assistance to universities and it tends as a part of corporate social responsibility (CSR). The assistance provided by industry in form of automotive machines is used by students as material practices in the laboratory of university. The automotive engineering research in university generally focuses on academic purpose rather than industrial application. *The results of academic research are available in forms of student theses and the papers of lecturers so far have not applied and utilized to help innovative capability of local automotive and component industry*. The areas of academic research in mechanical engineering research at three leading Indonesian universities are described below.

Department of mechanical engineering in university-1 is geared toward producing engineers that has the ability to do research, design, development, testing, control, and manufacture many different equipments or devices. The graduates are expected to have the ability to apply knowledge of mathematics, science and engineering to identify, formulate and solve mechanical engineering problems. There are four research groups in mechanical engineering university-1. *First mechanical design group* has an active research and development in the area of mechanical engineering design, dynamics and control, and vibration-based predictive maintenance. *Second energy conversion* group has active research and development in conversion energy processes, i.e., thermo-fluid engineering, power engineering, computational fluid dynamics, renewable energy/biomass, etc. *Third, materials science and engineering group* has an active research and development in field of material processes, steel processing, ceramics, composites, and advanced materials. *Fourth, mechanical production engineering* group has an active research and development in the areas of production, manufacturing engineering, quality control, CNC machines, CAD/CAM, automation systems, and robotics.

Department of mechanical engineering university-2 has two fields of research that is i) energy conversion and, ii) design, manufacturing and automation. *First, the field of energy conversion* to develop science and technology in the conversion and energy conservation which includes the development and utilization methods, phenomena, and principles in fluid systems, thermodynamics, heat transfer and the period, the cooling system and air-governance. *Second, the field of designing, manufacturing and automation* to develop science and technology related to product development and manufacturing-oriented energy conservation, which include among others: the method and process of product design, product manufacturing methods and processes, manufacturing systems, and automation of the design process and manufacturing. Mechanical engineering research in university-2 focus on energy conservation through efficient design and manufacturing. There are some research activities, namely: i) advanced manufacturing technology and; ii) automation; iii) thermal and fire safety engineering; iv) advanced refrigeration system and technology; v) high efficiency fluid engineering; vi) advanced heat transfer technology, and; vii) naval architecture.

Department of mechanical engineering in university-3 has three laboratories to facilitate student to develop skill and ability by practicing and doing observation on how the application of engineering in workplace. *First, process and production system laboratory* has functions as service unit that supports learning activity especially the one concerning production system, production process, factory layout planning, industrial transport tools planning and controlling. *Second, simulation and computation laboratory* has function to develop skill in manufacturing system simulation, automatic production and its design, modeling and programming by computer simulation. *Third, work analysis and ergonomic laboratory* has function as tool provider for designing comfortable, safe, and productive working system. Besides being used as a place to conduct work design experiment, this lab can also be used by students for finishing their final project on design, public service, and other learning practices.

5.3. The Potential Role of PRI as External Resources of Innovation

The more progressive research in automotive engineering in PRI only occurred in the Indonesian Institute of Sciences (LIPI). The LIPI has conducted R&D on electric car since 1995, and has succeeded in creating the environmental friendly electric car the so-called Marlip. Source of innovation for Marlip electric car came from the future ideas in the field of transportation to develop the energy-efficient and environmental friendly technology. The development of electric car has been done for several reasons namely due to high fuel price, the problem of exhaust emissions, and need for low operational and maintenance costs. Then in 2010, LIPI launched its first prototype of hybrid car.

Electric car

The Marlip electric car of LIPI has the driving system with switch back and forth mechanism (SM3). The SM3 driving system mechanism was successfully designed to reduce costs to 10 percent, compared to the solenoid driving system. The SM3 system in the Marlip electric car work manually. The mechanism is more cost efficiency and more easy maintenance. The Marlip have eight variants for special purposes in limited areas, such as airports, hospitals, and environmental friendly areas for tourism. The maximum speed is only 40 kilometers per hour, now it has been operated in several police districts in Indonesia.

AUTOMOTIVE PRODUCT INNOVATION DESIGNED BY PUBLIC RESEARCH INSTITUTION (LIPI)

Electric car "Marlip-LIPI" **Electric car "Kijang electric"** **Hybrid car "LIPI EHV"**

source : the courtesy of LIPI Bandung (2010)

SM3 technology is the embryo automotive industry with the idea of energy-efficient car and eco-friendly. The commercialization of Marlip technology needs further developmental research. The R&D investment has been funded by the government in the early stages. For the scale of mass production the private company is expected to get involved. However, since 2008 R&D investment for the Marlip car was stopped. The focus of automotive R&D in LIPI now is more on the fuel conservation engines to reduce the dependency on oil that is increasingly limited.

Modified electric car

Based on Marlip as a foothold, the modification of electric car technology is the conversion of gasoline engines to electric motors in the Toyota Kijang car. LIPI conduct research on applied AC electric motor and has resulted in the electric car of Toyota Kijang. This innovation becomes a bridge for next LIPI automotive research to build the concept of electric hybrid car with AC electric motor.

There are some differences between these LIPI Kijang electric and Marlip electric car that had already been sold. The concept of Marlip was designed as a mode of transportation for specific areas, such as airports, hospitals, or tourist areas, while electric Kijang car is designed as the vehicle to be used in public roads.

Hybrid Car

The next LIPI innovation in automotive engineering was the success of making new breakthroughs by building hybrid car that claimed very fuel efficient. The twin-engine car using gasoline and electricity is called as "The LIPI 1st Electric Hybrid Vehicle" with the concept of hatchback. The work of gasoline engine is just to fill the electric machine, while the electric engine works to drive the rear axle.

LIPI Hybrid car is energy efficient vehicle. The capacity of 160cc and capable of reaching 70-80 km distance. The construction of engineering system in car is the transformation of gasoline into electricity, which is used not to run the car, but to be used as electric charge. So the car 100% driven by electricity stored in batteries supports. Thus, when the electricity in the battery is full then this automatic smart car will stop the flow of gasoline. When the electricity was not able to perform the mechanical functions of car, i.e. the car on the uphill road, then gasoline will automatically replace the role of electricity in running the car.

The first prototype of hybrid car has been tested on the streets and climbing roads. This car can be compared with foreign-made car in the capabilities and features of the standard car. The advantages of hybrid car is that kinetic energy from the engine-driven by fuel is able to supply power directly to the battery. Hybrid car, has several advantages than that of conventional car. *Firs*t, a significant reduction in fuel usage can save fuel by 50%. *Second*, it can contribute to the reduction of carbon emissions from burning fuel. And *third*, the use of hybrid car can save on operating costs because it is cheaper than conventional car.

The role of LIPI as external resources of innovation in Indonesia automotive companies is very limited and seems to be not relevance. (See also figure 7). It is because there is no relationship between LIPI and automotive companies in field of innovation activities. The automotive companies in Indonesia are subsidiary companies of MNCs which their core activities are car assembling and marketing. The R&D activities of the MNCs are conducted generally by principals and their own regional research center in supporting their global production. In other word, it is not viable the MNCs subsidiaries will use LIPI as their external resources of innovation, i.e. in commercializing the products innovation of LIPI. Although, subsidiaries and local companies tend to be indifferent to recognize the results of PRI product innovation due to the subsidiaries companies is entirely dependency to the product innovation determined by principals. However, public research institutions like LIPI has shown the potency to be the external resources of innovation in local automotive companies in the future.

5.4. Innovation Cooperation between Industry and PRI

Engine design

Indonesian government through ministry of research and technology (KNRT) encourages innovation cooperation among PRI, industry and university by providing grants to finance R&D the so-called “rusnas program”. The program aims to mobilize and improve the HR competency on specific technology areas in PRI, industry and universities that work together in utilizing the existing facilities. For example, in the field of automotive, the rusnas program developed engine design that was managed by BPPT (Board of technology assessment and application) in cooperation with SMEs.

The engine had a single cylinder diesel engine to be utilized in production units including hand tractors and generators. This engine design program has build a network of cooperation between local industry, SMEs, engineering communities in engines and automotive products, research institutes, universities and laboratory facilities, R & D, training and business workshops..

PTN is a SMEs that already has experienced in producing diesel engines with 1 cylinder and the power of 8.5 hp. PTN in cooperation with BPPT produced a 1 cylinder engine with capacity of 500cc gasoline. PTN has been successfully designing and building the jigs and fixtures as mechanical process in engine components. In the production process PTN applied the concept of 'low volume-low cost'. As for the making of cast aluminum components for engine, BPPT in cooperation with PTL conducted experiment on casting engine components that succeeded in reducing production cost significantly.

Product development in the form of 500cc engine by using raw material from aluminum alloys and utilizing the existing facilities (i.e. casting and machinery industry, testing units for machinery and tools technology center at BPPT) to produce the engine prototype. The engine development started from size (500cc) that did not collide with a similar engine in the market. The mastery of existing engine technology could be developed into next sizes e.g. 750cc, 1000cc, 1600cc and so on. Engine was developed with the basic concept of big torque at low rpm, so that it can be developed into multi-purpose machine.

The basic concept of multi-purpose engine provided opportunities for application in non-automotive products. Given the automotive products exist in very competitive market, some types of applications such as hand tractors, rural generators, compressors, water pumps, river transport and rural vehicles become its competitive value. Engine was tested and applied in river transport / brackish water, rural vehicles, generators, and micro-car fuelled with compressed natural gas (CNG) to support the energy diversification program, which was cheaper than gasoline and support a clean environment.

The engine production will developed industrial cluster with its *core element* is the engines factory PTN. *The supporting elements*: KNRT, BPPT, universities, training institutions, ministry of industry, ministry of education, local government and associations. *The supplier element*: foundry industry, dies & mold industry, basic components industry, industrial rubber components / plastic and electronic components industries. While the *related elements* are shipbuilding industry, automotive and car body factory. *The elements of users* are private companies, educational institutions and governments that use applications for boats, generators, water pumps, multipurpose vehicles, and agricultural tools.

Light-car prototype

Other product design developed through partnership scheme between industry and the PRI was the creation of light-car prototype the so-called Sunny 500. The design was developed by BPPT financed by rusnas program. The car was the results of innovation cooperation with industry PTITM with BPPT. The car was light because the frame was made from steel pipes while the car body was made from fiber glass materials and powered by two cylinder gasoline engine with a capacity of 500 cc, the so-called rusnas machine.

