CHAPTER II

LITERATURE REVIEW

Introduction

The U-I collaboration and technology transfer is a critical aspects of contemporary knowledge and technology promotion. Linkages between the university and the industry are particular significant, given the prominence of the university and the photovoltaic industry in capacity, skills and knowledge building, economic and performance increasing, and scientific and technology progress. This chapter aimed (1) to review the literatures related to technology transfer, U-I collaboration and U-I joint research and the situation in Thailand, (2) to provide background of Thai photovoltaic industry; and (3) to critically review the existing literatures and studies on growth and effectiveness of U-I collaboration and technology transfer to develop a conceptual model for the effective UIJRPTT. At the completion of this chapter, the enabling factors affecting the effective UIJRPTT and the outcome factors in the model were clearly defined altogether with their respective variables. The theoretical relationship between the enabling and outcome factors was also indicated in the conceptual model. A review of the said issues was provided in the following section.

Technology Transfer

1. Definition and Technology Transfer Process

Technology and technology transfer are defined in many different ways depending on the context they are used. Schmookler (1996) defines **technology** as a resource embodied not only in physical capital but, also equally importantly, in human skills, institutions and social structure. Technology represents the capacity to create and extend and existing pool of industrial skills and knowledge. Williams and Gibson (1990) and Burgelman, Clayton, and Whellwright (2004) define **technology** as the theoretical and practical knowledge, skills and artifacts that can be used to develop products and services, the production and delivery system. **Technology transfer** is defined as the movement of know-how, technical knowledge or technology from one organizational setting to another (Cohen, 2004). William and Gibson (1990) define

technology transfer as the shared responsibility between the source and destination by ensuring that technology is accepted by someone with knowledge and resources to apply and use the technology. For the purpose of this research, **technology transfer** is defined as (1) physical assets such as plant, machinery, and equipment; (2) information, both technical and commercial, relating to such matters as process know-how, choice of technology, engineering design, and plant construction, organization and operating methods, quality control; (3) human skills, especially those possessed by specialized professionals and engineers, that are transferred between Thai university and industry in the field of photovoltaic technology.

Empirical results from the studies of Krugman (1995) and Grossman and Helpman (1990) evident that technology transfer is the attribute to the economic growth and development in the developed and developing countries. Denison (1962) states that the economic growth in the U.S. during 1929-1957 is partly a result of advance of knowledge and technology transfer. The issue of technology transfer was raised since 1960s by the United Nations aiming to bridge the development gap between the north and south countries. Gerschenkron (1962) states that developing countries can catch-up technology development and achieve rapid economic growth by exploiting technological knowledge accumulated by firms in advance economies through learning. Mathews (2002) states that, in order to gain advantage from catch-up, late-coming firms need to tap into advanced technologies and accelerate their uptake linking, learning and leveraging efforts to build up technological capability. Firms should combine new and existing knowledge for the adaptation, improvement and recombination of technology (Cohen and Levinthal, 1990). Different transfer media or mechanism for technology transfer can be utilized. Those include foreign direct investment, joint venture, licensing, capital goods import, subcontracting, development assistance, and joint research.

In the technology transfer process, the object transferred is knowledge. Knowledge can be viewed both as a **thing** to be stored and manipulated and as a **process** of knowing and acting (Coe, Helpman and Hoffmaister, 1997). While codified knowledge is written down in articles and manuals or is embedded in technology; tacit knowledge is bound to specific person and organizations. It reflects a person's skills or firm routines and is context-specific. Since tacit knowledge is difficult to articulate, its transfer is restricted to social interaction such as observation, imitation and practice (Kim, 1999). Nonaka and Takeuchi (1995) study how knowledge can be transferred through firm's interaction and their research describes the knowledge-creation as a dynamic and continuous process involving the acquisition, accumulation, creation and exploitation of new knowledge. The knowledge-generative process moves through four realms in its journey from tacit-explicit-tacit: socialization (via social interaction through experience exchange), externalization (via means as metaphor, analogy, hypotheses or models), internalization (via organization framework), combination (reconfiguration of existing information to new knowledge). While Gregersen and Johnson (1997)' and Kim (1999) state that learning is in the technology transfer process which individual or a firm acquires, creates and disseminates new knowledge. More literatures identify four main learning modes from technology transfer process which include:

1.1 **Learning by searching**: Firms learn while conducting R&D-activities in order to explore new knowledge and technology (Bathelt and Gloeckler, 2002, p. 244);

1.2 **Learning by doing/using:** Firms learn while producing goods (learning by doing; Arrow, 1962) as well as by using products, e.g. capital goods (learning by using; Rosenberg, 1976);

1.3 **Learning by training/ hiring:** Firms learn by acquiring human capital, either through personnel-training (learning by training) or through recruitment of professionals (learning by hiring) (Berger, 2005);

1.4 **Learning by interacting:** Firms learn while interacting with other companies, especially customers and suppliers (Lundvall, 1988).

From the process of technology transfer identified in the four realm of journey of tacit and explicit knowledge and learning modes, the result of technology transfer was further reviewed in the following section.

2. Issues in Technology Transfer

The major issues related to technology transfer widely studied were: absorptive capacity, technological capabilities, and innovation. They were identified as followed:

2.1 Absorptive Capacity (ACAP)

A concept of absorptive capacity (ACAP) is emerged by Cohen and Levinthal (1989, 1990) who indicate that absorptive capacity is the ability of firm to recognize the value of new, external knowledge, assimilate it and apply it to commercial ends. It consists of three components or dimensions. Those are: a) recognizing the value b) assimilating and c) applying new external knowledge to commercial ends. Besides this most widely cited definition, two other slightly different constructions are used in empirical research (Zahra and George, 2002).

Zahra and George (2002) later re-conceptualize the ACAP. They view that ACAP is a dynamic capability that helps a company to cope with efficient organizational change by influencing, creating and deploying the knowledge necessary to build other organizational capabilities such as marketing, distribution and production (van den Bosch, Volberda, and Boer, 1999). Second, ACAP is made up of four capabilities (acquisition, assimilation, transformation and exploitation) that are combinative and build upon each other. Third, potential and realized ACAP can be distinguished. While potential ACAP encompasses the ability to value and acquire external knowledge, realized ACAP is determined by the transformation and exploitation aspect of absorptive capacity. The first describes how well a firm is organized to know about, assimilate and acquire external knowledge, the latter shows how well a company can use this knowledge to commercialize on it.

2.2 Technological Capabilities

Technological capabilities are defined as the knowledge and skills required to identify, apraise, utilize and develop technologies and techniques. According to Bell and Pavitt (1992), it is not sufficient for late coming firms to import the machinery from advanced countries and simply acquired technology and start operating. They argue that in fact technology consisted of complex 'bundles' of information – both codified and tacit – as well as physical capital.

Since the tacit components are not transferred easily, it is necessary for latecomer firms to build up **production capabilities.** This means firms have to accumulate experiences by trial and error, by experimenting and understanding the technology. Therefore, technology has to be combined with a local effort of adaptation and learning in order to be run efficiently. This process requires a new user to build skills, knowledge and institutional routine or capabilities (UNIDO, 2002a, p. 94). However, in order to be competitive in an ever-changing environment, production capabilities are not enough. The late industrializing firms need to develop **technological capabilities** to generate and manage technical change (Bell and Pavitt, 1995, p. 78). According to Lall, 1992, p. 166; UNIDO, 2002a), technological change is a continuous process to absorb or create technical knowledge, determined by external inputs and partly by past accumulation of skills and knowledge (Lall, 2000, p. 13).

2.3 Innovation

Innovation is a learning result of technology transfer (Gregersen and Johnson, 1997, p. 481). Technological change can be divided into three steps: (a) invention, i.e. the discovery of new problem solutions; (b) innovation, which described the very first (economic) implementation of the invention and (c) diffusion, in which the innovation was spread across the economy by imitation and adaptation (Berger, 2005). For the "impact on the economy, it is not the basic innovation but its diffusion across industry or the economy, and the speed of this diffusion, that matters" (Malecki, 1997, p. 75).

Most definitions of the term innovation, which are applied for empirical studies, do not require an innovation to be 'new to the world' but only to be 'new to the firm' (OECD, 1996). Thereby, innovations are either technologically new or significantly improved products, including goods and services (product innovation), or new or significantly improved production methods, including organizational changes (process innovation). Firms in late-industrializing countries rarely work at the technological frontier, but are rather concerned about the diffusion and adaptation of existing technologies from advanced countries.

3. Effective Technology Transfer

The important measure of "successful" or "effective" technology transfer is the extent to which the transfer is complete and adds value to a receiving organization's competencies to use and advance technology. This implies that the technology and knowledge is economically viable (US National Research Council, 2002). The prerequisites for successful technology transfer comprises of (1) technology must be appropriate for the proposed application; (2) the technology must be at an appropriate level of maturity; (3) the recipient must be at an appropriate level to apply the technology; (4) the technology must meet the organizational needs of the recipient and (5) the technology must be economically viable. Technology transfer is a complex process of cumulative learning. Brooks (1995) indicates that technology transfer depends on the transfer in knowledge in the specific context of the adoption location; therefore, understanding the reasons for a particular technological choice and the complete process of technology transfer is essential for building on the transferred knowledge. The US National Research Council (2002) indicates that technology transfer is a way of linking knowledge to need. It is necessary to understand the user and producer needs and their special circumstances. Extensive informal and formal contacts between individuals in the transferring and receiving organizations are essential for a successful transfer. Publication and reports are generally less effective than the movement of people for transferring technology, because much technical know-how is typically unwritten. Personal relationships and a degree of trust also help bridge organizational and cultural differences that can delay technology implementation. Gibson and Smilor (1991) and von Bondsdorff and Lindell (1997) state that successful technology transfer can be reached when (1) communication is interactive; (2) the corporate cultures are closely linked; (3) the technology is concrete; and (4) the organization rewards and supports technology transfer.

4. Government Roles in Technology Transfer

The government plays an important role in supporting technology transfer. Various governmental policies and policy issues affect directly and indirectly to the promotion of technology transfer. From the study of ESCAP (1999), technology transfer are greatly influenced by government policies including technology policy and other policies such as industrial and investment policies, fiscal and trade policies, tax rates and tariff rules, legal and financial instruments. Those policies affect to the production/procurement of equipment, materials and components, and in the provision of technical consultancy services. In Japan and South Korea, the strengthening and development of technological capabilities and technology transfer are achieved through a well-structured policy framework, strong institutional mechanism, development of human skills, and encouraging for in-house R&D in industry. China is one example showing that the government policy such as feed-in-tariff and domestic and export market stimulus helps which can support China as a major global supplier. The integration of S&T policies with the trade, investment and other policies, internationalization of production, strategic alliances, international cooperation, inward and outward FDI and financing of technology and adequate infrastructure evident as the factors that strengthen the technology transfer and industrial development .

In sum, technology transfer mainly intends to capitalize technological knowledge resources. The final goal is to sustainable increase competitiveness of the organization through the use of absorptive capacity, technological capabilities and innovation. The process of technology transfer is the learning process which is complex and difficult and involves technology, knowledge, human and financial resources and support of the organization. The success of technology and knowledge transfer depends on various factors in terms of technology itself, the transferor and transferee context and the appropriate government policy supports. Next section described the U-I collaboration to understand the reason why and how the collaboration for technology transfer is established.

University-Industry Collaboration and Joint Research for Technology Transfer

1. The World Perspective

The importance of technology transfer has been increasing for the development of firms' competitiveness. The technology transfer processes are intimately linked to the generation and optimization of knowledge flows and technology spillover (Mitra and Formica, 1997; OECD, 1996). The improvement of firms' innovative and competitive performance is not only depended on firms' own actions but it is also strongly influenced by working and interacting with scientific research and technology development institutes in the country's innovation system such as universities (Nieminen and Kaukonen, 2001; Foray, 1997; OECD, 2001; Nelson, 1993). Firms and universities have mutual interests in cooperating with each other in technology transfer process. For firms, relations with universities for technology transfer can increase their capabilities and innovation, and improve their competitive positions through the process or product technological changes (Martin, 2000; Jones-Evans, et al., 1999; Schibany and Schartninger, 2001; OECD, 2001).

Firms can: a) access basic and applied research results; b) access economically relevant scientific and technological knowledge; c) develop and test prototypes; d) gain medium or long-term perspectives; e) get support in solving specific problems and new products specification; f) recruit highly qualified human resources (Martin, 2000; OECD, 2001, OECD, 1996). The university benefits from cooperation with industry via: a) added resources, financially and otherwise; b) access to updated technical knowledge and good practices; c) access to networks of knowledge creation and utilization; d) access to industrial information; e) access to applied knowledge, with positive effects on the academic research and teaching; f) gains in image and visibility through the transfer of useful scientific knowledge coming from academic research to industry (Martin, 2000; OECD, 2001).

The study of Hermans and Castiaux (2007) examine the knowledge-flow process between university and industry in several concurrent phases. They state that the first phase starts with tacit knowledge sharing between individual university and industry staffs through socialization process, and they later decide to sign a formal agreement. The second phase is when the two sides consult each other and come up with the common concept. In the process of working together, the concept become crystallized and finally tested and summarized in publications. The next phase is the externalization process; that is when the knowledge in the publications will be justified by academic peers of journals and by the company exploitation. The new concept and knowledge will be shared at higher levels toward private partners and academic community in the justification phase.

