CHAPTER IV

RESULTS AND DISCUSSION

Introduction

This chapter presented the result of data collection and analysis by the use of mixed qualitative and quantitative research methodology of the primary study. The study consisted of: (1) analysis of factors affecting the growth of the UIJRPTT to answer the question of why there is little number of UIJRPTT in Thailand; and (2) analysis of factors affecting the effective UIJRPTT and the development of the effective UIJRPTT model. To obtain the quantitative data, the respondents were asked to complete the questionnaires measuring by Likert scale on: (1) factors and items were barriers to growth of UIJRPTT; (2) factors and variables affecting the effective UIJRPTT; (3) outcome factor of the effective UIJRPTT; and (4) the current status of the affecting the effective UIJRPTT. To acquire qualitative data, document analysis and the interviews were conducted with the purposely selected interviewees to reach the adequacy in understanding the factors affecting growth of the UIJRPTT and to confirm the model factors of the effective UIJRPTT and to refine with actions and activities. The qualitative data collection allowed respondents in giving open answers to explain their views on the issues in detail that might not be able to measure by the quantitative instrument. In the part of model validation, the quantitative data were further collected by questionnaire survey from three project case studies.

The results and discussion of the primary study and model validation were presented in four parts. The first part described characteristics and background of the respondents as well as their common perspectives toward the UIJRPTT. The second part reported the qualitative and quantitative data analysis related to factors affecting growth of the UIJRPTT with the conclusion to answer the question of why there was limited number of the UIJRPTT. The third part presented the statistics results of the factors influencing the effective UIJRPTT and the development of the model of the effective UIJRPTT was proposed. The current status of the factors and confirmation of the factors from the qualitative report shed light to equip the model with concrete suggestions and recommendation to improve the factors. The final part provided evidences from case study on the validation of the model of the effective UIJRPTT.

PART ONE Background of Respondents and their Perspectives on U-I Joint Research for Photovoltaic Technology Transfer

Introduction

This part provided an overview on characteristics and background of both the interviewees and the questionnaire respondents including position, working experiences and research projects which related to the photovoltaic technology that they were involving. Specifically, this part also presented the perception of the respondents on benefits of the UIJRPTT and data on the current situation of the UIJRPTT. The specific research areas that were of the university and industry interest and had potential in conducting the UIJRPTT were also reported.

Background of Respondents

1. Characteristics of Interviewees

The numbers of the interviewees involving was 63. Among those, the interviewees from the university and the industry were 45 and 18 respectively, accounting for 71% and 29%. Two key criteria were used to select the interviewees. First, the interviewee from the university should have an extensive knowledge and experience regarding the UIJRPTT and the university technology transfer promotion mechanism and the interviewees from the industry should be decision makers and senior staffs working and involving in the production and R&D of the industry. Second, some interviewees were selected from snowball sampling. A search of university and industry websites to identify experts in the area of the research was firstly judged by the researcher and when appropriate the interviewees were asked or sometimes identified the additional participating members. An in-depth interview which conducted to gain the data and information in this research meant as a personal interview which the author allowed the interviewees to talk freely on the relative subjects that the author asked and the interviewees could also express the detailed believe and feeling on the related topic of discussion.

Determining the working experiences of the interviewees was essential for ensuring the validity of results. As it was considered that the greater experience of the interview respondents, the greater their understanding of the nature of UIJRPTT, the obstacles and the idea to make the collaboration more effective. The highest frequency of the interviewees' experience was 0-5 years followed by 11-15 years and 6-10 years as shown in Figure 9. However, the interviewees with experience than 10 years account for 51% of all interviewees.

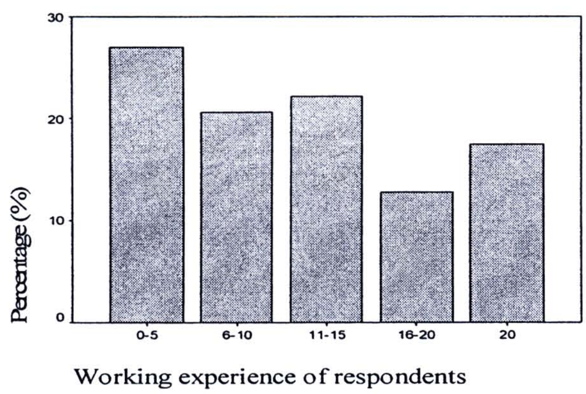

Figure 9 Interviewee's Years of Experiences

The position held by the interviewees in the university and the industry is illustrated in Figure 10. This was necessary to confirm the validity and reliability of the data derived from the respondents. The respondents included lecturers and researchers (49.2%), TTO administrators (23.8%), CEOs or their representatives (6.4%) and senior engineers and scientists (20.6%).

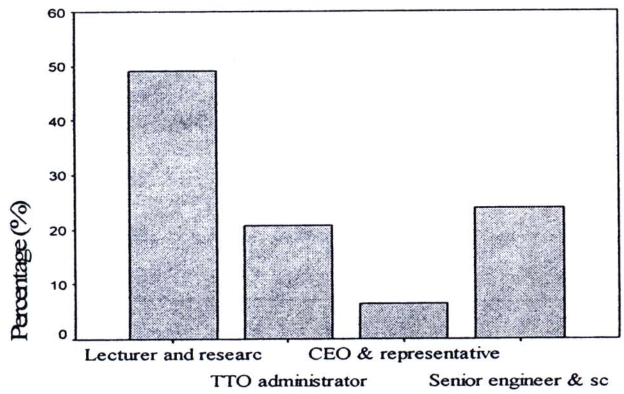

Figure 10 Interviewee Positions

2. Characteristics of Questionnaire Respondents

The questionnaire survey of the study was conducted with a number of respondents. Out of the 150 survey respondents, 96 were university respondents (64%) and 54 were industry respondents (36%). The university respondents included TTO administrative staffs which accounted for the highest frequency of respondents (38.54 %) followed by tenured and non-tenure researchers and PhD students (37.50%) and faculty members and head of the office (23.94%). The faculty members came from all ranks including: lecturers, assistant professor and associate professors. The industry survey respondents were including head of production and R&D departments, engineers, scientists and technical staffs. Groups of engineers accounted for the highest frequency of respondents (57%), followed by head of department (25.92%) and scientists and staffs (16.66%).

The length of working experience of the university respondent's was from less than one year to more than 25 years. Groups of university respondents who had working experience from 4-8 years were the largest group, accounting for 28.12%. 38% of the university respondents involved with the photovoltaic technology with a range of 1 to more than 3 projects while 7% of them had conducted the joint research for photovoltaic technology transfer more than 10 projects. Around 57% of university respondents never had experience in conducing photovoltaic research. This could be because of 38.54% of university respondents were TTO administrative officers. Majority of industry respondents (53%) had working experience of 1-3 years and most of them (70%) never involved in conducting research. Only 25% of the respondents experienced in conducting research related to photovoltaic technology development projects. This was partly because the industry administrative structure that allowed only groups of R&D staffs to conduct the research. Table 12 details a breakdown of the respondents' characteristics in several aspects.