The Rusnas machine had some advantages, in addition to efficient fuel consumption, it also could use two types of fuels, gasoline or CNG. This light-car was designed specifically to meet the transportation needs in the housing complex and for rural transport, capable of driving with a speed of 60-70 km per hour. The car could drive over 100 miles per hour, but considering this car is very light weight the speed should be limited to 60-70 km per hour to remains safely and comfortably.

PRI assistance to industry in engine testing

In 2001-2003, a local company PTK performed reverse engineering process in motorcycle. A certain type of motorcycle with its patent and industrial design was outdated. PTK improved it by styling the design and by optimizing the platform (frame and engine) with minimal platform changes, then applied the technologies by using the existing automotive component in market. The results of PTK's innovation, the company has commercialized various types of motorcycles with several brands such as

Taurus (2005), Taurus Ultima (2006), Taurus Grand with 110 CC engine (2006) and Taurus Supermoto with 120 CC engine (2007). Furthermore, PTK developed three prototype 135 cc engines by fuelled 50% bio-ethanol, LPG hybrid engines and fuel injection engines. In developing these engines, especially to test the strength of engine, PTK has been supported by technical assistance from PRI namely BTMP-BPPT.

PTK is currently able to produce and market the motorcycle of 3 thousand units per-month (its capacity of 10 thousand units per month). Based on its innovation success, PTK received numerous awards, such as Motor Plus Award for local design (2005), Golden Awards in Indonesian good design selection (2006) and Upakarti for technological innovation (2006). In this process, PTK has registered 24 patents and industrial designs in countries such as Indonesia, Malaysia, Thailand, Vietnam, China, Taiwan and India.

6. Conclusion and Policy Implications

6.1. Conclusion

The study revealed that the resource of innovation in Indonesian automotive industry diverged from individual and organization actors, both from internal and external resources. The innovation resource mostly comes from internal organization of the company.

i) sources of knowledge in *product innovation* came from: *first*, external organization those are company's competitor that stimulates the creation of new product in sharp market competition and company's principal that transfers the product technology to its subsidiaries. *Second*, internal organization namely individual initiative inside company, such as the idea of top executive or experienced entrepreneurs to create new product.

ii) Source of knowledge in *process innovation* came from internal organization that is advancement of automotive engineering research done the principals, then they transfer the technologies to its subsidiary to increase company competitiveness in globally advanced technology race.

iii) Source of knowledge in *organizational innovation* came from internal organization such as the principals initiatives to create the alliance companies in fulfilling the company's needs to increase competitiveness and productivity through efficiency in market competition.

iv) Source of knowledge in *management innovation* come from internal organization such as the principal transfer of skill and expertise to its subsidiary for solving the problem that exists the production and organization

Furthermore the study results conclude that, *first,* main *external resource of innovatio*n in Indonesian automotive industry mainly came from company's competitor. *Second,* the role of university and PRI as external resources of innovation in Indonesia were very small (if not unavailable). *Third,* the dominant role of university was as the provider of educated people, mostly automotive engineers with bachelor degree. *Fourth,* innovative PRI has shown the potency to be the external resources of innovation for local automotive companies in the future. *Fifth,* innovation cooperation between industry and PRI was linked by R&D matching grant provided by the government. *Sixth,* The PRI's support to innovative industry occurred in the form of technical assistance.

Finally, the study confirmed the claim of terWal, *et al.* (2007) that the dynamic capabilities (including absorptive capacity, network stability, and capacity enhancement) of firms have an important function in influencing the company growth and evolution in the long run. *First,* absorptive capacity of company to absorb, understand and exploit external knowledge creates the differences in the patterns of company evolution. *Second,* the positioning and stability of company network determine the company's ability in exploiting external knowledge sources. *Third,* the company's dynamic capacity enhancement to serve new markets determines the company's dynamic growth in the long run.

6.2. Policy Implications

The role of university and PRI as external sources of innovation for Indonesian automotive industry needs to be strengthened in future. Some policy implications to encourage university and PRI to help the development of local automotive industry in Indonesia are as follows:

i) University should improve the graduates' quality in automotive engineering by continuously linking engineers supplied by university with the quality of engineers demanded by the MNCs in Indonesian automotive industry.

ii) University should perform the industrial application of research output in automotive engineering to help the local automotive companies.

iii) Innovative PRI that has shown the potency to be the external resources of innovation for local automotive companies should be promoted to realize its potency by encouraging the related state own enterprises (SOEs) to support the commercialization of PRI's innovation.

iv) Innovation cooperation between local automotive industry and PRI should be strengthened by increasing the allocation of matching grant for R&D in automotive engineering provided by the government.

v) The PRI's support to locally innovative industry should be expanded from technical assistance in product testing to technology assistance in product innovation, by sharing qualified research scientist and engineers (RS&E) of PRI to help and develop local industry.

Innovation through R&D activity inside local automotive industry is expected occurred parallel with the increase of efficiency, productivity and competitiveness of Indonesian automotive products. This implies that government should continue:

i) to upgrade local component competitiveness of non-OEM by applying product standardization;

ii) to increase OEM component export through export incentives by cutting high cost economy;

iii) to encouraging MNCs investment in raw materials by using domestic resources (i.e. aluminum alloy factory) by providing investment incentive in basic industry, and;

iv) to improve infrastructure for domestic transportation by encouraging public-private partnership to invest in transportation infrastructure,

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CHAPTER 4

Knowledge-Based Linkages and Local Firms' Capability Formation in the Vietnamese Motorcycle Industry

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Despite being one of the late comers among the Asian countries launching on the development of automotive industry, Vietnam experienced rapid growth of the motorcycle industry and gradual accumulation of domestic component supply base since the late 1990s. Based on the analyses of major learning milestones experienced by local component suppliers, this paper found that the sectoral system of production and innovation in the Vietnamese motorcycle industry is increasingly driven by firms, while non-firm agents including universities play relatively minor roles. Acknowledging the challenges that Vietnam faces in deepening basic production capabilities and moving towards accumulation of innovation capabilities in this sector, this paper presents sets of policy recommendations aimed at realigning the national-level policy agenda and the structure of incentives so as to meet the increasing need for greater roles to be played by non-firm agents in promoting accumulation of innovative capabilities.

Keywords: capabilities, knowledge sources, suppliers, motorcycle industry

1. Introduction

As one of the latest comers among the batch of Asian countries, Vietnam has made certain initial steps in developing the automotive industry. While the country's automobile production still lags far behind other countries in the region, the recent growth of the motorcycle industry has been truly remarkable. Within just 15 years of launching on industrialisation under transition to the market economy, the country has emerged as the world's fourth largest producer and market of motorcycles, only after China, India and Indonesia. More importantly, the dynamic development of the industry has been accompanied by steady progress in the build-up of local component supply base, consisting mainly of Japanese, Taiwanese and local Vietnamese component suppliers (Vietnam Development Forum 2007; Fujita, forthcoming). Indeed, a key challenge for Vietnam is whether or not the country can succeed in further deepening the basic production capabilities and moving towards accumulation of innovation capabilities in this sector. The formation of production and innovation capabilities in the design and manufacturing of automotive components would have major influence over the country's potential for developing a wide variety of complex assembly industries (Vietnam Development Forum 2007).

In exploring Vietnam's prospects for deepening production and innovation capabilities in the local component supply base, an important question is whether or not the sectoral system of production and innovation in this industry is structured in such a way that encourages knowledge flows between firm and non-firm agents and provides incentives with firms to engage in innovative activities. A sectoral system of innovation and production consists of a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production, and sale of those products. The constellation of firms and non-firm innovation-supporting agents—including universities and research institutes—shapes the nature of knowledge flows between agents, thereby affecting the trajectories of the buildup of production and innovation capabilities within agents.

Comparing the sectoral innovation systems of the Thai and Vietnamese motorcycle industries, Intarakumnerd and Fujita (2008, 2009) argued that firms—especially motorcycle manufacturers or "lead firms"—play decisive roles in the sectoral system of innovation and production in the Vietnamese motorcycle industry, while non-firm agents like universities and research institutes have developed limited dynamic linkages with firms. This is broadly consistent with findings of other existing works on the Vietnamese motorcycle industry (Nguyen Duc Tiep 2006, 2007; Pham Truong Hoang 2007). The discussion thus far has focused on whether the linkages between firm and non-firm agents have emerged. However, the questions remain as to the *nature* of the linkages, which none of the existing studies cited above empirically looked into. How do the agents interact in practice? Do the linkages promote knowledge flows between the agents? Where do the firms source the knowledge from as they engage in production and innovative activities? Only by empirically exploring these questions, it can be shown how the sectoral innovation systems in the Vietnamese motorcycle industry function in practice.

This is what this paper aims to achieve. By engaging in systematic empirical analyses on the relative roles played by varieties of firm and non-firm agents in promoting supplier learning, this paper seeks to present a comprehensive picture of the nature knowledge flows within the sectoral innovation system. The empirical analyses will be conducted in two complementary steps: the first step, which focuses on the suppliers' side, and the second step, which looks at the non-firm agents—specifically, local universities. On the basis of this discussion, this paper will also make suggestions as to how the sectoral innovation system might be better aligned in order to provide an environment more conducive to supplier learning.

The remainder of the paper is structured as follows. Section 2 provides an overview on the Vietnamese motorcycle industry, including the three-stage development and the two types of value chains. Section 3 develops the analytical framework. Section 4 discusses the methodology. Sections 5 and 6 comprise the core of the paper. Section 5 presents findings of the empirical analyses on knowledge sources mobilised by suppliers in acquiring important capabilities. Acknowledging that universities play relatively minor roles in supplier capability formation, Section 6 then turns the focus to the nature of university-industry linkages, presenting case studies of two major universities with programmes that are directly relevant to the automotive industry. This section will also discuss recommendations for strengthening knowledge-based university-industry linkage. Section 7 presents policy recommendations derived from the empirical analyses. Section 8 concludes the paper by summarising the findings.