In developed countries, the key mechanisms for technology and knowledge transfer for commercialization are licensing agreements, joint research and university-based startups between the university and private firms. In the U.S. and the U.K., organizations such as the U.S. Association of University Technology Managers (AUTM) and the University Companies Association (UNICO) and the U.K. Association for University Research Industry Links (AURIL) have promoted U-I technology transfer activities by publishing benchmarking survey which explore key research questions relating to the drivers of effective university technology transfer (Phan and Siegel, 2006, p. 75-76). Moreover, many national governments support the U-I collaboration via legislation to facilitate technological diffusion from universities to firms. Those include the Bayh-Dole Act of 1980 for technological diffusion, and the National Cooperative Research Act of 1984 for collaborative research in the U.S. The government also subsidizes research joint ventures involving universities and firms and shared use of expertise and laboratory facilities (Phan and Siegel, 2006, p. 78).

From the supports, the U-I collaboration and UIJR are becoming closer as number of the UIJR is rising in the developed countries. The UIJR has been considered a major reason for the success of the U.S. in innovation and economic growth in the past two decades (Hall, 2004). Many scholars study various types of the U-I collaborations and UIJR, the reasons why they have grown and what the obstacles of the partnerships are. There have been rising calls for effective UIJR for a decade (Tener, 1996). This is emphasized by the fact that many universities have been studying and trying to establish new mechanisms designed to bring more industrial resources into the universities and the industry have been investing more in sponsoring the joint research. Through the introduction of the U-I collaboration and joint research schemes, the cooperation has been deepened in many leading universities. Those universities include Massachusetts Institute of Technology, Cambridge University and University of Tokyo, Stanford and University of California (Hatakenata, 2003; Hall, 2004). From the increasing number of the collaborations, best practices for successful U-I collaboration and joint researches have been recently studied in many aspects. Those aspects include: (1) comparative analysis of the world's advance U-I collaboration and joint research system (Hatakenata, 2003, Adams, Chiang, and Starkey, 2001; Hall, 2004), (2) the cooperation model of university-industry-government (Etzkowitz and Leydesdorff, 1997; Etzkowitz, 2002), and (3) commercialization and management of intellectual property (Link and Siegel, 2005; Phan and Siegel, 2004; Hertzfeld, Link, and Vonortas, 2004; Hall, 2001; Palmberg, 2007).

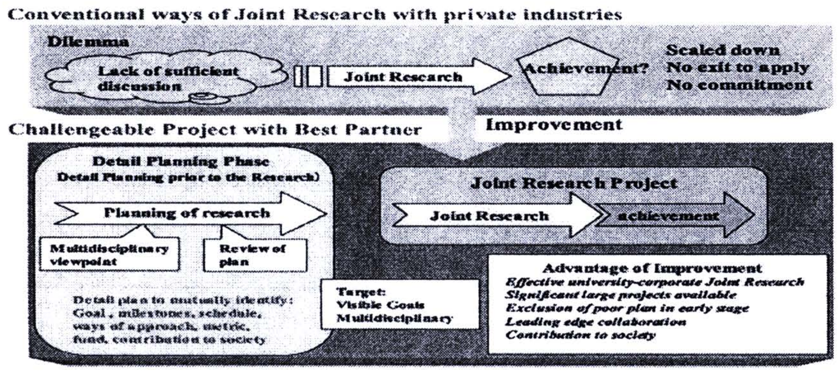

Figure 1 University of Tokyo's Joint Research Concept

Although the number of the U-I collaboration and UIJR for technology transfer is higher in developed countries but still in question as little in developing countries. Inzelt (2004) states that the lack of efficient institutions in developing countries particularly where legal systems are often weak, makes it difficult to conduct effective transactions and conclude contracts on research cooperation. Because of this, most of the relations entered into are informal and based on mutual trust (Knack and Keefer, 1997). Given Thailand as an example, some studies of Thai Commission on Higher Education (1991), World Bank (2005) and Thailand Research Fund (2006) indicate obstacles and problems in funding, human resources, value and capabilities of university and industry that prevent the growth of UIJR. Following section reviewed some literatures related to past and present situation of the U-I collaboration for technology transfer in Thailand.

2. Past and Present of U-I Collaboration and Joint Research in Thailand

In the Thai higher education system, there are 26 state universities that conduct graduate, postgraduate course and research, 54 private universities and a multitude of institutes of applied sciences, most of which specialize in bachelor studies (MUA, 2008). Major proportion of the R&D works conducted by state universities are mostly in applied research (NRCT, 2004), but more recently, universities have been expanding their R&D activities, particularly in the field of basic research. From the statistics of Chulalongkorn University, in 2003, there was an increase in corporate R&D expenditures to the university which was mainly due to experimental development activities (Chittmittrapap, 2008). According to Inzelt (2004), forms of U-I collaboration in Thailand differ in the different target sectors. The mechanical and electrical engineering, chemical and pharmaceutical industries tend to prefer research-oriented forms of cooperation, whereas traditional branches, such as food, textile, and primary industries, use consultation services that relate to human resources. The mechanical and electrical engineering industries are the only one by which 30% of all projects involve joint and/or contract research. One tenth of these projects result in joint patents, and researchers are beginning to plan the establishment of spin-offs. In the chemical and pharmaceutical industries, licenses on university research form the most important pathway of knowledge transfer, by being used in more than two thirds of all projects.

Several studies regarding the U-I collaboration in Thailand indicate critical issues and problems affecting the U-I collaboration and joint research. Those include the system and characteristics of the university and industry as well as the support from the government in terms of fund and policy for R&D. For the university side, NRCT (2004) indicates that the university R&D in Thailand is criticized in slow structural change towards more application-oriented disciplines. Thai universities only spend around one fifth of their R&D budget on engineering sciences which may be less of interest to business and industry. According to the study of Commission on Higher Education in 1991, even though thousands of research projects were conducted in Thai universities, but the follow-up system of the result of the project was not set up. Moreover, some problems are raised such as (1) the evaluation of the quality of the project results can not be clearly defined with specific output; (2) public universities do not implement university research plan and strategy (3) university lecturers can propose research proposal according to their interest and capability and (4) most of the university researches are conducted for course instructions which are partly of research procedures following the policy of central education authority (TRF, 2006). These problems hinder the U-I collaboration for technology transfer.

As far as the characteristics of the Thai private sector are concerned, the survey of 98 entrepreneur conducted by Commission on Higher Education (1991) reveals that 43 percent of the respondents view that the R&D for technology development is conducted in Thai private sector, but most of the technology development are meant only in the form of modification, adjustment, improvement of instruments or tools imported from foreign countries. It is far from the development of R&D for innovation (TRF, 2006). Moreover, shortages of human resource are found in responsible for the enterprise research. Previous studies of Hennemann and Liefner (2006) and Kiese (2003) indicate that corporate technological capabilities in Thailand are low compared to those of other Asian countries. The innovation activities of Thai enterprises focus on the acquisition of machines and equipment, on design, license purchases, and training rather than formal R&D activities. One important reason for the low level of corporate R&D activity is a prevailing lack of scientifically and technically qualified human capital (World Bank, 2005). The low level of R&D activities in Thai enterprises affects their cooperation potential. When enterprises do not conduct any R&D of their own and use universities as vicarious research institutions, the development of an effective innovation system with its own 'technological culture' becomes highly improbable (Lall, 2002; Nelson and Rosenberg, 1993).

According to Kirtikara (2001), Thailand's university landscape is undergoing a profound change. In recent years, government subsidies stagnated or declined, while universities had to meet more stringent requirements owing to increasing enrolment figures and other factors such as key performance index. There are long-term plans to convert all universities into autonomous institutions. This is why options of commercializing and opening up the transfer of knowledge through organizational innovations are being debated. At the same time, many professors are induced in the past to carry out informal projects of their own to enhance their personal income, as the wages paid within the university system are low.

In terms of history and government policy context, it is worth noted that the development of U-I collaboration in Thailand is based on the government policy infrastructure that can be traced back more than 40 years. The Thai government play an important role in establishing organizations to fund research activities in wide-ranging areas and support the U-I collaboration in the country. Those include the establishment of the National Research Council in 1956, Thailand Institute of Scientific and Technological Research (TISTR) in 1963, National Research Council of Thailand in 1980, Science and Technology Development Board (STDB) in 1985, National Science and Technology Development Agency (NSTDA) in 1991, and Thai Research Fund (TRF), the Science and Technology Development Agency, and the Health System Research Institute in 1993. According to Chantramonklasri (1996a), even though the government implemented policies and supports to stimulate technological development between university and industry particularly through the mechanisms of NSTDA and TRF, there has been limited utilization of public-sector R&D capability and tendency of researchers to carry out scientific and technological activities between the public sector including the university and in private sector. In an attempt to stimulate the investment in R&D within the industrious sector, the Board of Investment (BOI) that is the key organization responsible for granting privileges to promote investment projects has offered since 1989 various tax incentives associated with setting up R&D laboratories and the related imports of machinery and equipment for use in R&D activities. However, these mechanisms have not been well received by the private sector. The major cause of the government's ineffective incentives and financial support for R&D activities in industrial sector are because these incentives are mostly aimed at small and medium-sized local firms which usually do not possess sufficient in-house capabilities to engage in R&D activities. Moreover, Thai industrial firms normally draw on sources of technology other than in-house and public R&D. From the study of TDRI (1991), what most firms need is re-creation and assimilation of knowledge from elsewhere, especially from foreign sources rather than new technical knowledge. There is little or no need to invest in R&D and they will wait until it is time to choose another new production system. As a result, Thai industrial firms can simply undertake very limited technological learning, i.e., only at the minimum level needed to operate the systems. Moreover, firms tend to doubt the ability and effectiveness of universities and public technical institutes to solve practical industrial problems. This couples with the fact that firms lack of awareness in investing in R&D and, as a result, leads to the limited number of research activities and the U-I collaboration.

In terms of economic and technology development context, after the Financial crisis in 1997, Thailand's economy returned to the path of growth in 1999, expanding again at rates ranging from 1.8 to 6.1% (World Bank, 2005). Between 1981 and 2001, the share of agriculture in the GDP was halved, dropping from 21.4 to

10.2%. Industrial sector shares in GDP rose from 30.1 to 40.0% during the same period (UNIDO, 2002b). Foreign direct investments (FDI) provided a major impetus for Thailand's economic development, growing markedly from the mid-eighties onwards. FDI played an important role in promoting the spread of technological capabilities, given adequate absorption capacities among local enterprises (Dhanani and Scholtès, 2002). The industries largely depended on imports of purchased materials and services. Thailand's specialty is assembling rather than manufacturing its products. From the growth of economy, the development of technological capabilities was considered fail to keep pace with the swiftness of industrial development. Since 1990s, the share of R&D expenditures in the Thai GDP stagnated at 0.10 to 0.15% (NRCT, 2004). After the financial crisis in 1997, most companies still procured technologies (e.g. machines and software) as well as production licenses from providers abroad. However, recently, there are the relatively small local enterprises in particular that are unable to pay foreign consultancy firms due to the higher cost of technology transfer. Their interest in utilizing new services offered by the universities has grown correspondingly. Moreover, taking into account the support policies of the university to be active research-based university, the U-I cooperation have been increased and took place at various levels – between individuals, groups, or institutions through different transfer channels (consultation, licensing, contract research, joint research, spin-offs) (Inzelt, 2004).

In sum, the U-I joint research in developed and developing countries are increasing considering the benefit that both university and industry. In Thailand, the UIJR number has been reported increasing due to the support of the government and the changing contexts the university and industry have been facing. But, still, the Thai university and industry have been facing problems on human capabilities and financial resources and the perspectives on the value of R&D investment. Concerning on the U-I collaboration and joint research for photovoltaic technology transfer; the author found no literatures and studies concerning such issues. Even though technology transfer in renewable energy has received considerable attention from the research community, most literatures and studies are relating to overview on renewable energy program and policies, countries specific renewable energy development program and its barriers, and renewable energy development and program in the specific country.

The following section of this research reviewed the current status and challenge of Thai photovoltaic industry to understand the real context of the need for U-I collaboration and joint research for technology transfer.

Thai Photovoltaic Industry

1. The Current Status

Thailand has been using photovoltaic application over several decades. The Ministry of Public Health and the Medical Volunteers Foundation first launched a national program by installing photovoltaic module for power communication equipment in rural health center in 1976. The program to promote the renewable energy such as solar water pumping and solar home project and photovoltaic demonstration projects, rural electrification program using Battery Charging Stations (BCS) were implemented by many governmental organizations since 1980s (Shrestha, et al., 2006). But the Thai photovoltaic industry was established in 2003, when several groups of Thai business entrepreneurs viewed the opportunities in the world and domestic growing demand of photovoltaic. Presently, the structure of the industry comprises of five major local and joint venture manufacturing and assembling firms. There are also other business related to photovoltaic industry such as distributors and service agents of photovoltaic cells and module and of other designed products.

In 2003, Solartron Public Company Limited, which was founded in 1986 as the company providing alternative clean energy source, set up its first assembling line of photovoltaic module in Nakonratchasima province and called it "Solartron Technology Center" with a production capacity of 30 MW per year, the biggest solar modules factory in Southeast Asia. The company imported production line and machinery from Japan. In 2005, the company was listed in the Stock Exchange of Thailand (SET) and set up solar cell factory project with the investment capital of 1,300 million baht by importing technology from the subsidiary company of M+W Zander, Germany. The planned solar cell factory has the production capacity of 25 MW per year which equivalent to 7,000,000 solar cells per year (Solartron, 2008).

Bangkok Solar Co.,Ltd. (BSC) was established in 2003 as the first amorphous silicon (a-Si) photovoltaic modules manufacturer in Thailand with the capacity of 5MW. The capital investment was 500 million baht (Science Foundation, 2006). Bangkok Solar is owned by the Bangkok Cable Group, which is a key manufacturer of wire and cable in Thailand running its business since 1964. In 2005, the company invested more than 2,000 millions baht for production and technology with strict QC and complies with international standards (Bangkok Solar, 2008).