Table 12 Characteristics of University and Industry Questionnaire Respondents

Industry	Number	%	University	Number	%	Overall %
Total (n)	54	100	**Total (n)**	96	100	100
Gender			**Gender**			
Male	43	79.62	Male	35	36.45	52
Female	11	20.37	Female	61	63.55	48
Position			**Position**			
Installation Engineer	3	5.55	Assoc. Prof.	4	4.16	
Design Engineer	2	3.70	Assist. Prof.	5	5.20	
Engineer	26	48.14	Lecturer	12	12.5	
Head of Dept.	14	25.92	Head of Office	2	2.08	
Scientist/technician	9	16.66	Administrator	37	38.54	
			Tenure/non tenured Researcher and PhD. students	36	37.50	
Years of working with company			**Years of working with university**			
Less than 1 year	3	5.55	Less than 1 year	11	11.45	9.33
1-3 years	29	53.70	1-3 years	25	26.04	36
4-8 years	21	38.88	4-8 years	27	28.12	32
8-12 years			8-12 years	7	7.29	4.66
12-15 years			12-15 years	8	8.33	5.33
More than 15 years			More than 15 years	13	13.54	8.66
No information	1	1.85	More than 25 year	5	5.20	4
UIJR necessary	46	85.18	**UIJR necessary**	92	95.83	92
Not necessary	4	7.40	Not necessary	1	1.04	3.33
No response	4	7.40	No response	3	3.125	4.66
Researches involved with PV			**Researches involved with PV**			
never	38	70.37	never	54	56.25	61.33
1-3 projects	7	12.96	1-3 projects	35	36.45	28
More than 3 projects	7	12.96	More than 3 projects	7	7.29	9.33
No response	2	3.70				1.33

3. Characteristics of Case Study Respondents

The number of case study respondents was 30. The majority of the respondents had the length of experience during 1-5 years or 66.6%. 33.33% of the respondents involving the projects at the range of 1-3 projects and 36.66% conducted more than 3 photovoltaic technology related projects. The university respondents included lecturers (16.7%), researchers (13.3%), and TTO administrator (16.7%) whereas the industry respondents included CEOs and manager (13.3%), engineer head (23.3%), and engineer (16.7%). as illustrated in Table 13.

Table 13 Characteristics of University and Industry Case Study Respondents

		Project 1 (n=10)	Project 2 (n=10)	Project 3 (n=10)	Total	Overall %
SERT	Lecturer	2	3		5	16.7
	Researcher	3	1		4	13.3
NU	TTO administrator			5	5	16.7
Industry	CEO, Manager	2	2		4	13.3
	Engineer Head	1	3	3	7	23.3
	Engineer	2	1	2	5	16.7
Experience years	1-5 years	7	5	8	20	66.6
	6-10 years	2	5	2	9	30
	11-15 years	1			1	3.33
Research projects	never		1	6	7	23.33
	1-3 projects	4	5	1	10	33.33
	More than 3 projects	4	4	3	11	36.66
	n.a.	2			2	6.66

Respondent's Perceptions on Necessity and Benefit of the UIJRPTT

More than 90% of the survey respondents stated that the UIJRPTT was essential for the development of photovoltaic technology and beneficial to the university and industry. The university interviewees and questionnaire respondents perceived direct and indirect benefits it would acquire from the U-I joint research. From the research instruments, the respondents stated the benefits from UIJRPTT as followed:

1. Academics may learn from the real world problem and involve in problem solving with the industry;

2. Academics may be able to enhance knowledge in larger, complex and industrial scale production, which could increase the value of the academic knowledge and teaching;

3. University may accomplish their tasks and responsibility as public service provider by applying their knowledge to provide solutions for industry and, in addition, university may gain income from the research results in the forms of patents and licensing;

4. University could raise fund in conducting the research of their interest from both industry and government agencies. Such fund was essential for not only the faculty members in conducting the research work continuously, but also for the students who could utilize the fund as researching salary which could attract them to conduct research;

5. University could share skillful human resource, facilities and equipments that were used in the industry and the university could not purchase;

6. Students were able to learn and accumulate knowledge and experience from real practice which benefit their future job employment.

From an industry point of view, the UIJRPTT was viewed essential in many aspects. Those included:

1. Industry may acquire new information, idea, knowledge, and approaches to increase fundamental understanding on new theories and technologies which may be of the industry interest currently and in the future;

2. Industry professionals may gain in-depth knowledge about photovoltaic technology to help improve the efficiency of photovoltaic cell and module. This would lead to the development of photovoltaic technology;

3. Industry could benefit from funds granted for the U-I joint research by the government. The industry could both directly propose the projects to the government agencies and indirectly propose the projects through the university. The granted project could meet the demand of the industry;

4. From the UIJRPTT, industry could share knowledgeable human resources such as academics, researchers and students, the facilities and equipment in the university laboratory;

5. Industry could benefit from co-learning to develop new products that needed long term data collection and testing.

6. Industry could benefit from the faculty expertise and students through consulting and recruitment and access of experience and personal contacts with the key domestic and oversea knowledge source;

The result of the U-I joint research may lead to commercially valuable products or processes and responded to the market needs once the research questions was set by both university and industry.

Potentials and Proposed Projects under UIJRPTT

Despite the necessity and benefits from UIJRPTT, the current situation of the UIJRPTT was reported not progressive. Only two universities namely SERT of NU, and the KMUTT reported of official UIJRPTT projects with the industry. During 2005-2009, SERT conducted the UIJRPTT with the industry which covered three research types: (1) sponsored research: including grid connected system, solar water sprinkler and foggy system and other applications; (2) consortia: including research and test of solar cell and module equipment; and (3) exchange of research materials: including solar cell applications for agricultural-purposed engines. The joint researches between KMUTT and the industry during 2005-2009, covered the consortia including test of solar cell and modules.

Regardless of the unfavorable situation of the UIJRPTT, it should be further noted that the university and industry interviewees expressed the potentials and research questions that they could offer to their partners to conduct UIJRPTT. This was important because both sides would be able to know the demand and supply of their partners so that the future research potentiality could be established. The university respondents revealed the research topics that they could potentially conduct the U-I joint research and transfer technology to industry. Those included:

1. New generation of solar cell such as dye sensitized, CIGS, and quantum dot solar cell (but the development was still in early stage);

2. Quality and qualification of the photovoltaic cells and modules affecting the degradation and duration to be less than 25 years;

3. Improvement of EVA quality;

4. Solar electricity cogeneration system;

5. BOS and photovoltaic system installment with less cost and higher efficiency;

6. Solar cell applications such as water pumping and usage assessment in Thailand, solar cooling system, solar lighting, solar mix system for drying;

7. Standard testing;

8. Inverter and battery improvement;

9. Other certain specific research areas that were of interest of both;

10. Training and building public awareness.

All firms in the industry viewed the essence of research and development as a key to survive and compete in the market and also revealed the research questions and topics that they viewed important and preferred to conduct the UIJRPTT which included:

1. Improvement of amorphous and silicon based crystalline photovoltaic cell and module efficiency;

2. Improvement of BOS;

3. Improvement of efficiency in solar farm and grid connected system;

4. Design of junction box for plug and play of the module for roof top and large scale;

5. New products and design of photovoltaic module applications that responded to the market and customer needs;

6. Improvement of packaging.

Summary of Part One

Background and characteristics of interview and survey respondents were presented in this part. Most of the respondents had long working experience and involved directly in the area that covered this study. Those included faculty members and researchers in the field of photovoltaic technology, and TTO administrators from eight universities and industry CEOs, senior engineer and head of department and engineers from five major photovoltaic companies. This could confirm the validity and reliability of the data gathered from the interview and the questionnaire survey.

This part also provided the information on the perception of the respondents on the necessity and benefits that both sides could acquire from the UIJRPTT. Interestingly, despite the respondents viewed the necessity of the UIJRPTT, the current situation of the UIJRPTT was not in progress as there were only some official UIJRPTT projects indicated by the university respondents. However, the respondents revealed the specific research areas which were of interest of the university and industry and had potentials for the two sides in working together in the future.

Regarding the unprogressive situation of the UIJRPTT and the potentials and opportunities revealed by the university and the industry, it was the aim of this research to identify and analyze the factors affecting the growth and the effectiveness of the UIJRPTT. The next two parts of this research provided the analysis to answer why there was little number of the UIJRPTT and to develop the effective UIJRPTT model.