2. An Overview on the Vietnamese Motorcycle Industry

The decade-long development of the Vietnamese motorcycle industry documented by Fujita (2007, 2008, forthcoming) shows that the industry's development has been driven mainly by the competition between two distinct groups of lead firms. On the one hand, Japanese lead firms, i.e., Honda Vietnam, Yamaha Vietnam, and Vietnam Suzuki, are powerful global industry leaders producing high-priced, high-quality proprietary models. In the terminology of the global value chain approach (Humphrey and Schmitz 2001, 2004; Gereffi, *et al.* 2005), 'Japanese chains' coordinated by these Japanese lead firms are a typical example of captive chains in which small suppliers are under strict control and monitoring of powerful lead firms (Gereffi, *et* al. 2005). On the other hand, Vietnamese lead firms include numerous Vietnamese local assemblers, which started assembly of imported Chinese components in the early 2000s and later expanded local sourcing and in-house manufacturing of components, often in cooperation with Chinese companies. They mainly produce low-priced, low-quality imitations of Japanese models. Assembler-supplier relationships in these 'Vietnamese-Chinese chains' are market-based chains characterised by arm's-length transactions (Gereffi, *et al*. 2005).

The development of this industry can be explained primarily in terms of the emergence and transformation of these two types of value chains, as shown in the three-stage classification of the development process in Table 1. Stage I (the late 1990s) was the start-up phase. At this stage, only Japanese chains existed. Japanese motorcycle manufacturers set up their production behind the tariff wall and non-tariff barriers erected by the Vietnamese government. The Japanese manufacturers enjoying oligopolistic positions produced high-priced, high-quality product beyond the reach of most Vietnamese, and consequently the market stagnated during this period.

Table 1. Three-Stage Development of the Vietnamese Motorcycle Industry

Stage		Years	Market Size (Units sold per year)	Policies	Main Developments among Foreign Motorcycle Manufacturers	Main Developme nts among Vietnamese Assemblers
I	Start-up	late 1990s	300,000-500,000	Import substitution	Japanese companies dominated the market.	-
II	China Shock and its Repercussion s	2000-200 1	over 2 million	Weak enforcement of local content rules & import controls	Lost market shares.	Emergence of 51 local firms assembling Chinese components dominated the market.
		2002-200 4	Approxi-matel y 1.5 million	Strengthened enforcement of local content rules. Restrictive rules to limit the overall market growth and production of foreign manufacturers .	Diverse attempts at recovering the market shares. Honda Vietnam: launching of a low-priced model in Jan. 2002.	Decreased in number and market share.
II I	FDI-led Growth	2005-200 8	over 2.5 million	Deregulation on production and registration; protection on CBU imports remain.	Rapid expansion of production and recovery of market shares.	Further consolidatio n into a small number of large assemblers. Market shares reduced to 30-40%.

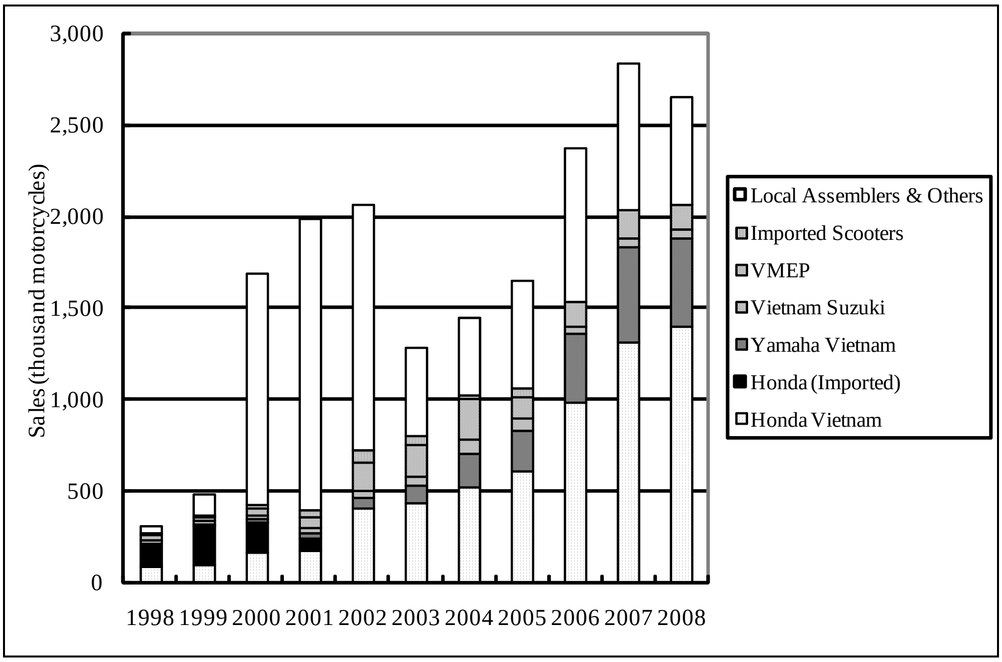
Source: Prepared by the author.

Stage II (2000-2004) is the period of market and policy turmoil triggered by an external shock. In 2000-2001, massive numbers of low-priced motorcycles were virtually smuggled into Vietnam from China, a time referred to as the 'China shock.' Since Vietnam had prohibited the import of assembled vehicles since 1998, Chinese imports arrived in the form of 'knockdown' component kits. More than 50 local assemblers entered into assembly of Chinese motorcycle component kits. With prices substantially lower than Japanese-brand models, these motorcycles quickly penetrated medium- and low-income consumer markets in urban and rural areas which had remained unexploited by Japanese firms. As a result, the annual sales of motorcycles expanded from 500,000 million units to more than 2 million units per year, and the local assemblers accounted for the bulk of this enlarged market (Figure 1).

The shock provoked a series of reactions, most notably, Honda Vietnam's (HVN) launching of a low-priced model in 2002 as an attempt to recover the market shares that had been lost. In the policy arena, the Vietnamese government reacted by enacting key policy changes to restore order and to promote sound development of the industry, e.g., stepping up the enforcement of local content rules and import tariffs, which had been circumvented by local assemblers, and introducing product quality and environmental standards. In desperate attempts to prevent uncontrolled proliferation of motorcycles, the government also resorted to more direct and arbitrary interventions to limit the production and sales of motorcycles. Foreign motorcycle manufacturers, particularly HVN, were seriously affected since these policies artificially prevented them from expanding production.

Stage III (2005-2008) was the period of FDI-led growth. By this stage, the Japanese motorcycle manufacturers fully recovered their market shares, while local assemblers were driven to the corner. During these years, Vietnam's moves towards deregulation, including the abolition of restrictive rules, and economic boom significantly boosted domestic motorcycle sales which climbed to 2.8 million units in 2007. As Figure 1, shows, this far exceeded the figures during the "China shock". The boom stimulated a new wave of FDI in the production of motorcycles and components, moving the industry even further toward an FDI-led development path. Even though the radical price reductions by the Japanese motorcycle manufacturers and changes in the policy environment drove local assemblers into a corner, they still held roughly one third of the market as of 2007-2008.

Figure 1. Sales of Motorcycles by Manufacturers



Source: For the years 1998 to 2005: Bo cong nghiep "Quy hoach phat trien nganh cong nghiep xe may Viet Nam giai do an 2006-2015, co xet den nam 2020", Vien nghien cuu chinh sach, chien lu oc cong nghiep, 2007.
Figures for the years 2006 to 2008 are estimated by the author base on interviews of Japanese and Tawanese motorcycle manufacturers and component suppliers in March 2009.

This research asks whether the remarkable industrial dynamism discussed above has been accompanied with the emergence of a sectoral system of innovation and production that is conducive of accumulation of technological and production capabilities of local component suppliers. The subsequent section will present the framework to be used for empirical analysis.

3. Analytical Framework

According to the evolutionary view of economic change, technical changes are not generated simply by adopting machinery or equipment that embodies new technology but require specialised resources accumulated through deliberate investment and efforts (Lall, 1992; Bell and Pavitt, 1995; Bell and Albu, 1999). Such specialised resources needed to generate and manage technological change such as knowledge, skills, experience, and institutional structure and linkages are called capabilities (Bell and Pavitt, 1995; Figueiredo, 2008).

Manufacturing firms in developing countries generally start production by importing technologies developed elsewhere. The key issue is how successfully they manage to move from acquiring and assimilating the imported technology to adapting it to the local needs, improving it, and finally creating new technology on their own. The key challenge for developing country firms is whether they could move from acquiring the capability to use the existing technology, i.e., to produce goods at given levels of efficiency and given input requirements technology-changing capability, towards accumulating the capabilities to change the existing technology, i.e., to create, change or improve products, processes, production organisation, or equipment (Bell and Pavitt, 1995; Ariffin, 2000; Figueiredo, 2008). The former is usually referred to as "production capabilities," while the latter is often called "innovation capabilities" (Schmitz 2007)[1]. The latter is much more difficult to acquire and therefore forms an important foundation for firms' competitiveness.