In 2004, Ekarat Solar Co.,Ltd. was established to manufacture poly-crystalline solar or photovoltaic modules. The company is a subsidiary company of Ekarat Engineering (Public) Co., Ltd. which is listed in Thai Stock Market under the name AKR, with the registered capital of 790 million baht (Ekarat Solar, 2008). Ekarat Solar invested 200 million baht in first construction of the module production line with the capacity of 15 MW per year and 1,500 million baht in the new silicon cell and module production line operated in January 2008 with the capacity of 25-30 MW per year. The machinery was imported from Centrotherm, Germany and M+W Zander, Germany, provided concept and detailed design for the manufacturing plant.

Thai Agency Engineering and Sharp, started their assembling line production in 2005 with the capacity of 10 MW per year and 7 MW per year by importing know-how and machinery from Japan.

Table 1 Thai Photovoltaic Manufacturers

Company	Products and Capacity (year of manufacturing)	Machinery and Investment Cost (mil.baht)
Solartron Public Co.,Ltd. (Assembling and Manufacturing factory in Nakornratchasima)	30 MW/year Si modules (2004) 25 MW/Pc-si cells (planned)	Japan (200) Germany (n.a.)
Bangkok Solar Co.,Ltd. (Assembling factory in Chachengsao)	5 MW/year A-Si modules (2004) 10 MW/year A-Si modules (2007) 15 MW/year A-Si modules (2007)	Hungary (500) USA(1,300) USA (2,000)
Thai Agency Engineering Co.,Ltd. (Assembling factory in Ayutthaya)	5 MW/year Pc-Si modules (2005) 5 MW/year A-Si modules (2005)	Japan (50) Japan (50)
Ekarat Solar Public Co.,Ltd. (Assembling and Manufacturing factory in Chachengsao and Rayong)	15 MW/year Pc-Si modules (2005) 25 MW/year Pc-Si cells (2006)	Japan (100) Germany (1,500)
Sharp Thebnakorn Co.,Ltd (Assembling factory in Nakornpathom)	7 MW/year Pc-Si modules (2005)	Japan (n.a.)

Source: Thai Solar Future, 2009

In 2009, Thailand photovoltaic industry consists of five major photovoltaic cells and module production manufacturers with the production capacity of more than 117 MW. The locations of the manufacturing plants are scattering in different provinces near Bangkok such as Nakornratchasima, Chachengsao, Rayong, Ayutthaya and Nakornpathom. The photovoltaic cells produced and exported from the industry are both polycrystalline and amorphous silicon thin films. In the assembling line, the manufacturers assemble the imported wafers into the module with the proportion of 30% of local content. In the cell production line, some manufacturers import silicon ingot to produce the wafer in the country and that makes the proportion of 50-60% of local content. For the amorphous thin film, the manufacturer can produce with the proportion of around 50% of local content. It is considered that if the Thai manufacturers can produce some raw materials and components such as Transparent Conducting Oxide (TCO) glass and ethyiene vinyl acetate (EVA), the local content might increase to 20%, those will reduce cost and price of the photovoltaic products (Sichanugrist, 2008).

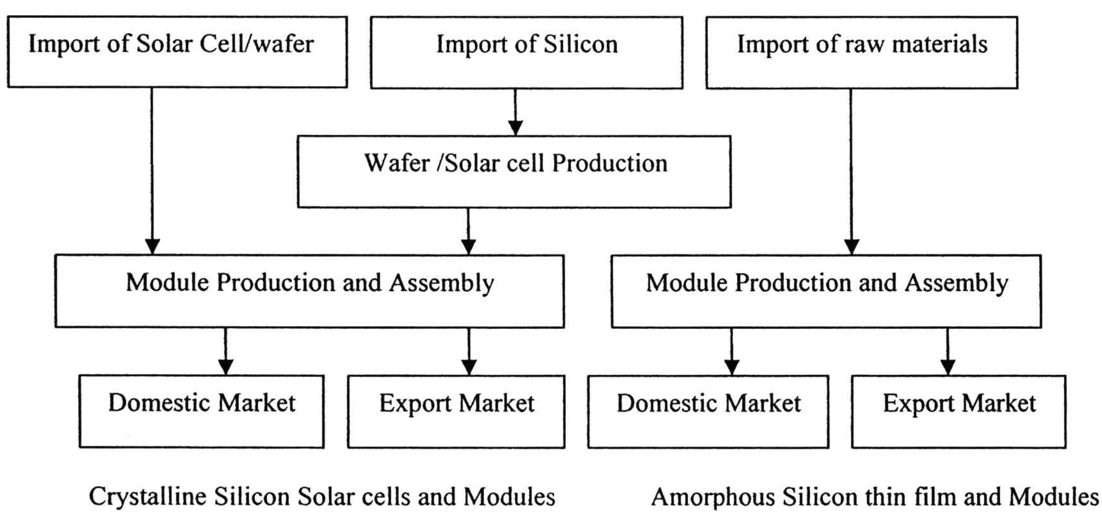

Figure 2 Overview of Photovoltaic Industry in Thailand

2. Thai Photovoltaic Industry's Market

International Market

In recent years, many developed countries have given efforts to the issues of global warming and zero carbon emission. Those countries also viewed that solar energy technology could be developed and sold in the future. This could maintain the economic growth and employment in those countries. Therefore, the development of technology research and market stimulus has been supported by the governments in the developed countries. It is found that the installations of Photovoltaic systems in the developed countries have increased widely as a result of supports by the governmental incentive programs (DOIS, 2008). The photovoltaic world market sharply increased from 2001 to 2006, at the growth rate of 38.4%. The accumulated installation on the application of the energy reached to 4.6GWp in 2005 and 6.3 GWp in 2006. The overall growth rate is expected to achieve 23-28% and the revenues from solar cells and modules will dominate more than half of the market. It is reported that, in 2007, Germany (47%), Spain (23%), USA (8%) and Japan (8%) dominated the market growth (DOIS, 2008). However, due to the financial crisis in the U.S. and in Europe in 2008 until today, the international photovoltaic market is expected to grow less in 2009. Moreover, part of the slow growth in the global market was because Germany and Spain, world's biggest market in 2008, has reduced its support for solar energy by cutting feed-in-tariff (Solar Plaza, 2008a).

The Thai PV industry has shown its ambitious production expansion to the world market. The PV production of major Thai manufacturers has reached 117 MWp in 2008 and expected to further growing. Bangkok Solar, with its production capacity of amorphous thin film around 50 MW/year, exports 85-90% of their modules to the US, European markets such as Germany, Spain and Italy, and Korea. Ekarat Solar, the manufacturers of mono and polycrystalline solar cells and module with production capacity of around 30 MW, planed to export around 90% of their products to Germany, Spain, Italy and France (Ekarat, 2008). Solartron, changed their strategy in 2008, from focusing on the domestic market to export market of around 60% of their products to survive the company from loss (Solartron, 2007). Part of the photovoltaic cells and modules of Thai manufacturers are sold to the companies in Europe that are assigned to install the solar electricity in the countries of their customers.

Domestic Market

A part of the reason for the establishment of Thai photovoltaic was the effect from the high price of oil, the awareness of the environmental affect and the government policies particularly the Renewable Portfolio Standard (RPS) and the Solar Home Project that supported the application of PV system for electricity generation to stimulate the domestic market growth (Energy News, 2006). In August 2003, the Thai government formulated a new renewable energy strategic plan and set an ambitious target of increasing sharing of new and renewable energy from 0.5% in 2002 to 8% of the primary energy supply in 2011. Moreover, the National Energy Policy Council (NEPC) issued a new Small Power Producer (SPP) regulation that called for a new SPP subsidy program and the Very Small Power Producer (VSPP) Program in April 2007 with an aim to allow customers with renewable energy generators (solar, wind, micro-hydro, biomass, biogas, etc.) to connect their generators to the grid and offset their consumption at retail rates. In 2007, about 32 megawatts of PV power generation systems were installed in Thailand; most of them were in remote areas beyond the grid systems (Amranand, 2008).

Even though the government implemented policies and regulations to stimulate the use and application of renewable energy, the photovoltaic domestic market is still limited and the Thai-based photovoltaic manufacturing firms tend to put more efforts in exporting most of their products. Therefore, in order to survive in the international market, the challenge of the Thai photovoltaic industry is to catch up the technology development and reduce cost. The challenge of the Thai photovoltaic industry was reviewed in the following section.

3. The Challenge of Thai Photovoltaic Industry

In order to be competitive in the world market, the critical requirements facing the Thai-based manufacturing firms are to reduce cost/MWp, to improve durability of cells and modules and to increase performance and quality of PV cell and module performance as well as to develop further innovation of products and processes (Sichanugrist, 2008). Normally, the source of those competitive factors mainly related to the cost reduction and growth strategies. Cost reduction motivated the firms to conduct product and technology improvement, to increase R&D and skilled staffs and to co-develop with other organization for future oriented products. In the aspect of cost reduction potentials, it could be conducted through (1) "scaling source": cell thickness reduction, higher efficiency, larger format, TCO producing and economy of scale which requires knowledge and technology and (2) "productivity source": cost input, manufacturing excellence and standardization which also required skilled human resource and technology. For growth strategy, feed stock supply, plant and capacity expansion and high value added products should be in concerned.

The present situation that the Thai photovoltaic industry are facing and will affect the high degree of challenge to the industry could be evaluated in 3 aspects: technology development, efficiency performance and price and cost. In terms of photovoltaic technology development, Thai photovoltaic industry is expected to face the challenge in catching up the next generation of photovoltaic technology with higher efficiency in the future. Today, there are a variety of technologies available, at various stages of development and commercialization. Three main technological families include (1) conventional crystalline silicon wafer-based solar cells, (2) thin film solar cells, and (3) new concepts, which include: thin film high efficiency solar cells under concentration and organic PV. More than nine tenths of photovoltaic cells that are currently sold in the world market are based on crystalline silicon wafers while the rest is for thin film solar cells (Solarbuzz, 2007). According to Marigo, Foxon, and Pearson (2008), the different photovoltaic technologies differ greatly in terms of technological maturity and diffusion in the market, with several technologies being at the R&D and demonstration stages such as organic solar cells while others are at a pre-commercial stage such as thin film CdTe. These differences in technological maturity are important factors for policy maker in designing policy support to foster photovoltaic development. Today, the dominant widely used cells technologies are mono-crystalline, multi-crystalline (first generation) and amorphous silicon (second generation). In Thailand, there are no silicon wafer produced, but Ekarat produces multi-crystalline silicon cells from imported wafers. Bangkok Solar produces thin film (second generation) production of amorphous silicon while there is no production of cadmium telluride (CdTe) or copper indium deselinide (CIS) and dye solar cells (DSC), a third generation technology based on artificial photosynthesis. The third generation technology is still in laboratory research at the early stage. Therefore, it will take much time before this lab scale research can be developed for commercialization for Thai PV industry. In terms of efficiency performance, it is the real challenge for the Thai Photovoltaic industry. With imported machinery from abroad, presently most of the Thai manufacturers can produce modules with almost the same average efficiency rate compared with that of the others world leading manufacturers. However, in the long term, the efficiency of the present dominant solar cell through the new PV technology will reach higher efficiency. Moreover, multi junction concentrator will be the leader in terms of highest efficiency solar cell for the future with the rate of around 40% while thin film technology (Cu [In, Ga] Se_2) can be developed to almost 20% efficiency rate (Marigo, Foxon and Pearson, 2008). Therefore, it is the challenge for the Thai PV industry to look forward to the future technology trend and plan to prepare for the new change and challenge.

In terms of price, the serious situation of oversupply throughout the solar supply chain and the financial and economic crisis in the U.S and Europe in 2008 and the years to come would result in rapid price decreases. This could offer new opportunities and new markets, but it would also force several manufacturers out of business (Solar Plaza, 2008b). The lower price in the market would force the Thai manufacturers to find the ways to reduce cost of production. In terms of cost, some of the Thai photovoltaic firms such as Bangkok Solar have been trying to conduct researches aiming to reduce cost of production by manufacturing materials such as the TCO glass and enhanced efficiency of the adapted machinery. Figure 2 illustrates the production line of technology for photovoltaic products in Thai photovoltaic industry. The production line of crystalline silicon cells and modules involves various technologies such as doping, metallization and etching, etc.; whereas production line of amorphous silicon thin film modules include technologies in TCO deposition, laser scribe, AC deposition and encapsulation, etc. (Spire Solar, 2009).