PART TWO Why There Is Little Number of U-I Joint Research for Photovoltaic Technology Transfer: Analysis of Factor Affecting the Growth of U-I joint Research for Photovoltaic Technology Transfer

Introduction

As witnessed in the previous part that majority of the respondents agreed that the UIJRPTT was essential and beneficial to both university and industry, but, still, the evidence revealed that the UIJRPTT projects were limited. The aim of this part was to answer the question of why there is little number of the UIJRPTT to understand the situation before the model of the effective UIJRPTT was developed in the next part. The roles, barriers, and determinants of growth of the UIJRPTT related to the hypothesized factors namely university characteristics, industry characteristics and transfer context and organization structure as well as public policy were examined. To do so, the data acquired from the collection from reliable sources, questionnaire survey and interview was presented and analyzed. This part was organized by starting with a presentation of the potential and gaps related to the factors in the context of Thai university and photovoltaic industry and followed by the empirical results from qualitative and qualitative data on barriers and determinants of the UIJRPTT. The analysis of the factors and root causes to answer the research question then was discussed and followed by the part summary.

U-I Promoting Photovoltaic Technology and Linkages: Potentials and Gaps

From literatures, the cultivation and formulation of the collaboration of UIJR required various combinations. Those included favorable national S&T and R&D policies, human capabilities in the university and the industry, institution and systems, perceptions and performances, institutional and organizational management. This section providėd the background and analysis of potentials and gaps in the context of UIJRPTT which were gathered from the data search and the interview used for further discussion at the end of this part.

1. Institutional and Policy Development to Photovoltaic Technology R&D

1.1 S&T Strategy and Policy

The first systematic attempt towards formulating a national policy on science and technology in Thailand was made in 1977 by the National Research Council of Thailand (NRCT) as the major organization responsible for setting up the national R&D policy and strategy. The recent National Research Policy and Strategy (2008-2010) was adopted as the guidance for national S&T development and technological consideration for R&D and allocation of resources in the same direction. In terms of energy research, the strategy prioritized energy research as one out of ten urgent matters. The government envisaged the commitment to support "the research and development related to the development of energy, quality of bio energy and other alternative energy in the area of technology and knowledge, worthiness, efficiency, safety and environmental effect". By that, the government stated that it would provide the budget of more than 1,100 million baht to such research. The National Energy Strategy implemented by the Ministry of Energy also provided wide ranges of guidelines for future development of photovoltaic technology and R&D. The strategy stated that the government planed to "2.4 research and develop the alternative energy and renewable energy and the new pattern of energy" by setting target to "develop and integrate the R&D framework in renewable energy of the organizations concerned to respond to the framework of REDP". The target would be conducted through "support the research that used the high technology such as hydrogen and solar cell and increase the proportion of technology that contributed by the local content".

Despite the great potential in the government's commitment in supporting the renewable energy, however, the agenda frameworks of the two strategies were found too general and no particular emphasis on major issues which could really shape the unified direction to major research theme related the renewable energy such as what technology and R&D on renewable energy should Thailand head for. It was obvious that the NRCT's National Research Policy and Strategies (2008-2010) was set up to be a national research policy and direction for research institutes to follow and to use it as the framework for analyzing research proposals submitted by public organizations for annual budgetary support during 2008-2010 as it stated, rather than being a real national strategic framework that could really answer the question of how the country's R&D related to renewable energy should go and with what technology development. Either, the National Energy Strategy was too general as it could not provide any details on how R&D projects related to photovoltaic applications should be carried out.

Therefore, given the question of whether or not Thailand had R&D strategy for the photovoltaic technology, it could simply answer that Thailand never had the real strategic R&D agenda for the renewable energy technology development which included the photovoltaic technology development. From the observation, the current R&D strategies for renewable energy which included photovoltaic technology still did not mention about major issues including: (1) what photovoltaic R&D and technology work for Thailand, for the photovoltaic industry and related industry; (2) what should be funded to make photovoltaic widely used technology that could generate significant economic return as well as how to put the strategy into practice; (3) how to implement the plan and how to undertake the appropriately-funded and coordinated joint efforts between the governmental organizations, the research funded institute, the university and the industry; (4) how to quantify the R&D needs associated with the research areas and the money should be spent on the needed research for the short, medium and long term; (5) what roles that public and private sectors should play in funding the needed research; and (6) how many of well educated and trained workers at all parts of the value chain, scientists, process engineers, plant managers, system installers, business developers and financial specialists should be supported.

This observation was also relevant to the presentation documents of the NRCT on National RE research system strategic development issues which drafted the innovation and R&D system of renewable energy technology in 2009. The NRCT accepted that there was no public central organization to look into the aspects of identification of cross-cutting issues, reviewing potential areas of coordinated projects, evaluating, monitoring and management of R&D functions in the renewable energy sector. The results of the situation evidenced in the document of Senate Commission on Science, Technology, Information and Communication of Thailand in 2007 which stated that: "Even though Thailand experienced the R&D related to solar cell technology for more than 30 years, still, the country has been facing the problem of good management system and budget to framework the research work to run systematically in the same direction with an aim to utilize and commercialize the research result for the industry and for the strong cooperation among the public organizations, education institutes and private sector to enhance the industry's competitiveness in the domestic and global markets."

1.2 Roles of Public Sector in Photovoltaic R&D and Technology Transfer

Currently, various governmental agencies played important roles in supporting the human resources and photovoltaic technology development in many aspects. The governmental organizations such as the Ministry of Science and Technology and Ministry of Energy undertook the R&D projects and supported funds for photovoltaic technology development. The Ministry of Education in the mean time had stimulated the university in more cooperation with the industry under the scheme of incubation center. The Ministry of Industry also supported the tax and non tax incentives for photovoltaic R&D, export and technology transfer through consulting services. Table 14 provides data on photovoltaic projects under the governmental agencies.

Table 14 Photovoltaic Projects under Ministries and State Enterprises

Ministry	Project	Major Research Theme
Ministry of Science and Technology	**Applied research and technology patents**	
- NSTDA	Amorphous Silicon Thin film Technology Development and Pilot line	-Development of amorphous silicon thin film technology (knowledge-know how and machinery). Current efficiency 10%, laboratory efficiency: 15.7% -Installation -Applications such as solar auto, solar radio, solar for water boiling
	Crystalline Silicon Solar Cell	-Silicon extraction from rice husks
	Prototype cell Development	-structure of solar cell development
	Fundamental study on new solar cell such as dye sensitized	
Ministry of Energy	**Utilities, implementation and demonstration**	
-DEDE	-PV demonstration projects	
-EPPO	-Study on policies and development strategy for renewable energy sources	
	-1 Amphur 1 Renewable energy project	-support funds for research
-DEDE/EPPO	Testing and standardization of PV system	-Center for Development on Testing and Standardization of PV system
Ministry of Industry	**Tax and non-tax Incentive**	
	Alternative Energy Promotion (via BOI)	-Tax and non-tax incentives for solar cell manufacturing -Support for energy service consulting
Ministry of Education	**University and Faculty Budget** **Center of Excellence and Business Incubation**	
EGAT	**Utilities, Implementation and Demonstration**	
	PV power generation project	-Large-scale grid-connected demonstration power station -Co-generation -Solar home (roof top) -Solar application
Past PV Industry Development Projects supported by the government		
DEDE	Study on Investment of Solar Cell Industry in Thailand	

As a high technology, the R&D for photovoltaic technology development and technology transfer needed a large amount of money. Public expenditure was considered a major fund for increasing technological knowledge and innovation. Most universities photovoltaic R&D were funded by the mentioned governmental organizations. According to the NRCT, the total financial grants for renewable energy projects received by the universities, during fiscal year 2004-2008 was around 2,163 million baht by which the projects on solar cell received around 475 million baht or 22%. From those number, NSTDA provided more than 300 million baht, followed by EGAT, more than 110 million baht, Ministry of Energy, more than 40 million baht and NRCT around 10 million baht. Most projects related to solar cell development, process development, material and utilizations. It was also observed that NSTDA and EGAT performed their own R&D projects with most of the budget because the two organizations had their own research institute and R&D units whereas the rest of the grants provided to private sector and KMUTT to perform the research.