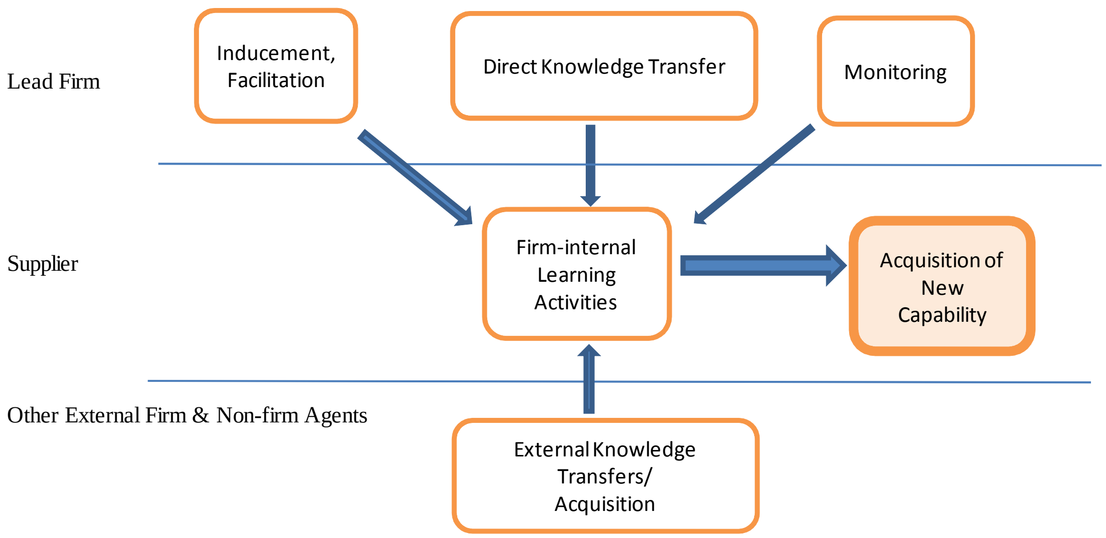
The present research is concerned with the sources of production and innovation capabilities in component suppliers in complex assembly industries. In this regard, various streams of literature have emphasised different groups of actors: (1) the suppliers themselves, the focus of the TC approach (Bell 1984; Bell and Pavitt 1995, 1997), (2) lead firms or buyers, emphasised in the GVC approach (Humphrey and Schmitz 2001, 2004; Schmitz 2006) and (3) other firm and non-firm agents including universities, research institutes, and business associations, highlighted by the innovation systems approach (Lundvall 1993; Malerba 2004). Since capability formation in essence involves accumulation of knowledge, we need to devise a framework that captures the modes of actor involvement and knowledge flows between the actors (Bell and Albu 1999; Ernst and Kim 2002). Figure 2 presents a model of supplier learning incorporating the roles played by the lead firms, suppliers and other external firm and non-firm agents—including both direct modes of involvement in the suppliers' sourcing or generation of knowledge and indirect modes in inducing and facilitating the suppliers' sourcing or generation of knowledge.

Suppliers: In the present context, suppliers are the very agents of learning. The TC approach has focused on the endogenous process through which local firms diffuse, adapt and create knowledge. In the case of component suppliers in motorcycle value

[1] Different authors use different terminologies to refer to technology-using capability and technology-changing capability. Bell and Pavitt (1995) use "production capacity" and "technological capability", while Ariffin (2000) and Figueiredo (2008) use "routine production capability" and "innovative technological capability".

chains, the main channels through which suppliers generate new knowledge include investment in physical resources like machinery and equipment, investment in human resources via recruiting and training, and in-house R&D and deliberate improvements in their activities (Bell and Pavitt 1995, 1997; Caloghirou, *et al.*2004).

Figure 2. Model of Supplier Learning Roles of Key Actors



Source: Prepared by the author

Lead Firms: Supplier learning also is heavily influenced by lead firms who place orders. The lead firms' roles in shaping supplier learning have been conceptualised by the literature on global value chains (Humphrey and Schmitz 2001; Schmitz and Knorringa 2001, Schmitz 2006) and technology transfer (Wong 1991, 1992; Capannelli 1999; Ivarsson and Alvstam 2004, 2005). On the basis of the existing literature, the lead firm's involvement in supplier learning is classified into the following categories. *Inducement* refers to the lead firm's roles in equipping suppliers with often challenging requirements and targets to be reached, thereby motivating them to learn and enabling them to come up with specific learning targets. Specifically, the lead firms provide supplier with product design specifications and performance requirements, which may include indirect forms of knowledge transfer, advance indications of future production plans and quality, performance, or feature requirements and targets (Ivarsson and Alvastam 2004, 2005; Wong 1991; Mitsuhashi 2005). *Direct knowledge transfer* includes advice or assistance on technical or non-technical aspects of production, on-site audit of plant operation, troubleshooting of specific problems, and training of supplier staff through formal programmes or informal consultations or visits (Wong 1991; Lall 1980; UNCTAD 2001; Ernst and Kim 2002; Ivarsson and Alvstam 2004, 2005; Mitsuhashi 2005; Schmitz 2006). *Monitoring* refers to testing and diagnostic feedbacks on quality and other dimensions of performance of suppliers or their products against the initially prescribed targets or requirements (Schmitz 2006; Wong 1991).

External Agents Other than Lead Firms: Apart from the lead firms and suppliers, other firm and non-firm agents also contribute to supplier learning as sources of explicit and tacit knowledge. Public and private innovation-supporting organisations such as business associations, government agencies, consultants, international and aid organisations, or research institutes and universities may act as providers of advice, training, knowledge, or consultancy services (Malerba 2004; Malerba and Mani 2009). Intra-cluster sources may also important source of knowledge for small suppliers, such as the mobility of skilled labour among firms and diffusion of know-how (Bell and Albu 1999).

4. Methodology

This paper will analyse the nature of linkages and knowledge flows in the Vietnamese motorcycle industry in two complementary steps. The first step will focus on the local suppliers. Based on case studies of 21 strategically selected local suppliers, the empirical analysis will look into the sources of knowledge that the suppliers mobilised in acquiring important capabilities. The second step, in turn, will focus on the non-firm agents. In-depth case studies of two major technological and industrial universities will provide the insights on the extent and the nature of the linkages that the universities have developed with firms operating in the automotive industry. I n both steps, data were collected via extended interviews with the respective firm and non-firm agents.

4.1 First Step: Analysis of Suppliers' Knowledge Mobilisation

In analysing the sources of local suppliers' capability formation, this paper adopts an event-based approach (Van de Ven and Poole 1995, Lema 2010). Based on the assumption that capability formation processes entail major leaps, incremental progress, halted progress, or even retrogression from previous levels, instead of progressing steadily along a linear, pre-determined path (Bell 2006), this approach focuses on important milestones in the capability formation process, which we refer to as "learning events." These are the incidents of major leaps in supplier capabilities in one or more of the key functional domains of motorcycle component suppliers' operation: new product introduction (including product design and development activities), equipment-related activities (operating, maintaining, and improving production equipment and machinery), and production management.[2]

An event has a start date, when the supplier launched a new initiative or target for new product introduction or improvement in equipment-related activities or production management. Events may last just for few months, or they might extend over several years. The goals or plans initially set at the start date may eventually have to be adjusted or altered. Events are perceived to have terminated when the supplier has achieved observable learning outcome ('end date'). Given that suppliers' activities are fundamentally constrained by the nature of the orders they receive from lead firms, it is basically assumed that an event takes place in the supplier's activities in one or more value chains.[3]

Since this research assumes learning paths and sources to differ widely by the nature of lead firm involvement, supplier learning activities and involvement of other agents, the research adopted multiple case study design. The strategy was to include five to six suppliers with different levels of learning performance for each of the three broad groups classified by the types of value chains and their positions in the value chains (i.e., first-tier suppliers in Japanese chain, second-tier suppliers in Japanese chain, and suppliers in the Vietnamese-Chinese chain[4]), and to identify, for each supplier, up to three most important milestones in the capability formation process after the supplier's participation in motorcycle value chains.

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2 For details of this classification, see Sato and Fujita (2009).

3 It is also possible for learning to take place for exploring completely new markets, in which case an event may not be associated with specific value chains. However, this was rarely observed among local motorcycle component suppliers in Vietnam. Unstable market and policy conditions made it high risky for suppliers to engage in medium- to long-term R&D without any market assurance.

4 This classification is based on the author's previous research (Fujita 2007).

Table 2 shows 21 suppliers selected for case study. Given the diverse patterns of value chain participation and their changes over time, suppliers are broadly classified into three groups according to the types of motorcycle value chains they participate: *Group A*, which includes eleven suppliers that have participated in Japanese chain but not in Vietnamese-Chinese chain; *Group B*, which includes five suppliers that initially participated in Vietnamese-Chinese chains but eventually entered into Japanese chain; and Group C, which includes five suppliers that have participated in Vietnamese-Chinese chains but not in Japanese chain. None of the suppliers in Group A shifted from Japanese chains to Vietnamese-Chinese chains. Suppliers in both groups also participated in value chains other than Japanese or Vietnamese-Chinese chains at different points in time.

Data were collected via interviews conducted by the author in between September 2008 and March 2009. All of the firms except for A5, A10, A11, C1, C4 and C5 were interviewed more than once. The first interview was usually with the top management of the companies, and aimed to identify up to three major learning events experienced by the suppliers since the mid-1990s. The second interview was usually with the manager(s) who directly took charge of new product introduction or production activities, and focused on collecting detailed data learning events consisting of thick description of the process of events as well as the roles of various actors involved in the events—including the suppliers themselves, lead firms, and other firm or non-firm agents.

Table 2. List of Case Suppliers

Supplier	Owner-ship	Type of components	Number of Employees	Start of operation	Previous Products/ Experience	Value Chain Participation							
						Stage I		Stage II			Stage III		
						J	Other	J	V-C	Other	J	V-C	Other
A1	State	Metal (overall)	1,350	1974	Bicycle components	✓	✓	✓			✓		
A2	State	Metal (overall)	1,000	1974	Household Products	✓	✓	✓		✓	✓		
A3	State	Plastic	550	1972	Household Products	✓	✓	✓		✓	✓		✓
A4	State	Metal (overall)	1,000	1968	Agriculural machinery and components		✓	✓		✓	✓		✓
A5	Private	Assembly type	500	1994	Automobile components for export to Japan		✓	✓		✓	✓		✓
A6	Private	Plastic	1,000	1988	Plastic packages for foreign buyers		✓	✓		✓	✓		✓
A7	Private	Specialised (Dies & Molds)	81	2004	General director and key engineers gained experience at a Japanese mold company						✓		
A8	State	Metal (overall)	1,100	1980	Diesele engines for the domestic market		✓	✓✓		✓	✓✓		✓
A9	Private	Specialised (Plating)	150	1988	Replacement components		✓	✓✓			✓✓		✓
A10	Private	Plastic	182	1994	Household products and packages.		✓	✓✓			✓✓		✓
A11	Private	Specialised (Precision Machining)	170	1999	Components of dies and molds.					✓	✓✓		✓
B1	State	Metal (overall)	600	1974	Bearings for the domestic market.		✓		✓		✓		
B2	State	Metal (overall)	157	1970	Components for agricultural machinery.			✓		✓	(✓)		
B3	Private	Metal (diecasting)	200	1986	Replacement components		✓	✓✓	✓		✓✓		✓
B4	Private	Metal (overall)	400	1981	Bicycle components		✓	✓✓	✓		✓✓	✓	
B5	Private	Metal (diecasting)	150	2001	Trading				✓		✓✓		
C1	Private	Metal (overall)	150	1959	Bicycle components		✓		✓				✓
C2	Private	Metal (overall)	450	1987	Bicycle components		✓		✓				✓
C3	Private	Metal (overall)	170	1996	Replacement components		✓		✓			✓	✓
C4	Private	Assembly type	115	1988	Trading		✓		✓			✓	
C5	Private	Assembly type	100	1999	Trading				✓				✓

Notes: Types of value chains are abbreviated as follows: J (Japanese chain), V-C (Vietnamese- Chinese chain), and Other (other types of chains).
Source: The author's interviews.