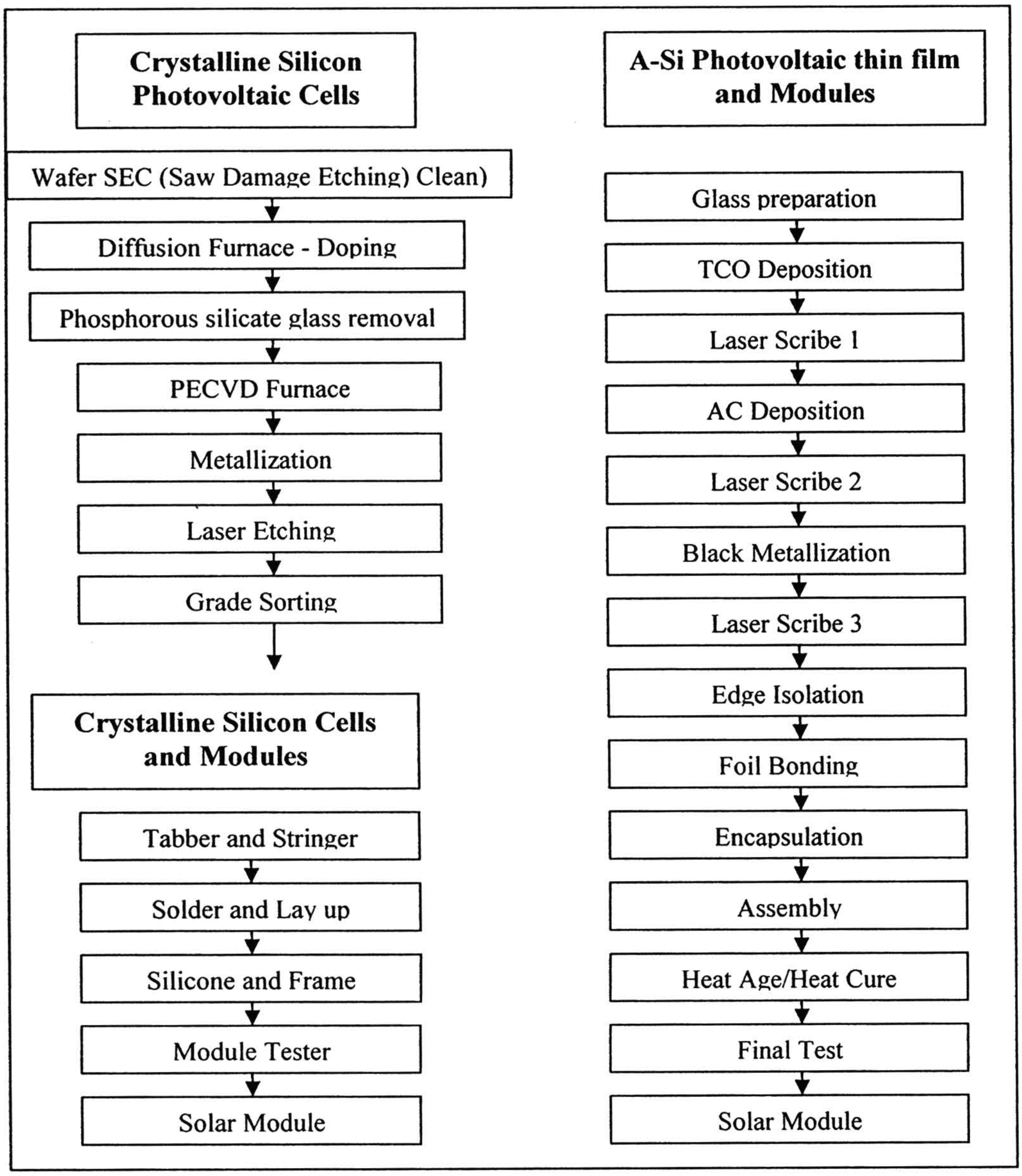

Figure 3 Production Line Diagram of Technology for Thai PV Products

From the development of the context on technology transfer, the university-industry collaboration and joint research as well as the challenge of the Thai photovoltaic industry in the current and future situation, it is viewed that the U-I collaboration particularly joint research for photovoltaic technology transfer should be increased, considering that the Thai university could be a partner for the industry in developing innovation and access to knowledge. However, due to the real situation, the U-I joint research for photovoltaic technology transfer is still limited. The next section therefore investigated the factors affecting the growth and effective U-I joint research for technology transfer in the existing literatures. The factors of the former and the latter issues were later criticized and synthesized to be the hypothesized factors in the conceptual model of the effective U-I joint research for photovoltaic technology transfer in Thailand.

Factors Affecting Growth of U-I Joint Research for Technology Transfer

This section aimed to address the factors affecting the growth of U-I collaboration and joint research to develop hypothesized factor to explain why there was little number of UIJRPTT in Thailand. A large number of researchers studied of barriers of U-I collaboration, U-I joint research, and of knowledge and of technology transfer, mostly, through overall industry sectors in international context. Samli (1985) and Egbu (2000) state that geography, culture, economy, business, people and government are barriers and obstacle in technology and knowledge transfer. Heide, Gronhaug, and Johannessen (2002) indicate that organization culture, allocation of adequate resources and personal management affect the level of organization in implementing R&D strategy for cooperation. Greiner and Franza (2003) categorize barriers to technology transfer into technical, regulatory and people barriers. Technical barriers consist of technical risk, lack of a defined requirement, lack of operational test data and risk aversion. Regulatory barriers comprise of lack of technical orders for the user, lack of regulations defining the use of the technology, long development and procurement lead times and changing specifications. People barriers comprise of unawareness of new technology, lack of communication, lack of information, technology push versus market pull, lack of transfer experience, lack of motivation, distance, being too busy, unimportant job function and lack of trust. In terms of theoretical contexts, existing theories such as neo-classic explain reasons of limited growing incidence of collaboration in R&D of firms. Neo-classical theorists are skeptical of the benefits of cooperation and tend to emphasize the role of side-payments such as selective incentives, opportunities to compensate for underdeveloped labor or capital markets, etc, rather than the fruits of research itself. For collective perspectives, cooperation distorts markets, breeding inefficiencies such as high prices and low production and retarded innovation. For individual firm perspectives, cooperation is irrational and tends to be unsustainable in the long run.

Moreover, cooperation in R&D limits the appropriation of innovation ideas and share benefits make investment in invention less attractive. Company's investment in cooperative research and development ties up with scarce funds and personnel and entails concessions and compromises with partners. It is also viewed that collaboration only dilutes a firm's own technology strategy. Researchers themselves, from the neo-classical theory, views that they have to serve too many masters and too much time is spent on the coordination and little useful and appropriable knowledge are generated (Levy and Samuels, 1992). The culture theorists suggest that cooperation in R&D arises from certain feature of national culture and organization culture. Certain features of national culture such as propensity to work together in groups, a willingness to subsume individual interests for the greater good and an emphasis on consensual decision making will affect the growth and limit of cooperation in R&D (Hofstede, 2001). Constructive organization culture, such as achievement focused, humanistic-encouraging and affiliate focused, support the cooperation among groups in and between organizations (Cooke and Lafferty, 1994).

Several studies indicate the factors affecting the growth of U-I collaboration in the Thai context in particular. Brimble and Doner (2007) analyze the U-I linkages (UIL) in Thailand in four sectors (automotive, textiles-garments, agro-industry, and electronics) and state that public officials and firm managers recognize the importance of UILs for meeting challenges facing Thai producers. But Thai UILs are frail because of (1) protection and low levels of innovation resulting in few private sector efforts to link up with universities; (2) rigid structures and (3) weak incentives in the Thai universities discouraging ties with business; and (4) generally fragmented Thai bureaucracy. Monaiyapong (2004) also indicates that the factors hindering university-industry-government linkages are limited resources, asymmetric information and government policies in the context of national innovation system.

Due to limited studies of factors affecting growth of the U-I collaboration and joint research for technology transfer in Thai context, the author therefore decided to review the studies of BHEF (2001), Casey (2004), Szulanski (1996,2000) and TDRI (1992) that indicated the barriers and factors affecting the growth of joint research and technology transfer. The scopes and results of those studies were also relevant to the aspects of the U-I collaboration and technology transfer and in some aspects related to neo-classical economic and organizational culture. The first three empirical studies were helpful in explaining the barriers and factors affecting the growth of joint research and technology transfer broadly. The last review helped identify the hypothesized factors drawn from the real Thai context.

1. BHEF – Business Higher Education Forum (2001)

The U.S. Business-Higher Education Forum (BHEF) is an organization of Fortune 500 CEOs, prominent college and university presidents, and foundation leaders working to advance innovative solutions undertook a detailed assessment of the opportunities and challenges facing U-I research collaborations. The goals of the BHEF study are to understand better the issues involved, to highlight best practices and lessons learned, and to provide practical guidance to those involved in the U-I partnerships. In the assessment and analysis of the BHEF undertaken through the interview and forum brainstorm among their members, factors affecting the growth of the U-I joint research in the U.S. comprise of: (1) the university factor, (2) the industry factor and (3) the factor of possible liability of collaboration.

For the university factor, the factors preventing U-I research collaborations from being established or successfully accomplished include:

1. **Practical difficulties with negotiating and managing collaboration**: Concerned with university officials' lack of understanding of how companies operate, the differing time horizons of the two sectors, institutional reward structures, lack of structures to find compatible collaboration partners, manage collaborations, and coordinate university support services.

2. **Proper assessment for indirect costs**: Concerned with the university's research costs that is over and above researchers' salaries and the costs of new materials.

3. **Deleterious effects on faculty and students**: Concerned with the potential impact on faculty and students. The collaborative research efforts will hinder academic work of faculty and students by inappropriately involving them in confidential research or imposing restrictions on publication.

4. **Loss of academic freedom**: Concerned with the nature of some sponsored work that manifested in confidentiality restrictions and delays in publication

requested by industry partners which will counter the university's traditional ideal—an atmosphere of free and open inquiry.

5. **Impact on financing of a university**: Concerned with the industry research funding carrying other risks for universities. State legislatures may cut support for publicly funded universities.

6. **Background rights**: Concerned with the licensing rights provided to an industry partner by a university. Many faculty members believe that the intellectual property of one faculty member should not be mortgaged for the benefit of another, or even to permit the institution to get sponsored-research.

For the industry factor, factors preventing research collaborations with university from being established or successfully accomplished include:

1. **Respecting the value of research collaborations**: Concerned with the understanding and appreciation of the value each potential partner brings to the relationship. Company officials, however, are not always predisposed to see universities as a source of relevant ideas. Many do not believe that university researchers have valuable insights.

2. **Incorporating university research into product development**: Concerned with the task in integrating university research into the product development process which is complex and affect the limitation of the utility of external collaborations.

3. **Management Barriers**: Concerned with the level of corporate support for research collaborations which depends on factors such as cost, time to complete, and the risk of losing control of proprietary information as well as lack of understanding of how universities operate, inability to appreciate the different time horizons of the two sectors, and an incompatible institutional reward structure for researchers who participate in collaborations.

4. **Research tools: exclusive vs. non-exclusive licensing agreements**: Concerned with whether the research tools will be licensed broadly or exclusively to one company, frequently a faculty start-up.

Moreover, there are liabilities within the framework of collaboration which include:

1. **Conflicts of interest**: *Financial conflicts* arise when scientists' private financial interests and their research converge in a way that might call into question their ability to make unbiased decisions related to their work. Perceptions of a conflict of interest can damage the research enterprise by weakening public trust, a particular concern for research universities, which heavily depend on federal research funding. *Conflicts of commitment* are generally defined as anything that might interfere with a faculty member's full-time duties. *Institutional conflicts* of interest are source of concern. Some universities invest in start-up firms or accept equity in lieu of royalties on university-held patents, raising concerns that they might become beholden to a company in which they have a financial stake. Ultimately, developing multiple funding sources can help protect universities from becoming indebted to any one entity.

2. **Confidentiality.** The university concerns that the ability of faculty researchers to discuss their work with colleagues and to publish their results will be at risk. At the same time, the industry needs to protect the value of their investments. Companies recognize that universities are not the best place to try to keep secrets. To that end, various strategies are used to protect confidential information. Individual researchers may be asked to sign confidentiality agreements, while sometimes institutional signatures are used.

3. **Intellectual Property.** The most nettlesome area of negotiations is usually the ownership, value, and use of the intellectual property arising from the sponsored effort. In other cases, companies often want ownership so that they might manufacture, use, and sell products that emanate from the research. Universities often desire ownership to allow their faculties and graduating students to continue to work in the area, meet joint sponsorship obligations, ensure commercialization, meet tax regulations, and license the technology on a non-exclusive basis.

The analysis of the BHEF gave some insights from real experience into possible explanation of barriers to growth of the U-I joint research derived from university, industry and liability conflict factors. Although this study did not focused on photovoltaic industry in the context of Thailand, there were a broad range of factors from both university and industry that could be applied to overall factors affecting the growth of joint research and the effective U-I joint research for photovoltaic technology transfer in Thailand and further solutions for enabling factors to be used for the conceptual model for the effective university-industry joint research for photovoltaic technology transfer.

2. Casey (2004)

The study of Casey (2004) derives from extensive research and experienced involvement in the field of the U-I partnership. It is primarily concerned with the barriers to U-I collaboration and attempt to improve the U-I partnership. As a result of the data collection and analysis from the focus group of the U.S. National Council of University Research Administration (NCURA) in the annual meeting in 2003, Casey (2004) indicate barriers to the U-I collaboration which include:

1. **Communication**: Communication skills differ between and within universities and industry. Needs and expectations are often different between the parties and the failure to communicate them compounds the problem. The unfortunate fact is that university and industry representatives often have stereotypical visions of the other and that hampers communication for effective project finalization and execution. This also includes the lack of multiple levels of communication within organizations and the lack of communication between faculty and staff/administration at the university.

2. **Cultural differences**: There is the distinction between both (non-profit educational institutions vs. for profit companies) which leads to cultural differences within universities and industry.

3. **Secrecy or public dissemination of knowledge**: Universities desire to publish and disseminate the results of their work. Companies, on the other hand, are often more secretive about the results of research in the search for competitive advantage and ultimately profit.

4. **Fear factor**: Both parties, either through culture, prior experience, or stereotyping, often fear doing work with the other. It is the fear of having to divulge information in the partnership.

5. **Universities overvalue the value of technology or the research they do**: This is often a comment made by industry, who feels that faculty often overvalue the work they do on projects.