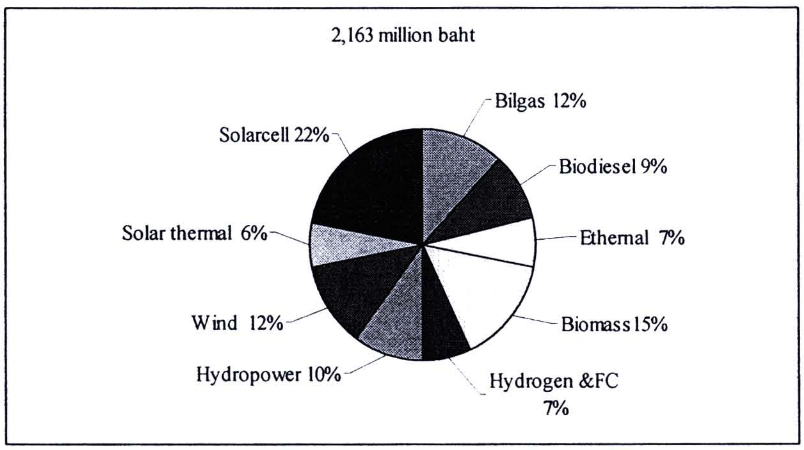

Figure 11 Renewable Energy R&DD Expenditure during 2004-2008

Table 15 Overall Funds and Funds for Photovoltaic Technology from Major Government Organizations

Unit: million baht

Organization	Type of Fund	2009	2008	2007	2006	2005
NSTDA	Overall research fund	1,696	1,425	1,460	830	1,828
NRCT	Research fund for urgent matter in the National Research Strategy/ integrated budgeting	305	213	-	560	500
	General Fund (for sustainability, for committee, payment for consulting)	41	332	300	65	268
	General Fund for innovation and industry and service sectors	180	-	250	138	-
	S&T Overall Fund Total	**2,222**	**1,970**	**2,010**	**1,593**	**2,596**
DEDE	Maintenance for solar cell system	8.1	7.6	-	-	-
	Installation of solar cell system in royal projects, school and remote area	27	87.4	-	76.34	66.13
	Others such as: Study of solar water pumping prototype Assessment of solar cell system Study of climate and solar light for renewable energy work in Thailand	-	3	4	-	7
	DEDE Fund Total	**35.1**	**98**	**4**	**76.34**	**73.13**

Source: Bureau of the Budget

Moreover, without the national R&D strategy on photovoltaic technology development, as a result, it could be viewed that many public organizations concerned had to convey and allocate budget to wide-ranging projects and supports on the basis of their organization tasks, responsibility and their interest without synchronized goal. The organizations under the administration of the Ministry of Science and Technology conducted and provided funds for applied research and technology patents related to the photovoltaic cell technology, organizations under the administration of the Ministry of Energy provided funds for utilities, implementation and demonstration projects, organizations under the Ministry of Education and Organization related to university affairs provided funds through university yearly budget and EGAT provided funds for PV power generation project. According to the interview, the absence of a well planned research management system of the organizations concerned and uncoordinated and fragmented support of the research activities was noted by the academic as a limitation affecting the long term development of the photovoltaic technology and scattered of fund allocation.

It was also worth noted that, from the CES report 2008 of the Clean Energy System at KMUTT, during 1986-2008, 73 projects were granted by the governmental funding agencies namely DEDE, NEPO, EPPO, TRF, NECTEC, MTEC, etc. However, none of the projects indicated that there was cooperation with the industry related to renewable energy sector. It could be said that under the support of governmental funding agencies, there was high possibility that the research findings or newly developed technologies did not reach beyond the premise and requirement of the research organizations. If the university did not have the cooperation with the industry, there would have the possibility that the research projects and research results were not in line with the industry need which as a result the industry would not take any serious initiatives to enhance the cooperation with the university in R&D activities.

2. University Photovoltaic Technology Development

2.1 Strategy

All sample universities normally stated their commitments to support research activities in five main areas: (1) research for building up and enhancing knowledge-base or academic excellence; (2) research for solving the problems communities or societies; (3) research for enhancing teaching and students capability building; (4) research for industry and nation's competitiveness; and (5) research for building up innovation in products and services. Many universities also aimed to be the research university, setting up objectives to enable economic progress and sustainable development by applying new ideas and technologies. Education and research therefore were the primary goals of the Thai surveyed universities.

Considering the aim of the university to be "research based university" by valuing the importance of research and supports, it was obviously noticed that most universities publicized the data broadly about university key research area in photovoltaic technology and specific goal of university research. However, none of university publicized data about: (1) proportion of basic and applied research the university would conduct to develop technology related to photovoltaic and applications; (2) human resources management plan such as how many of lecturers and scientists should be increased, and how many trained scientists, process engineers, and plant managers should be produced from the universities; and (3) long-term plan and cooperation among universities, governmental research institutes and between university and industry. As a result, as most interview participants revealed, the research works in the university faculty were mostly initiated and led by the interest of the researcher. It could also be more seriously concerned, when the supported R&D in the university was isolated from the photovoltaic industry, and the research achievement hardly supported the industry commercialization. Moreover, due to lack of clear policy in budgeting and human resource arrangement in focused key area, the university might suffer from shortage of human resources in the specific area.

2.2 Level of Knowledge and Technology Capabilities

Pattern of research, number of university researchers related to photovoltaic technology in the surveyed universities as well as number of patents (accumulated in three years) were collected to indicate the university capabilities and potentials as reliable knowledge and technology source for photovoltaic technology transfer. From the search results, the findings were as followed:

2.2.1 eight university faculties out of fourteen surveyed faculties/ laboratories/research units, mostly Faculty of Science, set their program objectives in developing thin film R&D and long term innovative research. Those R&D focused on next generation of thin film solar cell, which was believed that having the potential to reduce the cost of solar electricity, such as dye-sensitized solar cell, quantum dot solar cell and nano solar cell. The faculties of engineering and material science from the universities namely KMUTT and KMITL and SERT of NU emphasized their research to improve reliability of the systems and system components, to increase and assuring the performance of fielded system and remove barriers to the use of the technology. The point was that the basic research conducted by the university and their results were in the early stage and it was a challenge for the university whether it could lead to application so quickly that could convince the industry to invest in such research. It was also a challenge to those universities who conduct the research on system development and reliability to open up the research and development results for the meaningful industry participation. The open up should also be soon enough to meet the industry's expectation;

2.2.2 number of researchers conducting photovoltaic technology were not high compared to those of overall faculty they were working in. SERT was an exceptional case due to the fact that the school was set up to offer course and to conduct the renewable energy particularly solar energy in specific;

2.2.3 no patent registration of key researchers was found.

Table 16 Research in Sample University and Personnel Data

University and Faculty	Research	Data
Research Center in Thin Film Physics		
Semiconductor Physics Research Laboratory (SPRL) Department of Physics, Faculty of Science, Chulalongkorn University	-Semiconductor physics for thin film solar cell from Copper Indium Gallium di-Selenide ($CuIn_{1-x}Ga_xSe_2$) or CIGS -Transparent Conducting Oxide Thin Films	Lab faculty member: 4 Overall faculty member: 423 Patents: none Research assistants: none
Integrated Nanotechnology Research Center Department of Physics, Faculty of Science, Khon Kane University	-Multiple layer thin film developed from dye – sensitized solar cell (DSSC) and diamond-like carbon (DLC)	Lab faculty member: 21 (2 related to PV) Overall faculty member: 221 Patents: none Research assistants: 1
Thin Films Technology Research Laboratory Department of Physics, Faculty of Science, KMUTT	Coating of Indium Tin Oxide (ITO) thin film Coating of dielectric-Ag-dielectric Coating of TiO_2 thin film	Lab faculty member: 7 Overall faculty member: 107 Patents of key researchers: none Research assistants: none
Dye Sensitized Solar Cell		
Department of Chemistry Faculty of Science, Silpakorn University	Dye-sensitized solar cell (DSSC)	Lab faculty member: 3 Overall faculty member: 187 Patents of key researchers: none Research assistants: none
Department of Chemistry Faculty of Science, Kasetsart University	Dye-sensitized solar cell (DSSC) and some parts of battery improvement	Lab faculty member: 4 Overall faculty member: 296 Patents of key researchers: none Research assistants: none

Table 16 (cont.)