4.2. Second Step: Analysis of Universities' Knowledge-based Linkages with Firms

In order to complement the first step of analysis, the second step turned the focus to local universities as one of the key non-firm agents in the sectoral system of innovation and production in the automotive industry. The analysis attempted to examine the extent and nature of the knowledge-based linkages that the universities developed with firms in the automotive industry. At the same time, attempts were made to look for possible factors that inhibited the development of linkages and/or knowledge flows between local universities and firms in the automotive industry.

Two major universities of particular relevance to the automotive industry were selected for case study: Hanoi University of Technology (HUT) and Hanoi University of Industry (HaUI). These are renowned universities with different areas of specialisation, both of which are closely related to the needs of the automotive industry. While HUT is strongly oriented towards academic research and development, HaUI focuses on training industrial human resources with practical skills. Although there are numerous universities located in different parts of the country, universities in Hanoi were selected because the automotive industry is overwhelmingly concentrated in northern Vietnam.[5] In fact, most of the 21 suppliers selected for the first step of analysis were located in Hanoi or surrounding provinces, and the two universities were explicitly named by two of the 21 case suppliers as complementary knowledge sources for their important learning milestones. Data were collected via interviews with the respective universities in November 2010.

5 This is because the two largest foreign motorcycle manufacturers (HVN and Yamaha Vietnam), as well as many of the major local assemblers, are located in the North.

5. Local Suppliers' Capability Formation and the Knowledge Sources

This section presents the findings of the first step of empirical analysis on the sources of in local suppliers' learning. It will start by presenting an overview of the "learning events" and then proceed to discuss the roles of different actors involved in supplier learning.

5.1. Overview of Learning Events

Through in-depth interviews of 21 local Vietnamese suppliers of motorcycle components conducted between September 2008 and March 2009, the author was able to identify a total of 44 learning events that took place in the suppliers' activities in designing and manufacturing motorcycle components. An overview of the learning events is provided in Table 3.

Table 3. Number of Learning Events by Types of Chains, Functional Types of Capabilities Acquired, and Timings

Functional Category of Capabilities Acquired		New Product Introduction	Equipment-related	Production Management	Total Number of Events
Events in Japanese Chain (1st tier) (9 suppliers)	Stage I	0	3	3	3
	Stage II	0	5	6	6
	Stage III	0	7	9	11
	Total	0	15	18	20
Events in Japanese Chain (2nd tier) (7 suppliers)	Stage I	-	-	-	-
	Stage II	0	3	3	4
	Stage III	0	8	9	9
	Total	0	11	12	13
Events in Vietnamese-Chinese Chain (5 suppliers)	Stage I	1	1	1	1
	Stage II	5	5	4	7
	Stage III	3	1	1	3
	Total	9	7	6	11

Source: The author's interviews.

As regards the types of supply networks, 33 events took place in the suppliers' activities in Japanese chains (20 events at the first-tier and the remaining 13 events at the second-tier), while 11 events took place in the suppliers' activities in Vietnamese-Chinese chains. Though not the explicit focus of this paper, the functional categories and the levels of the capabilities acquired by the suppliers varied by the types of value chains in which the events took place.[6] Learning in Japanese chains focused almost exclusively on production-related capabilities, which included equipment-related and production management capability. Most suppliers experienced a series of learning events in the course of a decade, and the levels of attainment improved over time. By contrast, suppliers in Vietnamese-Chinese chains engaged in wider functional categories of activities including component design, though the levels of learning attainment remained limited.

The timings of learning events also deserve attention. Events in Japanese chains are concentrated in Stage III. In fact, more than half of all the learning events in Japanese chains took place in Stage III. This can partly be accounted for by the fact that more and more suppliers, many of which had previously participated in Vietnamese-Chinese chains, entered into Japanese chains—both at first- and second-tier in Stages II and III. However, remarkable increases in the *levels* of capability observed for given suppliers—particularly in Stage III—do indicate that Stage III was in fact the period of most intensive learning for suppliers in Japanese chain, which is due to increasingly challenging requirements imposed by lead firms on suppliers at this stage (Fujita, forthcoming). By contrast, learning events in Vietnamese-Chinese chain are overwhelmingly concentrated in Stage II. This is because many suppliers had exited

[6] Further details of the findings can be found in Fujita (forthcoming).

from Vietnamese-Chinese chain by Stage III and, even among those that stayed, few managed to substantially improve their capability levels in Stage III.

5.2. Contrasting Actor Constellations

The present focus is on identifying the sources of knowledge that suppliers mobilised in acquiring new capabilities. Table 4 shows key actors involved in the 44 earning events in the order of importance as identified by the interviewees. First, as regards the types of actors involved, the table clearly points to the importance of two types of actors: suppliers themselves and lead firms. Other firm and non-firm agents including consultants, aid organisations, related companies, training institutes, machinery or software suppliers, and universities were generally ranked at lower levels of importance, suggesting that they played relatively minor roles complementing those of the suppliers themselves and/or the lead firms. As far as universities are concerned, there were only two events in which local Vietnamese universities played any role: the second learning event in supplier A4 and the third learning event in supplier B1. Both of the two events took place in the suppliers' activities in Japanese chain.

Table 4. The Key Actors in Learning Events

Main Type of Value Chain	Stage	Firm	Event #	Key Actors: Most Important	Key Actors: Second Most Important	Key Actors: Other Actors Involved
J (first-tier)	I	A1	1	Suppliers themselves	Customers or customer-designated unit (HVN)	
		A2	1	Suppliers themselves	Customers or customer-designated unit (HVN)	
		A3	1	Suppliers themselves	Customers or customer-designated unit (HVN)	Codified information obtained from foreign journals
	II	A1	2	Suppliers themselves	Customers or customer-designated unit (HVN)	Vietnamese consulting company (consultancy)
		A2	2	Suppliers themselves	Customers or customer-designated unit (HVN)	Vietnamese Chamber of Commerce & Industry (training programme)
		A4	1	Suppliers themselves	Customers or customer-designated unit (HVN)	Japanese aid organisation,
		A5	2	Suppliers themselves	Customers or customer-designated unit (HVN)	Japanese companies in Vietnam (learning by observing)
		A6	1	Suppliers themselves	Customers or customer-designated unit (HVN)	Related company (training); Training centre funded and assisted by Japan (training)
		B1	2	Suppliers themselves	Customers or customer-designated unit (HVN)	Japanese companies in Vietnam (learning by observing); related company (mobility of human resources)
	III	A1	3	Suppliers themselves	Customers or customer-designated unit (HVN)	Training centre funded and assisted by Japan (training)
		A2	3	Suppliers themselves	Customers or customer-designated unit (HVN)	Vietnam Chamber of Commerce & Industry (training programme)
		A3	2	Suppliers themselves	Customers or customer-designated unit (HVN)	
		A3	3	Suppliers themselves	Othe external actors (supplier of machinery/equipment)	
		A5	3	Suppliers themselves	Other external actors (related company)	
		A6	2	Suppliers themselves	Other external actors (recruiting engineers)	Customers or customer-designated unit (HVN)
		A7	2	Suppliers themselves	Customers or customer-designated units	
		A8	3	Suppliers themselves	Customers or customer designated unit (Japanese company with technology transfer agreement)	
		B1	3	Suppliers themselves	Customers or customer-designated unit (HVN)	Japanese aid organisation (training programme); Hanoi University of Technology (training programme jointly offered with Toyota Vietnam); Japanese companies in Vietnam (learning by observing)

Main Type of Value Chain	Stage	Firm	Event #	Key Actors		
				Most Important	Second Most Important	Other Actors Involved
J (first-tier)	III	B2	2	Suppliers themselves	Customers or customer-designated unit (HVN)	
J (2nd-tier)	II	A10	1	Suppliers themselves	Customers or customer designated unit (Japanese motorcycle manufacturers & first-tier suppliers)	Software supplier (Europe) (knowledge transfer)
		A8	1	Suppliers themselves	Other external actors (Japanese aid organisation)	Japanese aid organisation (training programme)
		A9	1	Suppliers themselves	Customers or customer designated unit (Japanese first-tier suppliers)	Companies in Japan (learning by observing)
		B3	2	Suppliers themselves	Customers or customer designated unit (Japanese first-tier supplier)	
	III	A10	3	Suppliers themselves	Customers or customer designated unit (Japanese motorcycle manufacturers & first-tier suppliers)	Japanese aid organisation; Training centre funded and assisted by Japan (training programme)
		A11	1	Suppliers themselves	Customers or customer designated unit (Japanese first-tier suppliers)	
		A11	2	Suppliers themselves	Customers or customer designated unit (Japanese first-tier suppliers)	
		A4	2	Suppliers themselves	Customers or customer-designated unit (HVN & a Japanese first-tier supplier)	Hanoi University of Industry (training programme)
		A7	1	Suppliers themselves	Customers or customer-designated unit (Japanese first-tier supplier)	Recruiting engineers
		A9	2	Suppliers themselves	Customers or customer designated unit (Japanese first-tier suppliers)	Companies in Japan (learning by observing)
		B3	3	Suppliers themselves	Customers or customer designated unit (Japanese first-tier supplier)	
		B4	2	Suppliers themselves	Other external actors (Japanese companies other than customers)	
		B4	3	Suppliers themselves	Other external actors (supplier of machinery/equipment)	
		B5	2	Suppliers themselves	Other external actors (Thai consultant who had worked for a joint venture supplier in Vietnam)	Customers or customer-designated unit (Japanese first-tier supplier), Japanese aid organisation (training programme)
V-C	I	C1	1	Suppliers themselves		
	II	B1	1	Suppliers themselves		
		B2	1	Suppliers themselves		
		B3	1	Suppliers themselves	Other external actors (observing factories in China)	
		B5	1	Suppliers themselves	Other external actors (a partner in China)	Companies in China (learning by observing)
		C2	1	Suppliers themselves	Other external actors (observing factories in Taiwan)	

Main Type of Value Chain	Stage	Firm	Event #	Key Actors		
				Most Important	Second Most Important	Other Actors Involved
		C3	1	Suppliers themselves		
		C5	1	Suppliers themselves	Other external actors (a partner in Russia)	
	III	B4	1	Suppliers themselves	Customers or customer designated units (local assemblers)	
		C3	2	Suppliers themselves	Customers or customer designated units (local assemblers)	
		C4	1	Suppliers themselves	Customers or customer designated units (local assemblers)	

Source: The author's interviews.