6. **Lack of trust**: This is particular evident in areas of legal issues and contract negotiation and can be exacerbated by the departure of key personnel in establishing the relationship.

7. **Financial risk for universities**: It is financially riskier for universities to work with industries rather than government. The government in particular is seen as a stable source of research fund.

8. **Universities lack consistency**: Universities are fluid organisms. Administration and faculty come and go, making long term partnerships difficult. Agendas may change even if personnel are stable. Public universities are subject to the fiscal legislative process, and private universities have their own unique issues to a certain extent.

9. **Exclusive relationships**: Some companies want an exclusive relationship and often times universities and their faculty do not.

10. **Conflicts of interest**: Universities are very much concerned with conflicts of interest particularly financial conflicts of interest.

From the study of Casey (2004), several factors identified by the study such as communication skills, cultural differences, secret issues, and university consistency could be used to explain as barriers of growth of U-I joint research for technology transfer in the Thai context. The interesting point made by Casey (2004) was that the U-I successful relationship can be strengthened and developed further by addressing issues within the entire relationship, not just only those related to intellectual property management.

3. Szulanski (1996, 2000)

Szulanski (1996, 2000) underpins research in analyzing intra-firm knowledge transfer of best practice from a source to a recipient within a given media or context. It is recognized that the process of intra-firm technology transfer is one of the most influential factor on the fail or success of large industrial countries (Waroonkun, 2007). The significance of Szulanski's work is his analysis of the effects of certain characteristics of the context, the source, the recipient, and the knowledge or practice at various stages of the transfer process which can be applied and explained the barriers of the intra and inter-firm knowledge and technology transfer between and among organizations.

The work of Szulanski (1996, 2000) begins with the premise that the transfer of best practices inside the firm can be "sticky" or difficult. He explores the origins of internal stickiness as impediments and barriers of technology transfer in an intra-firm context. The analysis of the works is conducted through a two-step survey of 122 transfers of organizational practices within eight firms.

Table 2 Szulanski's Origins of Knowledge 'Stickiness'

Factors	Sub-factor
Characteristics of the Transfer Context	- Barren Organizational Context - Arduous Relationship
Characteristics of Knowledge Source	- Lack of Source Motivation - Lack of perceived reliability of source
Characteristics of Knowledge	- Unproven Knowledge - Causal Ambiguity
Characteristics of Knowledge Recipient	- Lack of recipient motivation - Lack of recipient absorptive capacity - Lack of recipient retentive Capacity

In terms of **characteristics of the transfer context**, recognizing the importance of organizational context to the gestation and evolution of a transfer initiative, Szulanski describes as 'fertile' or 'barren' those contexts that either facilitate or impede the number and fate of knowledge transfer attempts. His research confirms barren organizational context as an important origin of stickiness during the ramp-up and integration phases. Szulanski's research (1996) indicates that an arduous relationship - "laborious and distant" between source and recipient increases difficulty during the implementation phase of knowledge transfer, when interaction is at its most intense. This has notable implications for tacit knowledge transfer, which may necessitate numerous individual exchanges (Nonaka, 1994).

In terms of **characteristics of the knowledge**, Szulanski (1996, 2000) finds causal ambiguity as a significant origin of stickiness through all phases of the transfer process and particularly important during the first three stages. Causal ambiguity signals the absence of know-why, why something is done, and why a given action results in a given outcome (Szulanski, 1996). The proof of the usefulness of the source's knowledge is most important during the first two stages of the knowledge transfer process. The less substantiated the knowledge or the greater the speculation about claims it will solve the recipient's problem ("unproven knowledge"), the more difficult it will be to induce the recipient to engage in the transfer.

As for **characteristics of the source of knowledge**, Szulanski's research also supports the notion that stickiness may derive from lack of source motivation to engage in knowledge transfer. The source may be reluctant to share for fear of losing ownership or privilege, they may perceive inadequate rewards for sharing, or they may be unwilling to commit time and resources to the transfer. Confirming Arrow's (1971) view, Szulanski also determines lack of perceived reliability of the source to be an important origin of stickiness early in the initiation stage. Szulanski draws on persuasion theory in associating reliability with expertise and trustworthiness and notes that where these are perceived as lacking, transfer may be sticky and the source's advice challenged and resisted.

In the area of **characteristics of the recipient of knowledge**, Szulanski's research confirms that a lack of recipient motivation to accept knowledge from an external source and engage in particular activities that require its use will present stickiness. He also confirms that knowledge-related variables were more important barriers than motivation, and a motivated recipient may add to transfer difficulty. This is because impatiently enthusiastic recipients embraced transfers without meticulous planning, resulting in cost and time overruns.

Overall, Szulanski's (1996, 2000) empirical results from study of the origins of internal stickiness suggests that the major barriers to firm knowledge transfer were lack of absorptive capacity on the part of the recipient, causal ambiguity with regard to the knowledge itself and an arduous relationship between the source and the recipient. Moreover, the model of Szulanski can be used as the framework for analysis and assessment of origin of barrier to effective technology transfer process and U-I joint research collaboration in particular the framework to analyze the characteristics of transferor and transferees and transfer context.

4. TDRI – Thailand Development Research Institute (1992)

The Thailand Development Research Institute (TDRI) conducted a survey on the technological capability of the nation and its industry, and the strategies for enhancement of its technological capability to meet new demands, and to maintain international competitiveness and to sustain healthy economic growth. According to the survey in 1992, a sample of 119 firms across three industrial sectors, which use the key technologies in biotechnology, materials, and electronics technology, is employed in this study. The technological capability (TC) of these firms is assessed by categorizing some 20 components into four types of TC: acquisitive, operative, adaptive and innovative, and by rating each with a score between 0 and 5.

An acquisitive capability rated a firm's ability to search, assess, negotiate and procure needed technologies, and to install and start-up production facilities. Operative capability appraised the operation, control, and maintenance of production facilities, as well as skill development, production planning, and quality control. Adaptive capability concerned technology digestion and minor product and process modifications. Finally, innovative capability assessed the capacity to make radical product and process modifications, to carry out in-house R&D, and to invent new products and processes. Of the four technological capabilities, operative capability is generally found to be the highest among the three Thai industries, followed closely by acquisitive and adaptive capabilities, while innovative capability not only fared poorest, but lagged far behind the other three. Moreover, the study stated a number of problems and limitations which directly or indirectly had a bearing on the technology transfer and technological capabilities of the industries in the Thai context. They are:

1. **Inadequate supply of technical human resources**: Involved with the general shortage of S&T personnel, in particular of engineers, while the ability of S&T personnel is questionable, as newer technologies proliferate and push many existing technologies into obsolescence.

2. **Inadequate technical information services**: Related to the present technical information in the firm that is inadequate, while available information is spread over many different sources, making access to information difficult. This is detrimental to the acquisition, adaptation, and development of technology, and to the upgrading of human resources.

3. **Inadequate technical services**: Referred to the fact that available consultancy and technical services generally lack adequate standards and coverage while most small- and medium-sized firms need, from time to time, outside assistance to assess technology, install and start-up new production equipment, as well as to provide relevant testing, analysis, and certification of products and processes.

4. **Tax structure**: Involving the fact that import tariffs on testing and laboratory equipment for adaptive and innovative activities are prohibitively high, making firms less readily affordable, particularly to small-sized firms. Furthermore, multiple-taxation is widely seen to deter subcontracting, which in turn considerably reduces the levels of industrial linkages and technology transfer.

5. **Linkage to the S&T community:** Involved with the fact that industrial firms tend to doubt the effectiveness of universities and public technical institutes to solve practical industrial problems. As a result, the latter have not been given sufficient opportunities to gain the relevant experience. Most of the S&T community's research and development (R&D) activities, therefore, continue to be mainly for their own academic interests or for public and state benefits only.

6. **Attitude of entrepreneurs**: Referred to a widespread absence of a proper perception of the benefits of human-resource development, preventive maintenance practices, R&D activities, and modern management techniques. Also, protected industries tend to be complacent because of the lack of competition.

Although the study of TDRI was conducted more than 15 years, the author viewed that all barriers indicated in the study could be used to explain the nature of limited growth of U-I joint research and technology transfer in Thailand as evidence shown that some barriers still exist such as lack of human resources and lack of technical and information service which relevant to the later studies of Monaiyapong (2004) and Brimble and Doner (2007).

From the review of BHEF (2001), Casey (2004), Szulanski (1996, 2000) and TDRI (1992), groups of factors hypothesized as barriers affecting the growth of U-I joint research for technology transfer could be categorized into three groups. Those included:

1. **Characteristics of university**: Comprising of variables that are: lack of perceived reliability of source, lack of motivation, practical difficulties with negotiating and managing collaboration (loss of academic freedom, lack of structure to find partners, risks on fund, communication skill, lack of consistency) and concern on potential impact on faculty and students.

2. **Characteristics of industry**: Comprising of variables that are: technical knowledge and absorptive capacity, lack of motivation to learn, attitude of

entrepreneur (Respecting the value of research collaboration, university overvalue of technology), management barriers (level of corporate support depends on cost, time and control of information)

3. **Transfer context and organizational structure**: Comprising of variables that are: lack of technical and information service, lack of communication, lack of trust, cultural differences, inadequate infrastructure (inadequate supply of technical human resources, lack of linkage with S&T Communities) and confidentiality and intellectual property management.

Factors Affecting Effective U-I Joint Research for Technology Transfer

This section aimed to review the literatures to further develop a conceptual model for the effective UIJRPTT in Thailand. In the perspective of technology transfer studies, the effective technology transfer are considered the competitive position of the organizations that rests on their ability to utilize, enhance, and integrate the knowledge and competence located in different part of organization (Birkinshaw and Hood, 1998; Kogut and Zander, 1993). To reach that goal, the mechanism, by which the organization's knowledge and technology is transferred, therefore needs a certain amount of assessment. Those include: (1) strategic importance of technology transfer with the overall purpose and long term direction, (2) people possessing tacit and explicit knowledge, skills and motivation to perform tasks, (3) organization of work involving the creation and coordination of project terms and commercial networks, (4) interaction environment that affects the process to manage knowledge and communication (Sexton and Barrett, 2004). In the perspective of U-I joint research, a large amount of literatures has been written regarding the problems, benefits and models associated with type of U-I partnership. But effective U-I collaborations often remain a problem and present challenges to overcome. Etzkowitz and Leydesdorff (1995) indicate in the triple helix model that governments can play roles in facilitating the U-I relationship by offering incentives and pressing academic institutions to make more direct contribution to wealth creation. Wang and Lu (2007) developed a strategic framework of successful knowledge transfer between university and industry in China. A typology of four types of U-I interactions is presented using 2x2 matrix. The interaction based on the type of relation, different approaches and strategies. Although a large amount of literatures studied the effective U-I joint research for technology transfer, there were few suggested models and framework of U-I joint research and linkage suitable for Thai context. The author, therefore, decided to review factors affecting the effective U-I joint research through the studies and models of effective technology transfer, U-I collaboration and research cooperation from some studies (Fontana, Geuna, and Matt, 2006; Siegel, et al., 2004; Santoro and Gopalakrishnan, 2001; Miesing, Krieger, and Slough, 2007). Those study results assisted this thesis in identification of major factors related to U-I collaboration and technology transfer that were useful in developing the conceptual model for effective UIJRPTT.

1. Fontana, Geuna, and Matt (2006)

Fontana, Geuna, and Matt (2006) undertake an empirical study of the determinants of research cooperation between firms and public research organizations (PROs) which include university for small and medium-sized enterprises (SMEs). The aim of the study is to provide empirical evidence that confirms the models developed in the field of university-industry relationship and technology transfer. Fontana, Geuna, and Matt (2006) study focuses on the results of the KNOW survey carried out in seven EU countries during 2000 in five sectors: food and beverages, chemicals (excluding pharmaceuticals), communications equipment, telecommunications services and computer services, and on small and medium sized enterprises (SMEs) employing a minimum of 10 and a maximum of 999. Four groups of factors are investigated: firm size, firm R&D activity and status, firm innovative activity and openness of the firm. The nature of the factors and how they affect the effectiveness of technology transfer in R&D projects between university and SMEs concerned with:

1. **Firm size**: Focus on the role of the size and the R&D activity on the collaborative behavior (propensity and intensity) of the firms. The propensity to forge an agreement with an academic partner depends on the 'absolute size' of the industrial partner

2. **Firm R&D activity and status**: The level of interaction (as measured by the number of R&D projects) depends on their willingness to *signal(* the activity carried out by firms) their competences as well as on the relative weight of network interactions in their production of knowledge (as measured by their outsourcing

decisions) Firms with intense R&D activities to cooperate are much higher, as is the likelihood of concluding agreements with PROs; firms with small absorptive capacities had lower probabilities on both counts.

3. **Firm innovative activity:** Concern with the influence of the propensity for cooperation. *Screening* activities constitute important explanatory variables of R&D cooperation. Seeking information in scientific and business journals and participating in government-funded projects, positively affect the propensity for firms to collaborate with PROs.

4. **Openness of the firm:** The willingness to *search*, *screen* and *signal* of firms, significantly affects the development of R&D projects with PROs. Openness also positively affects the number of agreements concluded by firms through patenting. Patents may constitute a way to signal the firms' competencies, especially in the case of SMEs for whom secrecy is the usual way to approach appropriability.

There were several important factors that have been identified that could be developed from this study to produce the conceptual model for effective U-I joint research for photovoltaic technology transfer. In particular this study gives some insights for process technology transfer and possible factors in the perspective of firms that are relevant to knowledge transfer. Knowledge transfer is the process that requires commitment from both transferor and transferee. Therefore the willingness of firms (as stated in openness of the firm) and capability to learn (as stated in firm innovative activity) will also greatly impact to the effectiveness and success of U-I collaboration.