University and Faculty	Research	Data
Center for Alternative Energy (CAE), Department of Chemistry, Faculty of Science, Mahidol University	Dye-sensitized solar cell (DSSC)	Lab faculty member: 11 Overall faculty member: 279 Patents of key researchers: none Research assistants: none
Quantum Dot Solar Cell		
Semiconductor Device Research Laboratory (SDRL), Faculty of Engineer, Chulalongkorn University	Quantum dot solar cell Crystalline silicon solar cells Physics and application of amorphous silicon PV system design and application	Lab faculty member: 6 Overall faculty member: 320 Patents of key researchers: none Research assistants: 3
Applied Research and Development		
Renewable Energy Applications Laboratory (REAL) Department of Electrical Engineering, KMITL	Testing, consulting, training and designing Photovoltaic applications Energy system Micro-grid	Lab faculty member: 5 Overall faculty member: 313 Patents of key researchers: none Research assistants: none
School of Energy, Environment and Material KMUTT	Photovoltaic system and applications Balance of System (BOS) development	Lab faculty member: 3 (some names repeating with CES group) Overall faculty member: 41 Patents of key researchers: none Research assistants: none
Clean Energy Systems (CES) Testing Center KMUTT	Photovoltaic system (static and dynamic solar cells and module characterization, BOS development, PV pumping and battery charging, PV stand-alone and hybrid systems, PV grid interactive systems, designing, installation and modeling the system); Electrochemical energy storage; Test rig system; Solar cell testing center	Lab personnel: 36 Patents of key researchers: none
Department of Electrical Engineering KMUTT	Solar cell application and electricity	Lab faculty member: 6 (some names repeating with CES group) Overall faculty member: 218 Patents of key researchers: none

Table 16 (cont.)

University and Faculty	Research	Data
Laboratory of Atmospheric Physics and Solar Energy Research Laboratory, Department of Physics, Silpakorn University	Light lux meter for solar cell efficiency test Application of solar cell electricity for blower in solar thermal system	Lab faculty member: 2 Overall faculty member: 197 Patents of key researchers: none Research assistants: 3
School of Renewable Energy Naresuan University	Photovoltaic applications Testing Demonstration	Lab faculty member: 9 Overall faculty member: 9 Patents of key researchers: none Research assistants: 7
Faculty of Science Naresuan University	Photovoltaic applications	Lab faculty member: 6 Overall faculty member: 138 Patents of key researchers: none

2.3 Incentive Program

One of the university strength was that they were equipped with funds and incentives for academicians, researchers and students. All surveyed universities implemented incentives for researchers and students to motivate them to conduct research in the various forms of funding and incentive programs such as grants to support publications and best research and grants for center of excellence and for researches relevant to the country and university policies. Students could also be funded through the projects that their advisors received grants and when they were accepted to be the students under the royal golden jubilee PhD program which supported by the government and mainly focused on research study. Moreover, the overall university funding incentives were mainly administered under the university administrative and research committee and under the government funding organization including: NSTDA, TRF, NRCT and MUA.

NSTDA set renewable energy as one out of eight clusters in its Strategic Planning Alliance (SPA) and stated that it would consider granting fund to the clusters with high priority. TRF prioritized renewable energy as one of the national strategic topics to be granted. NRCT set the renewable energy as one of eleven topics that it should provide research funds for universities. MUA provided funds for academic research and training as well as for U-I joint research for commercial purposes with broad objectives. The good things about the university funding incentives were: (1) there were more varieties of funds and incentives that motivated the faculty to conduct more research. New researchers were motivated to conduct more researches. Famous researchers could gather in groups and conduct research; (2) some of the university funds and governmental organization funds had no deadlines to apply, and could be accepted and reviewed year round. The faculty did not need to submit proposal on yearly basis; (3) some university and governmental funds were awarded as seed funds to develop a partnership between the university and the industry. This showed the government and university attempt to bring the university and industry closer; and (4) the renewable energy related research which included the photovoltaic technology was in the governmental research agenda and funds support.

However, there were concerns over the funding program and incentives by university administrators and academics in photovoltaic technology. Those included: (1) the economic crisis would affected to the size of funds. As participants indicated that the university was allocated lower budget during 2008-2009 which was the results of global economic crisis; (2) as there was increasing costs of conducting scientific research and budget restrictions, they have led the university to seek new sources of funds which was finally the burden of faculty members in both seeking more funds, conducting researches and teaching at the same time. Moreover, it could create too much competition and not encourage the researcher to respond to the research agendas that they were interested in; (3) the university funds was considered scarcely and too little that the faculty member could not conduct research as it should be while the tools and equipments for research were expensive; (4) the overemphasizing of the peer review on a research publication record in evaluation of granting some governmental funds process might create disincentives for the faculty and researchers to pursue new and possibly risky (to fail) research.

Another reward that pushed the researchers to work on research was the academic promotion. Key performance indicator (KPI) of the university's academic quality assurance also played an important role not only in salary increase but also in researcher academic promotion. Normally, priority of the KPI devoted to the performance of the faculty in areas of: (1) teaching and learning, (2) research and creative activity, (3) public services and (4) culture of integrity. The value accumulated from each faculty members was collected to evaluate performance of the faculty. The point was that faculty members who were eligible to the university regulations and on basis of personal merit and could contribute to better performance of the faculty were normally be supported by the faculty when they wished to apply for promotion to Assistant Professor, Associate Professor and Professor. The personal merit and qualification of the faculty members to acquire academic promotion were based on years of continual service, teaching and teaching support, research works through academic journal publication and some specific research works such as patents as well as research publication or books. However, it was obvious that even though the works for public service and for industry were indicated in the KPI of the quality assurance evaluation, but not obvious as the criteria for the academic promotion. This could have led to the perception among the faculty members that it was better to conduct the research works for academic paper publishing for their career path development while still having academic freedom. This perception could lead to their insensitivity to the industrial needs.

Table 17 University Grants and Government Funds

Grants	Organization
Major University Incentives and Rewards	**Universities**
Grants to support publication of research results in international and domestic journals, international and domestic proceedings, patents and innovation	All
Awards for best research Academic ranking promotion	All
Research program grants that relevant to the country and university strategy	All
Grants for research (not more than 200,000 -500,000 baht)	All
Grants for development of new faculty staffs	All
Post Doc Research Grants	All
Grant for center of excellence and research unit	All

Table 17 (cont.)

Grants	Organization
Government Funds	**Funding Agencies**
Research grants for research relevant to development strategy of the government	NRCT
Research and Development Fund (within 3 years)	Thailand Research Fund (TRF)
Academic Research Fund - Fund for research groups (Senior researcher set new research team) - Fund for new knowledge for development (researcher should have at least 3 papers published in International Journal during the past 5 years) - Fund for researcher - Fund for increasing research capability (coordination between TRF and Office of the Higher Education Commission) (not more than 400,000 baht per year/ 3 years) - Fund for new researcher (not more than 240,000 baht per year/ 2 years) - Funds for developing the research works of new researchers (coordination between TRF and Office of the Higher Education Commission) - Fund for Post Doc (coordination between TRF and Canadian National Research Council) - Fund for basic research with specific direction - The royal golden jubilee PhD program	Thailand Research Fund (TRF)
Funds for Research and Development and Engineering (Through NECTEC) (in the field of electronics, computer, materials, polymer, design and production, nanotechnology, renewable energy, solar energy)	NSTDA
Fund for joint research between government and private sector for commercial purposes and academic research fund	Office of the Higher Education Commission (MUA)
Fund for setting up business incubator in university	MUA
Fund for renewable energy demonstration and special project initiated by DEDE	Ministry of Energy (DEDE, EPPO)

2.4 Infrastructure for Photovoltaic Technology Development

The development of a solid research program for photovoltaic technology development depended on access to sophisticated instruments and equipments. The universities and government organizations namely MUA supported the thin film partnership among four university laboratories (CU, KKU, CMU, KMITL) namely "Research Center in Thin Film Physics". The center was headed by the Faculty of Science, Physics Department, CU. The focus of R&D in the research center was on promising thin film candidates, such as dye-sensitized, copper indium gallium di-selenide (CIGS) and thin film coating. The research center was set up with the instruments, and equipments. For example, the Semiconductor Physics Research

Laboratory (SPRL) had Multi-source Evaporator System and Molecular Beam Epitaxy (MBE) System. The Applied Physics Research Laboratory (APRL) at CMU had the equipment for the sputtering and coating TiO_2 which comprised of System controller and Chamber Unit. Other laboratories and faculties that were not in the research group also had their own equipments and facilities that were essential for the research activities related to the photovoltaic technology development.