Second, as regards the roles of suppliers and lead firms as the key actors in supplier learning, all of the suppliers ranked their learning activities as the most important source of learning for all of the events they experienced, regardless of the types of value chains in which the events took place. While the suppliers' self-evaluation of their own roles needs to be interpreted with caution, taking into account that entrepreneurs tend to insist on the value of their own achievements, this is consistent with the insights of the TC literature that firm-level capability formation is ultimately determined by deliberate investments in specialised, change-generating activities by the firms as the very agents of learning (Bell and Pavitt 1995: 100).

Third, the key differences between the Japanese and Vietnamese-Chinese chains were observed in the role of lead firms. Lead firms turned out to be extremely important in learning events in Japanese chains especially in the early years. They were identified as the second most important actor for the majority of learning events that took place mainly in Japanese chain. In Vietnamese-Chinese chains, lead firms played minimal roles in learning events. In more than half of these events, suppliers turned out to be the only actors involved.

These very different actor constellations in Japanese and Vietnamese-Chinese chains point to two contrasting patterns of supplier capability formation. In Japanese chain, capability formation involves active roles of *both* suppliers and the lead firms. By contrast, in Vietnamese-Chinese pattern, supplier capability formation is achieved mostly by the suppliers' own initiatives with limited roles played by lead firms. The following sub-sections will examine the specific modes of actor involvement in greater depth, focusing on the intensity and nature of knowledge flows between the actors.

5.3. Knowledge Sources for Suppliers in Japanese Chain

While the main actors involved in the majority of learning events in Japanese chains were lead firms and suppliers, the relative importance and specific roles played by the respective actors, as well as the extent to which other actors were involved, changed over time. Table 5 shows the details of the roles played by suppliers, lead firms, and other external firm and non-firm agents.

As regards the learning events that took places in Stage I, suppliers and lead firms virtually turned out to be the only actors involved. The lead firm's roles were extensive, covering all three domains of lead firm involvement in supplier learning outlined in the conceptual framework: inducement, direct knowledge transfer and monitoring. Given the limited number of suppliers available in Vietnam, low initial level of suppliers' capabilities, and the limited experience they had had in serving foreign customers, a great deal of intervention on the part of HVN was required to bring the suppliers' capabilities up to the required standards.

Table 5. Sources of Learning in Case Suppliers (44 learning events experienced by 21 local suppliers in Japanese & Vietnamese-Chinese chains)

			J-Chain (1st tier)				J-Chain (2nd tier)			V-Chain			
Timing (Stages at which learning events took place)			Total	I	II	III	Total	II	III	Total	I	II	III
Total number of Learning Events			19	3	6	10	14	4	10	11	1	7	3
Lead Firm (or units designated by lead firms)	Inducement	Product specifications and QCD requirements	19	3	6	10	13	3	10	3			3
		Providing dies and molds	5	3	1	1	4	1	3				
	Facilitation	Financial support											
		Guarantee orders											
	Assistance	Technical Advices & Training	10	3	5	3	6	2	4				
		Troubleshooting	14	3	5	6	4	1	3				
		Transfer codified knowledge											
	Spillover	Learning by observing	4		2	2	2	1	1				
	Monitoring	Testing & feedback											
		a) OK/NG on final products					2	1	1	2			2
		b) Feedback on reasons for NG					6	1	5				
		c) Follow-up on the measures taken to overcome	18	3	6	9	5	2	3				
		Factory audit	19	3	6	10	9	4	5				
Supplier		Physical investment	13	2	4	7	10	3	7	6	1	3	2
		In-house improvements/R&D in product design								2			2
		In-house improvements/R&D in production	9	3	2	6	4	2	2	5		3	2
		Organisational changes	14	1	5	8	5	2	3	1			1
Other external actors		Technical Advice & Training (foreign organisations)	5		1	4	5	2	3	2		2	
		Technical Advice & Training (domestic organisations)	2			2							
		Consultancy											
		Recruiting individuals/Mobility of Human Resources	5	1	2	2	1		1				
		Learning by observing (foreign companies or companies abroad)	2		1	1	4	1	3	3		3	

Notes: Dark-shaded cells: The respective role of the key actor was observed in two-thirds or more of the learning events.
Light-shaded cells: The respective role of the key actor was observed in one-third or more of the learning events.
Source: The author’s interviews.

In Stages II and III, lead firms continued to be the main actors involved, yet their relative importance diminished for the majority of suppliers. As Table 6 shows, while the lead firm's roles in inducement and monitoring continued to be important, the role of direct knowledge transfer diminished in comparison to the previous period. This is because, with the new wave of FDI in component production and increased competence of incumbent suppliers, HVN no longer had to spare much time and resources for nurturing suppliers. In the meantime, intense competition with Chinese motorcycles meant HVN was compelled to reduce component costs while maintaining quality levels. Rapid increase in production in Stage III also meant much tighter delivery requirements on suppliers. Under the renewed circumstances, HVN made extensive use of *inducement* in the forms of tight quality, costs and delivery (QCD) requirements and regular and systematic *monitoring* of supplier performance to exert greater pressure on suppliers, while hands-on assistance was provided only selectively.

Another change that took place in Stages II and III is increased instances of involvement by external firm and non-firm agents other than lead firms. Table 5 shows increased incidence in Stages II and III of learning events that involve various firm and non-firm agents such as aid organisations, training institutes, consultancies, related companies, and/or local universities. Nevertheless, most of the linkages with these firm- and non-firm agents in fact developed largely out of the suppliers' relationships with the lead firms. This is evident from the fact that most of these external agents involved—whether private companies or public organisations—turned out to be Japanese. Most often suppliers gained access to these organisations or companies directly or indirectly through their relationships with HVN.

As regards the roles played by these external agents, these external sources largely turned out to be complementary rather than critical sources in their own. This is evident from the fact that these external actors are ranked generally low in the order of importance identified by the suppliers (Table 5). In order to reach the performance targets imposed by lead firms, suppliers essentially used the methods, schemes, or know-how sourced from these external agents to supplement their own learning activities. As Table 6 shows, the specific roles played by these external agents in the course of learning events include provision of technical advice and training is the most typical form of involvement, followed by provision of human resources and opportunities for suppliers to learn by observing sophisticated operations conducted at other companies.

An important point to note in the context of this study is the very low incidence of learning events in which local universities were involved. There were only two learning events for which the interviewed suppliers explicitly acknowledged the linkages with local universities as an important source of knowledge: the second learning event in supplier A4 and the third learning event in supplier B1. In both of these incidents, the respective suppliers took advantage of training programmes offered by local universities as one of the knowledge sources to supplement their in-house learning activities and technical assistance offered by HVN.

- While supplier A4started its relationship with HVN in 2001 by supplying sprockets, which required relatively simple processing technology, it started receiving orders for increasingly complex components around the year 2005 onwards. For processing these components, the supplier invested in a large number of CNC machining centres and sent its engineers to a training programme on operation of

CNC machines offered jointly by Hanoi University of Industry and a Japanese university.

- After supplying components to local assemblers for a few years in the early 2000s, supplier B1 started to make preparation for becoming a first-tier supplier of HVN. As the supplier was faced with the need to obtain ISO9001 certification, it started initiatives to improve production and quality management. Sending all the department and factory managers to training programmes organised jointly by Hanoi University of Technology and Toyota Vietnam helped the company to disseminate the basic principle of 5S within the company at this stage, which facilitated the subsequent processes of working directly with HVN to meet their specific requirements.

5.4. Knowledge Sources for Suppliers in Vietnamese-Chinese Chain

As discussed in Section 5.2, learning in Vietnamese-Chinese chain is broadly categorised as suppliers' independent learning with limited roles played by the lead firms.

During Stages I and II, there was no incidence of lead firms playing key roles—in any of the three domains of lead firm involvement. Learning inducement was extremely limited because specifications and requirements were only vaguely defined and thus failed to give incentives or targets for supplier learning. Given the lack of standards or requirements for the lead firms to check the products or processes against, monitoring was also largely absent. The low quality and precision requirements meant that direct technical assistance was not needed. Supplier learning during this period was instead largely a result of the suppliers' mobilisation of internal knowledge sources on the suppliers' own initiative. At the very minimum, in-house improvements in a wide range of activities including product design, equipment-related activities, or organisation turned out to be the main source of learning for most of the learning events in Vietnamese-Chinese chains.

While the essential features of the learning model remained unchanged, slight adjustments took place in the role of the key actors by Stage III. In three learning events took place in Stage III, the lead firm was identified as the second most important actor besides the suppliers themselves. However, the roles played by the lead firms in Vietnamese-Chinese chains were still limited to providing product specifications and monitoring of the supplier performance (Table 6). Interviews with suppliers also revealed that, while increased quality and precision requirements did exert pressure on suppliers, the ways lead firm implemented learning inducement and monitoring were still arbitrary, far from the detailed and systematic methods of providing specifications and performance monitoring implemented in the Japanese chain.

Suppliers in Vietnamese-Chinese chains occasionally mobilised external sources of knowledge other than lead firms. Particularly where the suppliers only had limited internal resources to leverage on, they turned to other actors to complement internal sources of learning. Table 5 indicates that most of these sources were firms, meaning that the linkages are largely business-based. There was no incidence of learning events where non-firm agents were involved. Two suppliers received direct technology transfer from abroad. In launching component production, supplier B5 went into a technology transfer agreement with a Chinese partner, which provided everything in a package: design drawings, dies, machinery and equipment, engineers, sub-components, and materials. The Chinese engineers stayed at the factory for throughout the period of contract, which extended for seven years, to assist operation of the machinery (the first learning event in supplier B5). Supplier C5 went into a technology transfer contract with a Russian partner to obtain technology to produce motorcycle chains, though in this case the Russian engineers stayed at the supplier's factory for several years only (the first learning event in supplier C5). Some suppliers exploited knowledge gained from visiting and observing factories abroad (the first learning event in supplier B3; the first learning event in supplier C2).