2. Siegel, et al. (2004)

Siegel, et al. (2004) undertake an exploratory study into the organizational issue in promoting the effective technology transfer particularly university/industry technology transfer (UITT) through technology transfer office (TTO). The study is based on qualitative evidence collected from 55 structured interviews of firms/entrepreneurs, TTO directors and university administrators, and university scientists. Five groups of organizational and managerial factors determine the effective UITT. Those are: (1) reward systems for UITT; (2) staffing practices in the TTO; (3) designing flexible university policies on technology transfer; (4) devoting additional resources to UITT, if that is consistent with the university's mission; and (5) working to eliminate cultural and informational barriers that impede the UITT process. The nature of the identified factors is identified as follow:

1. **Universities reward system:** This factor affects the level of patenting and the marketing of technologies to firms, because universities have a fixed budget to spend on patents.

2. **Resources devoted to UITT:** Insufficient university resources are impediment to UITT. Large TTO staff is often required to market university-based technologies effectively, especially when the reputation of the university is not sufficient to draw unsolicited attention to a school's patent portfolio.

3. **Marketing technology to firm:** Universities that allocate more resources to the TTO will devote more effort to marketing technologies to firms.

4. **Cultural understanding:** Cultural misunderstanding reduces the effectiveness of the university's efforts to market university-based technologies to firms. It also impedes the negotiation of licensing agreements and can also diminish a TTO's ability to market its technologies.

5. **TTO skills set:** TTOs managed by individuals with marketing experience and skills will expend greater effort in establishing partnerships with firms. TTOs that are managed by individuals with negotiation experience and know-how will be more successful at consummating technology transfer deals with firms.

6. **University Flexibility:** A high degree of university inflexibility will result in fewer technology transfer agreements with firms/entrepreneurs.

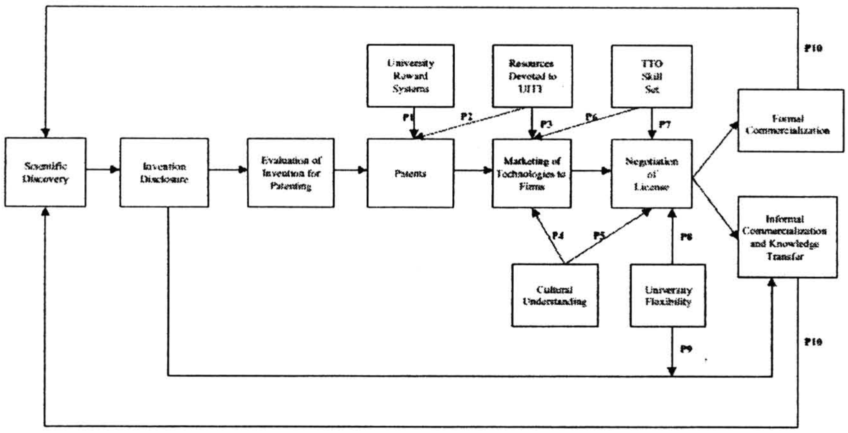

Figure 4 Factors Determining Successful UITT

Source: Siegel, et al. (2004)

An important conclusion made in the study of Siegel, et al. (2004) was that technology transfer should be expanding to the university management of the technology transfer office which is a relatively new phenomenon. The model of Siegel, et al. (2004) was an excellent foundation for identifying the key structural and institutional factors that influenced the success of U-I technology transfer such as the reward system, resources of university, cultural understandings and management skills of UITT. The linkage and relationships among the factors and the success or failure of technology transfer was also identified in the model.

3. Santoro and Gopalakrishnan (2001)

Santoro and Gopalakrishnan (2001) research focus on the U-I relationship that facilitated technology transfer process. This study indicate relationship-oriented factors such as trust, geographic proximity, communication, and university policies for intellectual property rights (IPR), patents and licenses and examines how these factors influenced the technology transfer process between university research centers and their industrial partners. Data for this study is collected from 189 industrial firms working with 21 research centers affiliated with prominent research-oriented universities in the US. Santoro and Gopalakrishnan (2001) indicate the factors influencing U-I technology transfer process are including: (1) trust of the university partner, (2) geographic proximity between the firm and its university partner, (3) communication effectiveness, and (4) flexible university policies for IPR, patents, and licenses. They are strongly associated with greater technology transfer activities. The nature of the four factors that make up the Santoro and Gopalakrishnan (2001) model are:

1. Trust: Trust in the U-I collaborative venture is important. Changes in the industrial firm's or university research center's leadership, untrustworthy actions by either the firm or the university research center, or new partnership alternatives can quickly change the level of trust in these collaborative ventures.

2. University center policies: Universities and industrial firms both view IPRs, patents, and licenses as an opportunity to increase revenues. If universities want to encourage relationships with industry to advance new technologies, then greater flexibility of university policy over the IPRs is needed.

3. Geographic proximity: Geographic proximity affects resource availability, transportation costs, and customer responsiveness of the firms across the various university research center models.

4. Communication effectiveness: Communication effectiveness is important to the relationship-oriented factors examined in affecting technology transfer although its important is less than other factors.

The identification of the interactive nature of the communication process in this model was useful in developing the conceptual model for technology transfer through joint research related to photovoltaic technology. Some important factors identified such as trust and university policies on intellectual property rights and communication effectiveness were key individual and work environment factors influencing effective technology transfer and U-I collaborations. The indication and explanation of the factors in Santoro and Gopalakrishnan (2001) were relevant to others research works in the field of technology transfer and organizational culture such as Knack and Keefer (1997), BHEF (2001), and Casey (2004).

4. Miesing, Krieger, and Slough (2007)

Miesing, Krieger, and Slough (2007) study how transnational can transfer both tacit and explicit knowledge between their units and between Chinese foreign invested enterprises (FIEs) and the parent organization to generate an effective model technology and knowledge transfer. Miesing, Krieger, and Slough (2007) state that successful intra organization knowledge transfer depends upon: (1) collective creation of knowledge as intellectual and social capital available throughout the organization; (2) trust-based collaboration among geographically dispersed entities that form the transnational organization; and (3) the willingness and ability of organizational units (absorptive capacity) to use that knowledge. Moreover, it is suggested that organizational knowledge should ideally flow in multiple directions, providing learning opportunities for both investing and host organizations. Implications for transfer of best practices, a specific form of tacit knowledge, are also offered. The effective intra-organizational transfer of knowledge and best practice requires: (1) the creation of social capital, (2) between members in a collective transnational strategy, (3) who are willing and able to absorb new knowledge.

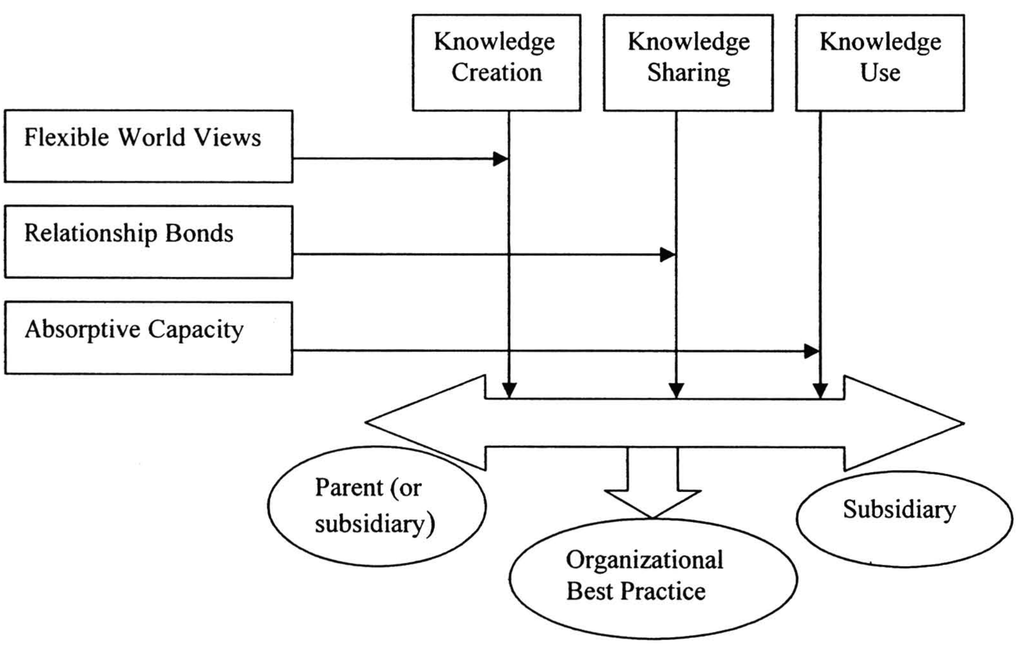

Figure 5 Model

Source: Miesing, Krieger and Slough (2007)

The conditions described above can be accomplished by carefully designing human resource policies to facilitate norms of reciprocity, by rewarding business units that are committed to developing intra-organizational relationships, and by cultivating collaboration—all within an organizational culture that encourages the creation, sharing, and use of knowledge throughout the firm. Miesing, Krieger, and

Slough (2007) model clearly demonstrates the factors of trust, absorptive capacity, network and learning through intra-firm technology transfer.

Rationale for Model of Effective U-I Joint Research for Photovoltaic Technology Transfer

Reviewing the models and research frameworks on barriers of technology transfer and effective technology transfer, it was found that some factors which were barriers to technology transfer and factors affecting growth of U-I joint research for technology transfer were, in some aspects, similar to the factors of effective U-I collaboration for technology transfer. Those factors could be identified in three major groups that were: (1) characteristics and perspectives of university, (2) characteristics and perspectives of university, and (3) learning and transfer context and organizational structure. From those factors as shown in table 3, the author viewed that there were many important factors that need to be incorporated in developing a conceptual U-I joint research for photovoltaic technology transfer in Thailand which were identified further in 2.7.

Table 3 Summary of Factors from Studies and Models

Factors of Barriers of Technology Transfer	Reference	Factors of Effective Technology Transfer	Reference
Main Factor 1	**Characteristics and perspectives of university**		
Sub Factor (1) Lack of perceived reliability of source	Szulanski (1996, 2000)	Sub Factor (1) Capacity to transfer (firm- specific knowledge, the ability to impart that the knowledge in a form that can be assimilated)	Siegel, et al. (2004) Fontana, Geuna, and Matt (2006) Miesing, Krieger, and Slough (2007)
(2) Lack of source motivation to engage in knowledge transfer.	Szulanski (1996, 2000)	(2) Willingness to transfer (with the relations of ownership type)	Fontana, Geuna, and Matt (2006) Miesing, Krieger, and Slough (2007)
(3) Practical difficulties with negotiating and managing collaboration (loss of academic freedom, lack of structure to find partners, risks on fund, communication skill, lack of consistency)	BHEF (2001) Casey (2004)		

Table 3 (Cont.)

Factors of Barriers of Technology Transfer	Reference	Factors of Effective Technology Transfer	Reference
(4) Concern on potential impact on faculty and students	BHEF (2001)		
Main Factor 2	**Characteristics and perspectives of industry**		
Sub Factor (1) technical knowledge and absorptive capacity	Szulanski (1996, 2000)	Sub factor (1) absorptive capacity	Fontana, Geuna, and Matt (2006) Miesing, Krieger, and Slough (2007)
(2) Intent to learn and lack of motivation to learn	Szulanski (1996, 2000)	(2) Intent to learn of the employees and link between learning and reward)	Fontana, Geuna, and Matt (2006) Miesing, Krieger, and Slough (2007)
(3) attitude of entrepreneur (Respecting the value of research collaboration, university overvalue of technology)	TDRI (1992) BHEF (2001) Casey (2004)		
(4) learning culture	Szulanski (1996, 2000)		
(5) management barriers (level of corporate support depends on cost, time and control of information)	BHEF (2001)		
Main Factor 3	**Learning and Transfer context and Organizational Structure**		
Sub Factor (1) lack of technical information service, inadequate technical services	TDRI (1992) Casey (2004)	Sub Factor (1) collective creation of knowledge as intellectual and social capital available throughout the organization,	Miesing, Krieger, and Slough (2007)
(2) Lack of communication between transferees and transferor	Casey (2004)	(2) trust-based collaboration in relationship bond	Miesing, Krieger, and Slough (2007) Santoro and Gopalakrishnan (2001)
(3) Cultural Difference	BHEF (2001) Casey (2004)	(3) Cultural difference Understanding	Siegel, et al. (2004)
(4) Transfer Infrastructure and organization context (inadequate supply of technical human resources, lack of linkage with S&T Communities)	Szulanski (1996, 2000)	(4) Transfer infrastructure and organization context (reward system, flexible policy, devoted resources)	Siegel, et al. (2004) Santoro and Gopalakrishnan (2001)
(5) Confidentiality and intellectual property management and lack of trust	BHEF (2001) Casey (2004)	(5) Confidentiality and intellectual property management	Santoro and Gopalakrishnan (2001)

Moreover, from the review of Fontana, Geuna, and Matt (2006), Siegel, et al. (2004), Santoro and Gopalakrishnan (2001) and Miesing, Krieger, and Slough (2007) on the factors affecting effective U-I collaboration and technology transfer, it was found that even though the previously studied models all achieved their desired objectives, none comprehensively described the factors affecting effective technology transfer process under the U-I joint research and its link to the outcome that was growth and quality and economic performance of U-I joint research. In order to provide the rationale for a new model, the limitation of existing effective U-I collaboration and technology transfer models and studies with some comments were presented in the following section.