Table 18 Equipment and Facilities in University Faculty and Laboratory

Faculty and Laboratory	Equipment and Facilities
SPRL at CU	Multi-source Evaporator System and Molecular Beam Epitaxy (MBE) System.
APRL at CMU	Equipment for the sputtering and coating TiO_2 which comprised of (System controller and Chamber Unit
SDRL at CU	Gas purifiers, four-point probes, ultrasonic cleaners, laser systems, liquid phase epitaxial furnace (LPE), for GaAs, molecular beam epitaxy (MBE), for quantum well (QW) devices, and other in-house constructed equipments a molecular beam epitaxial (MBE) system
Clean Energy System Group at KMUTT	Solar simulator, power supply, electronic load, power analysis, solar cell test equipment, solar cell system test equipment
SERT at NU	Solar data recorder, Pyranometer, Compotor Termococple Type K, Vol-meter, Am-meter
REAL at KMITL	Power and harmonic analyzer PZ4000, Power meter FLUKE41, Power Quality Meter FLUKE43, Digital storage oscilloscopes, MATLAB/SIMULINK, solar cell tester, Machine Test rig, Electronic ballast test set
Physic Department at SPU	Solar radiation mapping from satellite data

However, from site visits and interview data, the academicians and researchers revealed that the university was facing of existing deficiencies in infrastructure and equipment. Most universities faced the deficiency of new equipments due to the constraint in budget and funding scheme. To borrow and use the equipment and facilities of the research units in different universities was hard due to the loosing linkage and cooperation and difficult process. Moreover, for the industry, it complained that the charge fee to use the equipment and facilities was quite high and there was a deficiency of university's information on facilities and equipment.

3. Industry Technology Development

3.1 Technology Acquisition and Development

Thai photovoltaic industry commonly acquired technology rather than developed through turn-key plants, purchasing new technology embodied with designed and specification, used machinery and know-how from abroad (Detailed was discussed in Chapter II). The source of capital equipment and product technology were located in industrialized countries such as Germany and Japan. Moreover, in order to enhance the productivity and efficiency of the products, the industry had potentials in spending their efforts in engineering activities and R&D. Those included engineering-based improvement in process technology, improvement in product specification and designs, technology search and research close to the international competitors and search for new material and formula for developing the efficiency of their products. However, for design and reverse engineering, it was rarely done in the industry. A technological shallow path of the industry technology development was partly due to limited investment.

3.2 Firm-based Performance and Technical Knowledge

Data on capabilities in producing cells and modules and number of engineers were collected to indicate the industry performance and technical knowledge. One of the indicators for the potential performance and capabilities of the industry was the rate of efficiency. Data revealed that there was no big difference of the efficiency rate between the products of the Thai manufacturers and others leading companies. The Thai multi-crystalline solar module reached the efficiency of more than 12%, where as foreign leading firm produced the average efficiency of around 12-17%. The efficiency rate of Thai amorphous solar module was around 7%, whereas foreign leading firm produced the average efficiency of around 7-8%. Moreover, many companies gained international certificates such as IEC 61215 and IEC 61646 for products standard from TüV and management standards such as ISO 9001 and ISO 14001 as well as TIS which was the Thai standard equivalent to the IEC standard.

Such success story of the product and technology development did not come only from the fact that the Thai manufacturers imported the machinery and know-how from abroad. But it was considered mostly because of the in-house R&D,

QA and QC as well as capable engineers in the firms. Accepted by the companies, the in-house R&D, QA, QC units had taken part in developing a number of applicable product and process technologies for the industry which benefited the commercialization and development of cell and module efficiency. Considering the number of the engineers in the industry, the proportion of the engineer of the industry was at the average of 8-30% of overall employees. Four companies stated that they had capable engineers in their in house R&D, QC and QA units.

Table 19 Technological Performance of Thai Photovoltaic Industry

Company	Type of solar cells	Modules	% of efficiency	Certificates
Solartron	Silicon solar cell module	SP 125 (1502 x 662 mm), 12 kg SP 80 (1204 x 553 mm), 9.5 kg SP 50 (1291 x 329 mm), 5 kg SP 15 (436 x 369mm), 2 kg SP 10 (337 x 285mm), 12 kg	12.8 12.4 12.3 11.1 11.3	ISO 9001:2000 ISO 14001:2004 TIS 18001:1999 SA 8000 TUV (IEC 61215) TIS. 1843-2542 CE Mark (EMC-Directive 2004/108/EC) RoHS
Bangkok Solar	Amorphous silicon module	BS40 (635x1245 mm), 13.5 kg	6-7	ISO 9001:2000, 2008 TUV (IEC 61646) TIS 2210 CE Mark (EMC-Directive 2004/108/EC) RoHS
Ekarat	Silicon solar cell and module	Model 120/125 Watts ES20636120 (1482 x 662 x 37 mm), 12 kg (1488 x 975 x 37 mm.), 17 kg	>12 >12	ISO 9001:2000, 2008 ISO 14001:2004 TIS. 1843-2542 TUV (IEC 61215) Quality mark
Sharp	Silicon Module	NU-S5E3E (185 watt) (single crystalline) NU-SOE3E (180 watt) NE-080T1J (80 watt) ND-130T1J (130 watt) (multi crystalline) NA-90, 85, 80 (amorphous + micro crystalline)	14.12 13.7 12.1 12.1 8.5	IEC 61215 IEC 61646
Thai Agency Engineerin g (SPOT)	Silicon module	S-50 (976 x 451 mm), 5.7 kg S-75-80 (1171 x 536 mm),8.5 kg S-120 (1177x792 mm), 13.6 kg S-150 (1636x827 mm),16.4 kg	<12	ISO 9001:2000

Table 20 Employees and Engineers and Data on In-house Research Activities

Company	Employees	Number of Engineer	In house R&D,	QA,QC
Solartron	120	12	NO	YES
Bangkok Solar	461	41	YES	YES
Ekarat	144	44	YES	YES
Sharp	27	n.a.	NO	YES
Thai Agency Engineering	50	12	NO	YES

3.3 Business Nature and Technology Development

The data from interviews and reliable documents revealed that business nature of the firms in the industry was including: (1) cells and module manufacturing, distributing and exporting. Major market was domestic, European and Southeast Asian countries; (2) bidding for solar cell installation projects in domestic and abroad; (3) selling their products to governmental organizations and household customers. The products included roof top system, stand alone system, solar cell applications and installation projects (mostly to public sector) such as water pumping, electricity facility and system, solar cell traffic light and solar powered LED display; solar hybrid system, solar grid and off grid connected solar system; and (4) solar farming.

From the annual reports of the companies namely Solartron and Ekarat stated that the competitiveness of the manufacturing companies could be done through: (1) expanding of market share through expansion of operation which could access to cost reduction via economy of scale. Production line for wafer-based crystalline could be easily purchased and set up in a short period of time and could be operated by maximum two years; (2) building up production and service capabilities by developing technology for cell and module efficiency and developing products that responded to the customer's need and cost leadership and (3) overcoming business risks such as financial risks (fluctuation of exchange rate), business risks (domestic and targeted global market demand, importer's renewable policy, the national government support policy), and production risk (raw material such as silicon shortage and fluctuation in price in forward market).