6. The Role of Innovation-Supporting Organisations: The Nature of University- Industry Linkages

The analysis in the previous section revealed that universities played extremely limited roles in the acquisition of important capabilities by the 21 local motorcycle component suppliers. In an attempt to explore the reasons for the lack of dynamic university- industry linkages, as well as the possible approaches for encouraging the emergence of such linkages, this section turns the focus to the universities. It will conduct in-depth examination of two universities of direct relevance to the automotive industry yet with contrasting features: Hanoi University of Technology (HUT) and Hanoi University of Industry (HaUI). Unfortunately, neither of the universities compiled detailed data on the modes of engagement with firms in the automotive industry. The discussion will therefore be largely descriptive, with little details on the magnitude or frequency of the programmes.

6.1. Overview of the Two Universities

Since its establishment in 1956 as the first university of technology in Vietnam, HUT has consistently been regarded as the top natural sciences university in Vietnam. The university has churned out numerous engineers and scientists trained at the bachelor, master and doctoral levels. While it has numerous departments of direct relevance to the automotive industry, the university is particularly renowned for strong tradition in mechanical engineering. Every year, approximately 4,000 students graduate with the university with the degree of bachelor of science or engineering. Many of these graduates are employed as engineers in the automotive industry, including the major Japanese automakers, motorcycle manufacturers and core component suppliers.

HaUI, by contrast, started as a vocational school as early as 1898. After serving many years in vocational training in the fields of mechanical and electrical engineering, the school was upgraded to an industrial college in 1999 and further to a university in 2005. The university now has educational programmes at three different levels: university, college, and vocational high school. Apart from the Department of Automobile Industry, which is established exclusively to serve the requirements of the automotive industry, the university has departments that are directly relevance to the automotive industry including mechanical engineering and electrical and electronics. Every year, approximately a total of 10,000 to 15,000 students complete the university, college or vocational high school programmes. In contrast to the HUT strongly oriented towards scientific research and development, HaUI has focused on providing practical training for technical labour force.

6.2. University-Industry Linkages—Current Situation and Outstanding Issues

The author's interviews revealed that the roles that the two universities have played in capability accumulation of local firms in the automotive industry can be classified into the following three categories: (1) education via degree programs, (2) training courses for engineers and staffs working in the automotive industry, and (3) other forms of collaboration such as production to order and R&D projects. All of the three types of engagement were found in both of the universities, though their content or the relative importance differed between the universities.

Education via Degree Programs

At the most basic level, the universities have contributed to the industry by providing qualified human resources. HUT has focused on educating engineers and technicians. The author's research found that HUT's graduates worked at major Japanese motorcycle manufacturers as well as Japanese, Taiwanese and Vietnamese suppliers as engineers and managers in production engineering, equipment engineering, and product and process design. Many of the graduates of this university also became leading entrepreneurs. In fact, some of the local suppliers analysed in the previous section were established by the graduates of this university (e.g., A7 and B5), and many more managed by the graduates of this university. By contrast, HaUI has focused on practical vocational training for leaders and managers in the areas of production, production control, quality control, and/or production engineering.

However, there have been criticisms that education offered by the Vietnamese universities, industrial colleges and vocational schools has not responded sufficiently to the requirements of the industry. On the basis of the business surveys conducted by the Vietnam Business Forum and JETRO, Mori, *et al*. (2009) pointed out that many foreign businesses in Vietnam expressed difficulties in recruiting skilled labour—particularly middle managers and engineers. For this reason, Japanese motorcycle manufacturers and suppliers interviewed by the author have had to invest in substantial in-house training for new recruits (Intarakumnerd and Fujita 2008). The shortage of qualified teaching staffs and outdated facilities are among the reasons why the content and quality of the programmes failed to respond to the practical needs of the industry (Mori, *et al*. 2009).

One of the measures that have been taken to address the above gaps is the internship programme. According to the author's interviews, internship programmes had been implemented by both of the two universities to provide opportunities for students to gain first-hand working experience in the industry before graduation. HUT even required all undergraduate students to participate in internship programmes in their third, fourth and fifth years.[7] Both universities pointed out that foreign firms, in particular, made strategic use of internship programmes by linking them with their recruitment process. They sought to use the internship programmes as the chances to look at prospective employees in their own work environment and to select promising candidates. The period of internships generally extended from one to two months. The sorts of experience that the internship programmes offered to students varied by firms. While some foreign firms organised lecture-based training sessions for interns, much of the time was normally spent on practical on-the-job training in factories.

[7] However, students could choose to participate in internship programmes organised at workshops in the university rather than programmes organised by firms.

Considering the extreme cases where interns were simply “used” by the receiving companies as unpaid workers, or where sufficient safety standards were not adhered to in the workplace, some sorts of guidelines may be needed to ensure that the internship programmes would be beneficial for students, universities and firms.

Training

The two universities provide short-term training courses for engineers, managers, leaders and/or supervisors who are being employed in the industry. The main subjects covered included mechanical engineering (e.g., the operation of CNC machining centres) and production management (e.g., lean production, quality management, 5S, and kaizen). The requirements for university-run training courses were particularly large in suppliers that are short of internal resources for running in-house training programmes.

Some of the training courses directly assisted and funded by foreign companies have served as important bases for training qualified human resources. The training centre on mold/die manufacturing established as early as 1993 deserves particular attention. This centre was established by Shiroki Corporation, a Japanese auto component manufacturer, at HUT. The Japanese company provided machinery and equipment, textbooks, and instructors to train Vietnamese engineers in designing and manufacturing molds and dies to work at the joint venture mold manufacturer it established. Although the joint venture closed down in the early 2000s, its former engineers and staffs of are known to have played key roles in numerous die/mold manufacturers in the Vietnamese automotive industry—including suppliers A6 and A7 among the 21 suppliers examined in the previous section.

Another important initiative is the training course on manufacturing (*monozukuri*), which Toyota Motor Vietnam established at HUT in 2005. This initiative started with the three-month training organised by Toyota Motor Vietnam to teach the essence of Toyota's production system to two of the HUT's a faculty staffs, who became the core organisers of the course. Every year HUT runs three series of five different courses that cover various areas in production management like lean production and quality management. Participants so far came mainly from Japanese, Taiwanese and Vietnamese suppliers of automotive components. As discussed in the previous section, this training programme was mentioned as one of the complementary knowledge sources mobilised by supplier B1 in the course of one of its important learning incidents.

Project-Based Collaboration

Although precise numbers were not available, the author's interviews suggested that such project-based collaborations between universities and firms were largely limited in both number and content. There were no cases of collaborative R&D or R&D-based consultancies. While HUT was occasionally engaged in small projects subcontracted from foreign firms in Vietnam, the bulk of these projects mainly involved short-term, problem-solving activities using the existing technology such as development of electroplating lines incorporating environmental treatment facilities. HaUI often received orders for production of jigs, screws and casks, which, if ordered to independent suppliers, could be very costly as they are not usually demanded in large quantities.

Despite the limited cases of formal university-enterprise collaboration, the interviews pointed to the possibility of many more instances of informal forms of collaboration that are bypassing the universities. As various complex assembly industries emerged in Vietnam, an increasing number of university professors have set up private businesses producing components, dies or molds or providing relevant services. For firms, it is often faster and more flexible to work directly with these businesses. Although the precise numbers could not be obtained, it was suggested there were many instances where faculty members used their personal connections with foreign firms to direct their orders to their private businesses.

7. Policy Recommendations

The findings presented in Sections 5 and 6 suggest the role of universities in Vietnam still focuses largely on the conventional area, i.e., education. For suppliers, recruiting educated human resources is critical in laying the basic foundation for undertaking various innovative activities, yet it is rarely a direct trigger to specific innovation events. In the meantime, other forms of university-industry linkages, particularly joint R&D projects with firms, remained largely limited in both quantity and content. These results are roughly consistent with the findings of the previous section on the sources of knowledge mobilisation by local suppliers.

In the early years of Vietnam's market-oriented reforms and open door policy, universities acted an important knowledge centre in engineering technology. This is evident from the fact that HUT was selected by a Japanese mold/die company as the base for developing human resources for designing and manufacturing dies/molds in the early 1990s. However, over the last two decades, while universities have failed to keep up with the practical needs of the industry, increased access to diverse knowledge sources—both within Vietnam and abroad—opened up for firms in the automotive industry. As a result, firms have increasingly sought to develop direct linkages with foreign firms and/or non-firm agents, largely "bypassing" local universities.

On the basis of the analysis in this paper, the following sets of policies are recommended in order for universities to play stronger roles in promoting production and innovative activities of firms in the automotive industry,

The first set of recommendations concerns the national-level policy agenda.

- The issue of developing university-industry linkages should be addressed in Vietnam's science and technology policy agenda. While this has never been done in the past, the growing need for accumulation of innovative capabilities calls for greater roles played by non-firm innovation-supporting agents—in addition to firm agents that already play dominant role in the sectoral innovation system in the Vietnamese automotive industry.
- Although universities have been made more independent over the previous years, they still lack autonomy in their operations. They are still subject to many regulations imposed by the Ministry of Education and Training. Public universities, in particular, are subject to salary ceilings and personnel management and financial regulations, which significantly limit the scope of the activities that could be implemented by the universities. In order for universities to develop stronger linkages with the industry, more autonomy needs to be granted to national universities concerning the scope of their activities and programmes. In addition,

as a precondition for providing incentives to universities and university professors (see the second group of recommendations below), it is essential to grant greater flexibility in universities' personnel and financial management.

The second set of recommendations concerns the incentive structure. While the cases of training programmes and internship programmes proposed by firms (see Section 6.2) illustrates that there exists persistent interest from the firms' side in collaborating more closely with local universities, there was apparent lack of interest on the universities' side. Because of the current system that places emphasis on the teaching programmes, university staffs face heavy teaching and administrative workload and therefore have neither the time nor the incentive to interact with firms. The lack of financial incentive also explains why project-based collaborations seem to be increasingly "bypassing" universities.