1. Fontana, Geuna, and Matt (2006)

The purpose of the Fontana, Geuna, and Matt (2006) model was to describe the nature of the factors and to explain how they affect the successful technology transfer in R&D projects between university and SMEs. Even though there were several important factors that could be developed from this study to construct the conceptual model for effective UIJRPTT, there was limitation in the model. The study of Fontana, Geuna, and Matt (2006) focused only on the factors related to firm, while, in fact, numerous variables during technology transfer, both internal and external to the firms and the universities, affected the success or failure of the effective U-I joint research for technology transfer. Moreover, in some instances, recipient firms might learn new skills and be unable to fully exploit this new learning because of an inadequate institutional environment and capabilities. Some factors related to technology suppliers like university and its context would also affect the overall U-I joint research for technology transfer. Contextual and organizational factors of university therefore might affect the degree to which the cooperation was encouraged. The factors of effective UIJRPTT should be looked into the context of both firms and university.

2. Siegel, et al. (2004)

The model of Siegel, et al. (2004) was developed by looking into the organizational issue in promoting successful technology transfer particularly university/industry technology transfer (UITT) through technology transfer office

(TTO). This model applied the organizational and managerial views to identify factors that determined the effective UITT. However, the study of Siegel, et al. (2004) was limited by the scope of the technology transfer process that confined to the organization structure and management of the TTO and lacked in incorporating the context of university and industry. As well, the outcome factors of the model - the commercialization of technology transfer – were not exactly the destination of the complete conceptual model of effective UIJRPTT in Thailand.

3. Santoro and Gopalakrishnan (2001)

This research focused on U-I relationship that facilitated technology transfer process in the U.S. The research identified four set of factors that influenced the technology transfer process. For the photovoltaic industry in Thailand, these factors might not sufficiently describe all of the influential enabling and outcome factors. The important influences such as the capabilities of industry and university, motivation and different culture between university and industry had been neglected. However, it should be noted that the factors identified in the study could generally explain some aspect of the effective U-I technology transfer through joint research in all industries. University policies for intellectual property rights (IPR), patents and licenses and communication system might have strong interaction effects with other factors in Thai context and the outcome of U-I joint research particularly the relations to growth and quality and economic performance of U-I joint research in Thailand

4. Miesing, Krieger, and Slough (2007)

The main concerns with this research pertained to its case studies of transnational knowledge transfer between Chinese foreign invested enterprises (FIEs) and the parent organization to generate an effective model technology and knowledge transfer. The model of Miesing, Krieger, and Slough (2007) was more directed at identifying best practice through intra-organization knowledge transfer, this made the model not generalized and not directly concern with the U-I collaboration.

Conceptual Model for Effective U-I Joint Research for Photovoltaic Technology Transfer

The objective of the development of the conceptual model of effective U-I joint research for photovoltaic technology transfer was to capture all of the relevant factors that influence the effective UIJRPTT in Thailand and its outcome that were growth and quality and economic performance. These relevant factors were adopted from the previously examined studies in the field of U-I collaboration and technology transfer with the aim to develop the model to identify and explain factors which facilitate UIJRPTT in Thailand and to identify the way for ensuring the presence of these factors.

Through a process of factors categorizing from the previous studies, three factors namely: *characteristics and perspectives of university*, *characteristics and perspectives of industry* and *joint research mechanism*, were identified and hypothesized that they may lead to the effective UIJRPTT which was the outcome factor. These factors, the structure and their links in the model were conceptualized based on understanding of U-I collaboration and the technology transfer as reviewed previously as well as of the Thai photovoltaic industry and the university context, and were required testing to confirm their appropriateness and validity. The conceptual model was illustrated as follows.

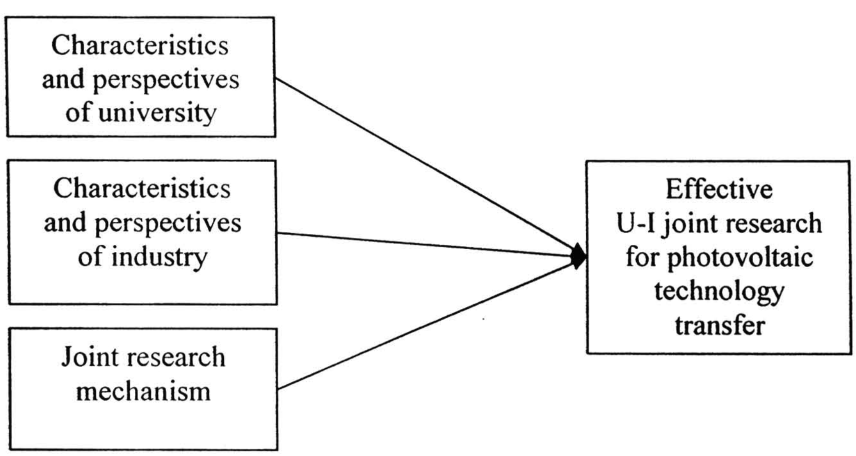

Figure 6 Conceptual Model for the Effective U-I Joint Research for Photovoltaic Technology Transfer

It should be noted that the literatures provided some evidences that the relationship between characteristics and perspectives of university and industry and joint research mechanism to the technology transfer under U-I collaboration existed. But the study also needed to examine the relationship of those factors in the context of effective UIJRPTT in Thailand. Moreover, although these links were said to have been described in past literatures, it did not mean that every variable contained in each factor impacted on every factor and variable in another as the review in this thesis does not reveal any support on the links between the enabling factors and variables. The following section described the persuasion for including each variable in the above mentioned factors and outcome factors. Each section concluded with a table consisting of sub-factors and associated descriptions and references.

1. Characteristics and Perspectives of University and Industry

The two factors are related to the characteristics and perspectives of university and industry. These enabling factors are concerned with the degree to which the characteristics and perspectives of the university and industry encouraged the effective UIJRPTT in Thailand. The *characteristics and perspectives of university* factor included four variables: (1) capabilities in receiving and transferring technology in terms of technical and funds, (2) adequate specialist, researchers and students, (3) adequate research tools and equipment, and (4) willingness and motivation for team work with shared value (Table 4). The *characteristics and perspectives of industry* factor included four variables: (1) capabilities in receiving and transfer technology in terms of technical and resources, (2) willingness and motivation to work with university with shared value, (3) perspectives on worthiness and value of joint research in terms of economic and intellectual value, and (4) understanding cultural differences (Table 5). The supporting literature for these variables is provided in the following paragraphs.

One of the essential factors in achieving effective UIJRPTT is the capability in receiving and transferring technology in terms of technical and funds. The knowledge base of both university and industry has been identified as having an impact on the effectiveness of U-I collaboration and joint research (Szulanski, 1996, 2000; Miesing, Krieger, and Slough, 2007; Fontana, Geuna, and Matt, 2006; Thursby & Kemp, 2002). The capacity to transfer and adopt technology of the university will depend on each (i) individual existing knowledge base, skills of faculty members, researchers, and staff, (ii) resources like books, data bases, and archives, (iii) basic skills and curiosity of students as well as (iv) the gap between this knowledge level and the level required utilizing the technology (Szulanski, 1996, 2000; Miesing, Krieger, and Slough, 2007; Fontana, Geuna, and Matt, 2006). For the industry, the knowledge base of university and industry is important in achieving the quality and performance of research projects which is the outcome of the technology transfer process. The ability to receive and exploit knowledge is a result of existing knowledge stock of the industry. Moreover, sufficient funding and efficient budgeting are the most important prerequisites for universities to carry out their academic tasks (Liefner and Schiller, 2008). Without high knowledge base the university is limited in the amount of useful knowledge that it can transfer. On the other hand, if the industry has poor level of knowledge base, they will have difficulty understanding and utilizing the new technology. With funds for R&D, the industry can extend the research works and finding solutions for technical and knowledge problems. This will affect the growth and value of the U-I joint research for technology transfer.

The degree of willingness and motivation of university and industry to work together with shared value should be a concern. The intent of university and industry as transferors and transferees to learn the new technology has been explored by some studies (Szulanski, 1995, 1996, 2000; Miesing, Krieger, and Slough, 2007; Fontana, Geuna, and Matt, 2006). The focus of those studies is to investigate the factors that influence the behavioral intention to conduct research and adopt new technology. Fontana, Geuna, and Matt (2006) state that the willingness of firms significantly affects the development of R&D projects of firms and university. Benefit and cost is another issue that should be taken not lightly as motivation for joint research. Instead of privately conducting R&D and coming up with unnecessary product, firms in the industry can cooperate through joint research that allows for wider and deeper distribution of technology, with all participants receiving the fruits of the cooperation. Pooled risks and economies of scale also make it feasible for participating firms and university including their sub-organization and network to conduct projects (Levy & Samuels, 1992, p. 17). Therefore, the willingness and motivation of university and industry to work together with shared value, which means the perceptions of both sides that benefits as a result from U-I joint research may occur, should affect the degree of effective UIJRPTT in Thailand.

In consideration of the Thai context, adequate specialist, researchers and students of the university relates to the growth and performance of joint research and collaboration between university and industry. TDRI (1992) state that shortage of S&T personnel, in particular of engineers, affects the technology pushes of many existing technologies into obsolescence. Siegel, et al. (2004) indicate also that insufficient university resource is an impediment to UITT. Large TTO staff is often required to market university-based technologies effectively, especially when the reputation of the university is not sufficient to draw unsolicited attention to a school's patent portfolio. This statement is relevant to the knowledge management, the effective technology transfer and management can be achieved through appropriate structure, financial and human resource management. Viewing that there are not many universities that conduct the research related to photovoltaic technology, product and process development, therefore, adequate specialist, researchers and students of the Thai university will relate to the effectives and success of technology transfer through joint research.

Inadequate research tools and equipment is also viewed related to the degree of the growth and performance of joint research and collaboration between university and industry. University and industry is supposed that they will not decide to conduct joint research if the support in terms of research work structure and tools are not adequate and appropriate. University's lack of consultancy and technical services, research tools and equipments will also affect the outcome of U-I joint research while most small- and medium-sized firms need outside assistance to assess technology, install and start-up new production equipment, as well as to provide relevant testing, analysis, and certification of products and processes (TDRI, 1992).

BHEF (2001) indicate that the understanding and appreciation of the value each potential partner brings to the U-I technology transfer affected the growth and effective U-I joint research. Industry staffs sometimes view universities as a source of relevant ideas but many do not believe that university researchers have valuable insights. Moreover, the obstacles and risks associated with cooperation such as joint research that might hinder its growth such as stifled innovation, market-rigging, freeriders, and the loss of valuable proprietary information. If the industry's long terms strategy is to develop technology for competition in the market and support of research to develop product and process technology, they realize the importance of joint research. Therefore, the perspectives on worthiness and value of joint research in terms of economic and intellectual value are perceived to be related to the growth and effectiveness of U-I joint research in Thailand.

As far as the cultural difference between university and industry is concerned, Siegel, et al. (2004), Casey (2004) and BHEF (2001) state that cultural misunderstanding reduces the effectiveness of the university's efforts to market university-based technologies to firms. Those include the perspectives that the industry does not understand how universities operate as nonprofit organization (universities and companies differ in the way that research is funded, the expected outcomes of research programs, and the way that each manages the results of research) (Severson, 2005); the industry does not have the ability to appreciate the different time horizons of the two sectors (i.e. industry needs the result of the research as soon as possible, while the university needs time for research confirmation and publication) and to understand that university researcher normally work individually.

Table 4 Characteristics and Perspectives of University

Sub-factor	Description	References
Capability in receiving and transfer technology in terms of technique and funds	Concerned with the university capability knowledge and technical base in advance basic and applied photovoltaic technology and financial funds for transferring and receiving technology.	Szulanski (1996, 2000) Miesing, Krieger, and Slough (2007) Fontana, Geuna, and Matt (2006) Thursby & Kemp(2002)
Adequate specialist, researchers and students	Concerned with the university adequate specialist, researchers and students to conduct research related to photovoltaic technology that can respond to the industry's need.	TDRI (1992) Siegel, et al. (2004)
Adequate research tools and equipment	Concerned with the university adequate research tools and equipment to conduct research with photovoltaic industry.	TDRI (1992)
Willingness and motivation for team work with shared value	Concerned with the university's willingness to transfer photovoltaic technology and to work with industry in team with shared value within the different culture.	Szulanski (1996, 2000), Miesing, Krieger, and Slough (2007) Fontana, Geuna, and Matt (2006). Siegel, et al. (2004) Casey (2004)

Table 5 Characteristics and Perspectives of Industry

Sub-factor	Description	References
Capability in receiving and transfer technology in terms of technical and funds	Concerned with the industry capability knowledge and technical base in advance basic and applied photovoltaic technology and financial funds for transferring and receiving technology.	Szulanski (1996, 2000) Miesing, Krieger, and Slough (2007) Fontana, Geuna, and Matt (2006); Thursby & Kemp, (2002)
Willingness and motivation to work with university with shared value	Concerned with the industry's willingness to transfer photovoltaic technology and to work with industry with shared value.	Szulanski (1996, 2000), Miesing, Krieger, and Slough (2007) Fontana, Geuna, and Matt (2006) Siegel, et al. (2004) Casey (2004)
Perspectives on worthiness and value of joint research in terms of economic and intellectual value	Concerned with the industry's perspectives on the joint research value in terms of economic and intellectual value.	BHEF (2001)
Understanding cultural differences	Concerned with the understanding of the differences between university and industry culture (i.e. how universities operate as nonprofit organization, ability to appreciate the different time horizons of the two sectors, and freedom of university researcher in working individually)	Siegel, et al. (2004), Casey (2004), BHEF (2001) Sevenson (2005)

2. Joint Research Mechanism

The *joint research mechanism* is focused at the micro managerial and organizational perspective in the study of U-I collaboration and technology transfer. This factor includes five variables namely, (1) communication effectiveness; (2) management of coordination office and joint research program; (3) IP management and (4) incentive system. The supporting literature for these variables is provided in the following paragraphs.