Table 21 Income and Profit of Photovoltaic Firms

Company	2006 (mil. baht)		2007 (mil. baht)		2008 (mil. baht)	
	Income	Profit	Income	Profit	Income	Profit
Solartron	1,111	51.13	115.25	-91	435.96	2.20
Bangkok Solar	n.a	n.a.	n.a.	n.a.	n.a.	n.a.
Thai Agency Engineering	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Ekarat Solar	n.a.	n.a.	48.89	-72	419.75	-190
Sharp	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

It was obvious that profit and lost ratio of the company could tell the tendency and the ability of the company to invest in the research. If the firm did not have enough income and gain; if the government policies did not support the growing market and allow more opportunities for the industry; and if the global market did not expand, it could assume that the firm should not be motivated to invest in researching. From the annual reports, the two companies absorbed sometimes profit and losses. One company reported their loss due to the investment in manufacturing operation and purchase of the new production. From the financial situation of the companies, it could be assumed that the tendency of the company to support the R&D may be low due to the weak performance of the income and lost and the trend that the companies preferred to pay for know-how and technology abroad was higher than spending money in R&D by itself.

The government policies and the growth of the solar cell market could indicate the tendency of the Thai photovoltaic industry in implementing its business strategy which also could link to the tendency in conducting the research. From data collection, it was found that the business strategies of the Thai photovoltaic firms linked with the growth of the global solar cell market and the Thai government policies. Last couple of years, the photovoltaic market grew yearly around 30% which meant the industry had the market demand, the Thai companies had expanded their production capacities, and exported more to foreign countries. The Thai government policies that supported domestic market development had led the companies to diversify many application products for domestic use. Those strategies linked also to the pattern of research and U-I collaboration. It could be found that the U-I joint research mostly involved with research in applications such as water pumping and street lighting, and test of the efficiency of cells and module for export market and for government certification because selling the modules and system to the government projects. For the time being, it could be forecasted that the demand for research related to solar farm should be increasing. From the interview data, a company revealed that it was interested in solar farm technology and it need the research or university's knowledge about how to develop the solar farm system with more efficiency, reduce losses and the academic research on the environmental effect from electricity generation to confirm the reliability and advantage of the solar cell electricity generation that was beneficial to the company and photovoltaic industry.

4. Promotion of Linkages

4.1 Collaboration and Negotiation Process

Most collaboration was created by acquaintance, interpersonal relationship and personal contacts between the researchers and industry staffs. They discussed informally about their interests and research capabilities. After agreed by the two sides, the formal collaboration and negotiation process started when the industry and the university researchers discussed the specifics detail of the research projects and develop a written research plan or statement of the project work. The research plan normally included the goal, project process, specific results, and completion of milestones and detailed research to be performed. Moreover, the level of funding for the project would be further discussed. After receiving guidance from the faculty and university organization such as TTO, the research plan would be approved and the researcher could start conducting the research. In case that the project was sponsored by the company, the TTO would arrange the agreement or contract. If the project needed funding support from the government fund, the researchers had to send proposal to the funding agencies which mostly were open to receive proposal year on year basis. When the project was approved, the agreement and contract that complied with the university research policies on publication, intellectual property, ownership/right to use research data would be signed. Then the project could be started.

4.2 Technical and Information Service

The universities namely SERT, KMUTT and KMITL offered technical services such as testing and data collection which related to photovoltaic technology for private company. For example, from part one, there were also some universities offered technical service to the industry by testing to prove the efficiency of the industry's products.

In terms of information service, most universities publicized the research results in university journals, newsletter, radio, television, data research base, academic showcase and websites. However, it was viewed that the distribution of information and research results was not expanded to wider community and industry. For example, the strongest information service of today included the internet website because it was the easiest ways to access into university research base. However, from the observation in the research unit websites of the sample universities, it was found that majority of the websites provided least detail of: (1) the research projects and research specific plan in year on year basis, (2) research results and how the knowledge could be utilized, (3) paper or result abstracts of each researcher, (4) cooperation works which have been and needed to be done with industries and other organizations, (5) success story of the research works. This information was important for industry and other academicians to update the knowledge and research in university and use as the information to cultivate further cooperation with the university in the future.

4.3 Communication Channels

All sample universities tried to develop formal linkages to contact with the industry. Several universities such as SERT, KMUTT, CU and KU supported the multi-university technology transfer conference, seminar and show cases and publicized the data base on technology services through publications and websites.

Classroom linkage was another important source of university and industry to communicate to each other due to the fact that the industry supported their personnel to take refresher course or enhance level of education and to create networking. CU, SERT, KMITL and KMUTT had students in Master degree and in PhD who were currently working in the field of photovoltaic industry and supporting industries. Classroom interactions resulted in interpersonal networking not only between students and teachers but also among students who worked in the industry and governmental agencies that supported funding program.

From the government perspectives, the movement to facilitate the communications and cooperative R&D with the university and industries had been emphasized. The university researchers in photovoltaic technology and the industry were occasionally invited by several government organizations such as the Ministry of Energy and NSTDA to the meetings to engage in the public policies and funding projects.

4.4 Confidentiality and Intellectual Property Management

Confidentiality and intellectual property management was important and the issue was stated in every research collaboration contract agreement. The key points that both university and industry were concerned were ownership of inventions and intellectual property derived from research results, instruments, allocation of benefits and the extent of publication related to research results. Normally, the university would state in the agreement that it would retain ownerships of any research data developed by university during the term of the project. However, if the company funded the research, in contract, it would be given the right to use the technical reports provided to the company. The company was allowed to review, identify, and mark "confidential" code on any confidential information before the journal publications or abstracts of research results were published.

However, in practice, the problems related to the IP management could occur such as (1) both university and industry did not know to what extent each side should gain benefits especially when there was the uneven proportion of the form of in-kind and funding; and (2) university academicians and industry staffs lacked of understanding in intellectual property law and regulation which lead to the unfair contract. This happened with the case the university researcher and industry member drafted and agreed with the contract before sending to the university intellectual property office.

For the university side, most of the sample universities implemented regulations on management and recovery allocation from IP and research results to stimulate external research funding and to provide incentives for researchers, departments, schools and research units to conduct research. Different recovery allocation from intellectual property and benefit of research were stated in the various university regulations. It could be noticed that the recovery, in the aggregate, to the investigators on the research project was quite high, at the range of 50-80%.

In sum, this section provided the background of the U-I promoting photovoltaic technology and linkages and evaluated the potentials and gap. The key findings were:

1. The Thai government recognized the need for formulation and the commitment to support and promote the research and development related to the renewable energy and photovoltaic technology. However, there was no legitimacy from the government to the photovoltaic technology and there was an absence of an organized and well planned research management system of the organizations concerned particularly the uncoordinated and fragmented support of the research activities and funding.

2. The university played important roles in promoting the U-I joint research toward the goal to be the research university. However, the university still lack of strategic plan on the development of photovoltaic technology in particular which affected to identification of number of scientists, students, equipments that should be supported and built up. Academics also faced scattered funding allocation and concerned over smaller university funds affected by the economic crisis.

3. The university was potentially capable in being the knowledge center for basic, applied and development research. However, some obstacles for the UIJRPTT remained such as (1) number of key researchers conducting photovoltaic technology was reported not high; (2) deficiency in infrastructure and equipment; and (3) early stage of the basic research and applied research that could not reach to commercialization.

4. Industry had potential capabilities in adopting and adapting the technology on its own. This reflected in the capabilities of the industry in producing quality products, certificates and number of engineers. However, level of profit and loss of the company, the growth of global market and domestic government support might affect the strategy for R&D investment of the industry.

5. Linkages between university and industry through transfer context and organization structure such as increasing communication channels, improving confidentiality and IP management rules and regulation and facilitating the process of negotiation were promoted by the university TTO and organization concerned. This indicated that the university organizations concerned had recognized the importance of the factors in formulation and supporting of the UIJRPTT.

The next section presented evidence on barriers and factors affecting the growth and fostering of the U-I joint research for photovoltaic technology transfer based on the qualitative and quantitative data sources.