- In line with the emphasis on university-industry linkages in the national science and technology agenda, universities' performance needs to be evaluated on the basis of a broad range of contributions they make to the industry in addition to the existing set of criteria.
- The current system that rewards university professors on the basis of their teaching should be adjusted to reflect contributions and impact that the professors make to the industry.

The third set of recommendations concerns the ways of improving substantive activities and programmes implemented by the universities.

- As a broader attempt to accommodate the industry's needs into the programmes and activities, universities should engage in closer dialogue with the industry.

- Considering that universities are mandated to educate and train students, priority of action should be on improving educational and training programmes. Specifically, universities should reflect on the industry's practical needs into the contents of their teaching curriculum. HaUI's initiatives at reflecting on suggestions from enterprises in improving the university's teaching curriculum[8] can be seen as an important initial step in this direction.

The fourth set of recommendations relates to the measures to improve the universities' capacities. In order for universities to continue to serve as technological hubs for the Vietnamese industry—as they used to be in the early 1990s, their resources need to be upgraded substantially.

- Universities consistently suffer from limited number and low qualification of teaching staffs, which have resulted in excessive workload on the incumbent staffs, and outdated facilities. The human and physical resource constraints need to be addressed urgently, as they directly influence the prospects for improving the quality of the teaching and training programmes discussed above.

8. Conclusions

This paper sought to explore whether the sectoral system of innovation and production in the Vietnamese automotive industry functioned in such a way that encourages accumulation of innovation and production capabilities on the component

[8] Every three years, HaUI reviews its teaching curriculum on the basis of comments and suggestions from firms (the author's interview in November 2010).

supply base. To this end, analysis on the nature of knowledge flows between firm and non-firm agents was conducted in two complementary steps. The first step focused on the firms' side. Attempts were made to identify where the local component suppliers mobilised knowledge for acquisition of new production and innovation capabilities. The second step turned the focus to the non-firm agents. It looked specifically into the nature of linkages that two major technological/industrial universities developed with firms in the automotive industry.

In the initial step, systematic, empirical analysis on the sources knowledge in suppliers' acquisition of new production and innovation capabilities found that knowledge sources for suppliers were in fact limited primarily to firm-internal sources and, in some instances, external firm agents—often foreign companies in Vietnam or companies abroad. Particularly in suppliers in Japanese value chains, lead firms played powerful roles in guiding and assisting the suppliers' capability formation processes. In the meantime, the roles played by non-firm agents were found to be extremely limited. Universities were found to be playing complementary roles in only two of the 44 learning events analysed in this paper.

The second step turned the focus to the non-firm agents. The case studies of two major technological/industrial universities revealed that the two universities so far have contributed to capability formation in the automotive industry primarily in the form of providing qualified human resources, while other more direct forms of university-industry linkages have remained limited in both intensity and content.

On the whole, the sectoral system of innovation in the Vietnamese motorcycle industry has indeed come to be driven increasingly by firms over the past few decades. Vietnamese firms, in particular, are increasingly relying on linkages with foreign firms and non-firm agents, based in Vietnam or abroad, as sources of knowledge. On the basis of the empirical findings, this research presented policy recommendations at different levels: national-level policy agenda, incentive structure, specific programmes and activities, and the capacity on the part of the universities. Given the persistent interest shown by automotive firms in engaging with local universities, it is imperative to realign the national-level policy agenda and the structure of incentives so as to meet the increasing need for greater roles to be played by non-firm agents in promoting accumulation of innovative capabilities in this strategic industry.

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Appendix. List of Learning Events

Supplier	Event #	Event title	Stage of Industrial Development	Main Value Chain	Capabilities Acquired		
					New Product Introduction	Equipment-related	Production Management
A1	1	Improving processing and production management capabilities for obtaining a contract to supply chain cases to HVN	1	HVN-1		X	X
A1	2	Improved processing and process design capabilities for higher product variety with higher precision levels for HVN	2	HVN-1		X	X
A1	3	Instituting organisational arrangement for making constant improvements in process design to meet HVN's tighter QCD requirements	3	HVN-1		X	X
A2	1	Improving processing and production management capabilities for obtaining a contract to supply toolboxes to HVN	1	HVN-1		X	X
A2	2	Improved processing and process design capabilities for higher product variety with higher precision levels for HVN	2	HVN-1		X	X
A2	3	Improved production management and establishing high-precision procesing lines at a new factory to meet tigheter QCD requirements	3	HVN-1		X	X
A3	1	Improving processing and production management capabilities for obtaining a contract to simple plastic components to HVN and VMEP	1	HVN-1		X	X
A3	2	Developing and instituting a company-wide management system for improved QCD performance; obtaining ISO 9001 certification without the assistance of external consultants.	3	HVN-1			X
A3	3	Upgrading the capacity to design and manufacturing plastic molds of higher precision; obtaining HVN's recognition as a supplier of plastic molds.	3	HVN-1		X	
A4	1	Improving processing and production management capabilities for obtaining a contract to supply sprockets to HVN	2	HVN-1		X	X
A4	2	Establishing and operating a new high-precision forging process to supply core engine components for Japanese first-tier supplier of HVN	3	HVN-2		X	X

Supplier	Event #	Event title	Stage of Industrial Development	Main Value Chain	Capabilities Acquired		
					New Product Introduction	Equipment-related	Production Management
A5	2	Setting up oprerations to source sub-components and assemble wire harnesses to be supplied to HVN.	2	HVN-1			X
A5	3	Improved production management to meet HVN's tighter cost reduction targets and environmental standards (obtaining knowledge and skills for mold maintenance for improved supplier management)	3	HVN-1		X	X
A6	1	Improving processing and production management capabilities for obtaining a contract to supply simple plastic components to HVN	2	HVN-1		X	X
A6	2	Setting up mold design and manufacturing operations; started to in-house production of molds to be used for manufacturing components for HVN.	3	HVN-1		X	X
A7	1	Setting up operations to design and manufacture dies and molds to be supplied to HVN and its suppliers.	3	HVN-2		X	X
A7	2	Improved production management to meet large orders with HVN's tighter lead time/delivery requirements.	3	HVN-1			X
A8	1	Improved production management practices in the course of supplying sub-components to a local first-tier supplier of HVN.	2	HVN-2			X
A8	3	Setting up high-precision forging lines for supplying core engine components to HVN.	3	HVN-1		X	X
A9	1	Developing a new plating line with improved production management practices for subcontracting plating process for Japanese and Taiwanese supplieres of HVN and YVN.	2	HVN-2		X	X
A9	2	Acquring the new plating technology (trivalent chromium plating) to meet the tighter environmental standard imposed by HVN.	3	HVN-2		X	X
A10	1	Improved mold design/manufacturing capability to supply plastic molds to Taiwanese & Japanese 1st tier suppliers of Japanese motorcycle manufacturers.	2	HVN-2		X	
A10	3	Improved production management to meet QCD requirements under a larger scale of orders; obtaining ISO 9001 certification.	3	HVN-2			X

Supplier	Event #	Event title	Stage of Industrial Development	Main Value Chain	Capabilities Acquired		
					New Product Introduction	Equipment-related	Production Management
A11	1	Improved processing and production management practices for supplying sub-components to first-tier Japanese suppliers of HVN and YVN.	3	HVN-2		X	X
A11	2	Improved processing and production management to realise higher precision level and shorter lead time required by customers.	3	HVN-2		X	X
B1	1	Reverse engineering and manufacturing metal stamped components to the order of local assemblers.	2	V-C	X		
B1	2	Improved processing and production management practices to obtain a contract to supply components to HVN.	2	HVN-1		X	X
B1	3	Improved production management to meet HVN's tighter QCD requirements, awarded as one of HVN's best suppliers in 2007.	3	HVN-1		X	X
B2	1	Improved processing capability to produce engine components for local assemblers.	2	V-C		X	
B2	2	Improved production management in preparing to obtain a contract to supply components to HVN.	3	HVN-1			X
B3	1	Reverse engineering and manufacturing aluminium diecast components to the order of local assemblers.	2	V-C	X	X	X
B3	2	Improved processing and production management practices to obtain a contract to supply components to a first-tier Japanese supplier of HVN.	2	HVN-2		X	X
B3	3	Improved production management and mold maintenance capacities for a new product to be supplied to the Japanese first-tier supplier of HVN.	3	HVN-2		X	X
B4	1	Improved design capability for regularly launching new designs of silencers incorporating cosmetic and functional improvements potentially demanded by local assemblers.	3	V-C	X		
B4	2	Improved production management to meet tighter QCD requirements for the first-tier Japanese supplier and to explore new customers of motorcycle components.	3	HVN-2			X
B4	3	Setting up mold design and manufacturing operations to explore new customers of motorcycle components.	3	HVN-2		X	

Supplier	Event #	Event title	Stage of Industrial Development	Main Value Chain	Capabilities Acquired		
					New Product Introduction	Equipment-related	Production Management
B5	1	Launching production of clutches to be supplied to local assemblers	2	V-C		X	X
B5	2	Meeting the precision and production management requirenments of Japanese first-tier suppliers	3	HVN-2		X	X
C1	1	Reverse engineering and manufacturing metal stamped components to the order of local assemblers.	1	V-C	X	X	X
C2	1	Reverse engineering and manufacturing an increasing variety of engine components to the order of local assemblers.	2	V-C	X	X	X
C3	1	Acquisition of reverse engineering capability for producting silencers to the order of local assemblers.	2	V-C	X	X	
C3	2	Improved reverse enigneering and processing capability to meet design and quality requirements of local assemblers	3	V-C	X	X	
C4	1	Setting up assembly operations of shock absorbers to local assemblers	3	V-C	X		X
C5	1	Setting up production lines to manufacture motorcycle chains to be supplied to local assemblers	2	V-C	X		X

Note: Types of value chains and suppliers' positions are abbreviated as follows.

HVN-1: first-tier supplier of HVN

HVN-2: second-tier supplier of HVN

V-C: supplier in the Vietnamese-Chinese chain

Source: The author's interviews.