Communication effectiveness is concerned with degree to which communication encourages and hinders the growth and effectiveness of technology transfer through U-I joint research. Communication involves the transfer of meaning from one person to another (March and Simon, 1958). Effective communication requires that information and ideas are conveyed and understood between individuals. Effective communications helps (1) articulate technology transfer objectives and expectations among partners (2) enables decision making in both university and industry to take place faster and allows collaborating parties to be more aware of expectations from the relationship thereby reducing uncertainty. Thus, there is greater confidence in university and industry resulting in more time being spent on technology related activities and less time on personality-related issues (Santoro and Gopalakrishnan, 2001). Moreover, communication effectiveness in terms of U-I collaboration means the establishment of communication mechanism such as meeting, seminars, conferences, class room linkages and websites where communication between the university and industry are allowed.

Management of coordination office and joint research program management are a major concern before, during and after technology is transferred under the U-I collaboration (Siegel, et al., 2004; Santoro and Gopalakrishnan, 2001). The nature of technology transfer generally requires the adoption of new management technique, photovoltaic related technique of product and process development and even a new way of thinking. For effective long term conduct and adoption of new technology, there must be continuous management. Commitment from the senior management and university flexibility to encourage relationships with industry were identified as influential factors for effective technology transfer under U-I collaboration in the studies of Siegel, et al. (2004) and Santoro and Gopalakrishnan (2001). Moreover, within the perspective of knowledge management and the study of BHEF (2001) the structures to find compatible collaboration partners, management of collaborations, and coordinating support services within the university departments and between university and industry are more likely to the growth and effectiveness of technology transfer through joint research.

Intellectual property rights - IPRs., patent, and licensing agreements are a major consideration in U-I collaborative ventures (Reams, 1986) Since universities and industrial firms both view IPRs, patents, and licenses as an opportunity to increase revenues, establish competitive advantage, and enhance recognition, competition over these rights is often contentious (Phillips, 1991). Lockett and Wright (2005) conclude that there are positive correlations between start up formation and the university intellectual property protection. That is relevant to the studies of Santoro and Gopalakrishnan (2001) and Thursby and Thursby (2004), IPRs protection for promising discoveries is critical to success of transfer process and knowledge management.

The incentive system from university and the government affects the level of U-I joint research and technology transfer. Siegel, et al., 2004 state that patenting and marketing of technologies are increasing because universities have a fixed budget to spend on patents and patents can be further reward for university and partner firm. Miesing, Krieger, and Slough (2007) also indicate that conditions of successful technology transfer can be accomplished partly by providing incentive and rewarding business units that are committed to developing intra-organizational relationships, and by cultivating collaboration. Siegel, et al. (2003) found that universities allocating a higher percentage of royalty payments to faculty members tend to be more efficient in technology transfer activities. This finding was independently confirmed in Friedman and Silberman (2003) and Lach and Schankerman (2004). In the case of R&D cooperation, firms are convinced by prospective partners of opportunities available from engaging in a good R&D project to conduct U-I research collaboration (Fontana, Geuna, and Matt, 2006). Moreover, as far as the government roles as technology and market facilitator is concerned, ESCAP (1999) state that government national policies related to technology, S&T, trade and finance, industry and investment as well as infrastructure improvement affect strongly to technology transfer. Therefore, it is likely that the degree of incentive and reward system from the university and government policy support should influence the growth and effectiveness of UIJRPTT.

Table 6 Joint Research Mechanism

Sub-factor	Description	References
Communication effectiveness	Concerned with establishment and good communication system between university and industry within the joint research mechanism and program.	Santoro and Gopalakrishnan (2001)
Management of coordination office and joint research program	Concerned with the management of the joint research program, including commitment of senior management, structure to find partners, coordinating services.	Siegel, et al.(2004) Santoro and Gopalakrishnan (2001)

Table 6 (Cont.)

Sub-factor	Description	References
Intellectual Property (IP) management	Concerned with the degree of IP management of the joint research through technology transfer process	Santoro and Gopalakrishnan, (2001) Lockett and Wright (2005) Thursby and Thursby (2004)
Incentive system	Concerned with the degree to which government policies and university support to encourage joint research (i.e subsidiary and budget for research)	Fontana, Geuna, and Matt (2006) Siegel, et al. (2004) Miesing, Krieger, and Slough (2007) Siegel, et al. (2003) Friedman and Silberman (2003) Lach and Schankerman (2004) ESCAP (1999)

3. Effective UIJRPTT

The interrelationship between the mentioned enabling factors contributes to the degree of the effective UIJPRTT in Thailand. From literatures, the author identifies two main areas that are hypothesized to be facilitated by the effective UIJRPTT. These variables are discussed as follows:

3.1 Growth of UIJRPTT

Thai-based photovoltaic companies and universities should be highly motivated and responsive to participate in collaboration due to the changing context of the competition and technology in the world market. The growth of technology transfer through joint research should be more achieved. According Panich (2005), practical guidance as to how university and industry avoidance of technology transfer barriers by facilitating both technology transferor and transferees need and by understanding both side contexts, could help increase U-I joint research. Some studies (Szulanski ,1996; TDRI, 1992; Miesing, Krieger, and Slough, 2007; BHEF, 2001; Baron, 1990) identify several key barriers encountered in the transfer of technology. Those include characteristics of university and industry, technical barriers, transfer context barriers, organization and regulatory barriers and people barriers. Overcoming those barriers will help increase the growth of cooperation between university and industry in the process of technology transfer. The conceptual model factors draw some recommendation about what is required for greater effectiveness and increase in joint research for technology transfer. This highlight the importance of many factors as previously reviewed.

3.2 Joint Research Performance

It is normally accepted that the objectives for U-I joint research are quality performance and economic performance derived from effective technology transfer. Williamson (1979; 1981) states that man with limited capacity need to acquire and process information in economically efficient way. To attain this goal, they economize as much as possible on knowledge transfer costs. Through collaborations, a company and university can also improve its exploration and exploitation capabilities through learning process and consequently improve its innovative capacity and product development (Faems, Van Looy, and Debackere, 2005). The better research result will come from networks and face-to-face contacts and communication in solving potential problems which make socialization and learning easy, and provide psychological motivation (Wilhelmsson, 2007). The U-I joint research performance should be usually measured in terms of time, cost and quality. It is accepted that the major goals of U-I joint research are concerned with benefit and cost, quality of research works and time of research works. The successful implementation of joint research programs should lead to reduction in cost and time of research and improvement of product or process development. Firms are faced with the competitive pressure; therefore, joint research will help firms in reducing cost overhead, less in-house basic search, spending less on training and reducing time in research. Professionals and students in the university also can try out new thing for innovation and cost effectiveness. Moreover, great improvement can be seen in IP rights ownership of both sides (Dasher, 2005; Kazuyuki, 2004). Table 6 details these sub-factors as well as their description and support reference.

Table 7 Joint Research Performance Sub-factor

Sub-factor	Description	References
Quality performance	Concerned with the degree to which joint research program and mechanism can help improve quality performance (i.e innovation in products and process, technology, better quality of research result) between university and industry	Kazuyuki (2004) Wilhelmsson (2007) Dasher (2005)
Economic performance	Concerned with the degree to which joint research program and mechanism can help improve economic performance (i.e. less investment in resources, less time in conducting research, IP rights) between university and industry	Kazuyuki (2004) Faems, Van Looy, and Debackere (2005) Dasher (2005)

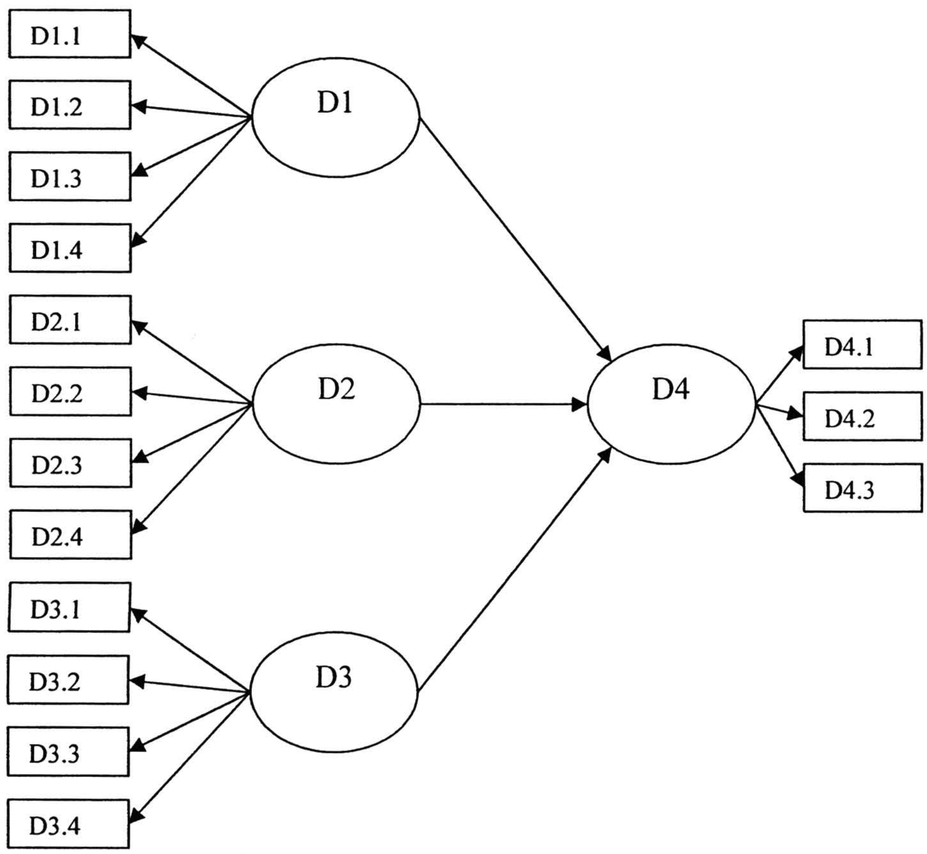

Figure 7 Conceptual Causal Model for the Effective U-I Joint Research for Photovoltaic Technology Transfer with Factors and Sub-factors Summary

Note: D1 = Characteristics and perspectives of university

D1.1 = Capability in receiving and transferring technology in terms of technique and funds

D1.2 = Adequate specialists, researchers and students

D1.3 = Adequate research tools and equipment

D1.4 = Willingness and motivation for teamwork and shared value

D2 = Characteristics and perspectives of industry

D2.1 = Capability in receiving and transferring technology in terms of technique and funds

D2.2 = Willingness and motivation in working with university with shared value

D2.3 = Perspectives on worthiness and value of joint research in terms of economic and intelligence value

D2.4 = Understanding cultural difference

D3 = Joint Research Mechanism

D3.1 = Communication effectiveness

D3.2 = Management of coordination office and joint research program

D3.3 = Intellectual Property management

D3.4 = Incentive System

D4 = Effective U-I joint research for photovoltaic technology transfer

D4.1 = Growth of U-I joint research for photovoltaic technology

D4.2 = Quality performance from joint research

D4.3 = Economic performance from joint research

In sum, the conceptual model which comprised of 4 factors (3 enabling factors and 1 outcome factor) and 15 observed variables (sub-factors) were illustrated in the proposed model as shown in Figure 6. From the literature reviews, the hypothesis for this research part on the factors affecting effective UIJRPTT were: (1) the enabling factors (*characteristics and perspectives of university and industry and the joint research mechanism*) which were able to forecast the effective UIJRPTT through the outcome sub-factors with statistically significant; and (2) the conceptual model of effective UIJRPTT was relevant to the respondent data that would be tested through the research methodology stated in the following chapters.

Summary

The objective of this chapter was to review the past and existing studies on the technology transfer; university-industry collaboration, to provide the background on joint research situation in Thailand and Thai photovoltaic industry as well as to examine and critically review the studies in explaining the growth and effectiveness of U-I joint research for technology transfer, and to develop a conceptual model for the effective UIJRPTT. In addition to the critical review of eight existing studies and models, some other studies related to theoretical perspectives were also examined in order to identify factors that could have influences on the effective U-I joint research for technology transfer and the outcome result from them. The four studies and models of factors affecting growth of U-I joint research for technology transfer were BHEF (2001; Casey, 2004; Szulanski, 1995; 1996; 2000; TDRI, 1992). The factors affecting the growth of the U-I joint research photovoltaic technology transfer in Thailand were hypothesized into three groups: characteristics of university, characteristics of industry and transfer context and organizational structure. The four studies and models of factors affecting effective U-I joint research for technology transfer were Fontana, Geuna, and Matt (2006; Siegel, et al., 2004), Santoro and Gopalakrishnan (2002; Miesing, Krieger and Slough, 2007). The latter studies and models were also critically reviewed. Each of these studies and models contributed to the development of the effective U-I joint research for photovoltaic technology transfer. With some modification, these factors become essential in building constructs for the developed conceptual model. The model comprised of a set of enabling factors: characteristics and perspectives of university, characteristics and perspectives of industry and joint research mechanism. The model also incorporated the outcome factor with sub-factor that could be measured as growth and performance of U-I joint research for photovoltaic technology transfer. The contribution and relationship between enabling and outcome factors were indicated as shown in figure 6.