Barriers of UIJRPTT

The background and potential and gaps in the previous section shed light on the picture of the photovoltaic technology development of university and industry and promotion of linkages between them. Identification of the variables that significantly affected the growth of the formulation of the UIJRPTT was required to achieve the objective of this research. This section presented the research results from the quantitative data to answer the question of why there was little number of the UIJRPTT and to identify and analyze factors impeding the formulation and growth of the UIJRPTT. The questionnaire survey aimed to quantify the rating of the respondents on statements related to hypothesized factors and variables affecting growth which they agreed as barriers of the UIJRPTT.

The survey respondents (n=150) were asked specifically to state their opinions on variables in the three hypothesized factors as barriers (Column A) and their potential impacts (Column B) to the growth of the UIJRPTT. Those hypothesized factors and variables included: characteristics of university (C1), characteristics of industry (C2), transfer context and organizational structure (C3); and 14 observed variables. All variables were measured by five-point Likert scale rating. The variables were selected as influential when their mean value, computed by equally weighting the mean values of all variables in each mentioned factor, were equal or higher than 3 which indicating the potential barriers of the variables.

As for column A, the attitude data was collected, through a Likert scale instrument with responses that ranged from strongly agree (five points) to strongly disagree (one point). The overall respondents rated agreed that all factors as barriers to the growth of the UIJRPPT. The characteristics of university (C1), characteristics of industry (C2), transfer context and organizational structure (C3); were rated with the mean value higher than 3. This revealed that overall respondents perceived that majority of variables were potential barriers to the UIJRPTT. All variables except university reliable of knowledge and technology source (C1.1), industry lack of motivation (C2.2) and attitude of the industry (C2.3) were rated with the mean value lower than 3. Eleven variables that rated with the average mean value over 3.00 were considered as barriers which included:

1. Industry's management barrier (C2.4) was rated with the mean value of 3.67. The majority of respondents (48%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT.

2. Lack of communication channels (C3.2) was with the mean value of 3.66 The majority of respondents (47.3%) agreed (mode =4) this factor as barriers to the growth of the UIJRPTT.

3. University's difficulty with negotiating and managing collaboration (C1.3) was rated with the mean value of 3.55. The majority of respondents (46%) agreed (mode =4) this factor as barriers to the growth of the UIJRPTT.

4. Inappropriate confidentiality and intellectual property management (C3.6) was rated with the mean value of 3.43. The majority of respondents (37%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT.

5. Cultural difference (C3.4) was rated with the mean value of 3.41. The majority of respondents (43%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT.

6. Inadequate infrastructure (C3.5) was rated with the mean value of 3.41. The majority of respondents (46.7%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT.

7. University's potential impact on faculty and students to work with industry (C1.4) was rated with the mean value of 3.32. The majority of respondents (43.3%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT.

8. University lack of motivation was rated with the mean value (C1.2) of 3.20. The majority of respondents (38%) agreed (mode =4) this factor as barriers to the growth of the UIJRPTT.

9. Inadequate technical and information service (C3.1) was rated with the mean value of 3.14. The majority of respondents (34%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT. The remainders of the responses were quite varied between mode 2 and 3.

10. Lack of trust (C3.3) was rated with the mean value of 3.14. The majority of respondents (30%) agreed (mode=4) this factor as barriers to the growth of the UIJRPTT. The remainders of the responses were quite varied between mode 3 and 2.

11. Industry's technical knowledge and absorptive capacity (C2.1) was rated with the mean value of 3.02. The majority of respondents (32.7%) agreed (mode =4) this factor as barriers to the growth of the UIJRPTT. The remainder of the responses was quite varied between mode 3 and 2.

The respondents majority of 34.7% disagreed (mode=2), when asked if they believed that the university reliable of knowledge and technology source (C1.1) and 26% and 22.7% of respondent disagreed and neutral perceived the industry lack of motivation (C2.2) and attitude of the industry (C2.3) as barriers of the UIJRPTT. The impact of the factors and variables were measured in column B. However, due to the technical problem in weighting the number of the respondents caused by unclear questionnaire, the result was calculated by using the data from 97 respondents. Data from column B which revealed that the respondents rated all factors could lead to negative impact to the growth of UIJRPTT.

Table 22 Respondents' Rating on Barriers of UIJRPTT Growth

Code	Description	Column A		Column B	
		Mean	S.D.	Mean	S.D.
C1	**Characteristics of University**	**3.08**	**1.07**	**2.03**	**.06**
C1.1	Reliable of knowledge and technology source	2.28	1.14	1.88	.76
C1.2	Lack of motivation	3.20	1.06	2.04	.66
C1.3	Difficulties with negotiating and managing collaboration	3.55	1.07	2.05	.65
C1.4	Potential impact on faculty and students to work with industry	3.32	1.02	2.18	.63
C2	**Characteristics of Industry**	**3.11**	**1.10**	**2.15**	**0.65**
C2.1	Technical knowledge and absorptive capacity	3.02	1.13	2.32	.60
C2.2	Lack of motivation	2.88	1.16	2.10	.63
C2.3	Attitude of industry	2.90	1.10	2.09	.70
C2.4	Management barrier	3.67	1.02	2.09	.70

Table 22 (cont.)

Code	Description	Column A Mean	Column A S.D.	Column B Mean	Column B S.D.
C3	**Transfer Context and Organizational Structure**	**3.39**	**1.09**	**2.11**	**0.68**
C3.1	University's Inadequate technical and information service	3.14	1.12	2.17	.66
C3.2	Lack of communication channels	3.66	1.01	2.09	.70
C3.3	Lack of trust	3.14	1.18	2.06	.68
C3.4	Cultural differences	3.41	1.12	2.17	.76
C3.5	Inadequate infrastructure	3.57	1.01	2.07	.69
C3.6	Inappropriate confidentiality and intellectual property management	3.43	1.10	2.11	.64

The mean value difference and similarity from the university and industry respondents also were compared from the data in column A. Table 23 shows the comparison between university and industry perspectives using Levene's test show no significant difference for most variables at the confidence level of 95% except university lack of motivation and university's inadequate technical and information service. Thus, the equal variance estimates were interpreted for most variables. Regarding the t-value and two-tail significance, there was no significant difference in all variables accept variable titled university lack of motivation, indicating that there was no difference of perspectives between the university and industry respondents. Five key barriers identified by the university respondents were including:

1. Industry management barriers (C2.4) with the mean value of 3.66;
2. Lack of communication channels (C3.2) with the value of 3.61;
3. Inadequate infrastructure (C3.5) with the mean value of 3.52;
4. Difficulties with negotiating and managing collaboration (C1.3) with the mean value of 3.51;
5. Cultural differences (C3.4) with the mean value of 3.47;

Whereas the industry respondents rated the following variables as three key barriers:

1. Lack of communication channels (C3.2) with the mean value of 3.75;
2. Industry management barriers (C2.4) with the mean value of 3.68;
3. Inadequate infrastructure (C3.5) with mean value of 3.66;

4. Difficulties with negotiating and managing collaboration (C1.3) with the mean value of 3.62;

5. Inappropriate confidentiality and intellectual property management (C3.6) with the mean value of 3.55.

Table 23 Factor and Variables Comparison

Code	Description	University (n=96)		Industry (n=26)		Levene's Test	t-value Sig.
		Mean	S.D	Mean	S.D		(2-tailed)
C1	**Characteristics of University**	**3.01**	**1.11**	**3.22**	**0.98**		
C1.1	Reliable of knowledge and technology source	2.18	1.16	2.44	1.09	.926	-1.326 (.187)
C1.2	Lack of motivation	3.02	1.15	3.51	0.81	.016	-2.801 (.006)
C1.3	Difficulties with negotiating and managing collaboration	3.51	1.09	3.62	1.05	.468	-.649 (.517)
C1.4	Potential impact on faculty and students to work with industry	3.33	1.05	3.31	0.98	.274	.106 (.916)
C2	**Characteristics of Industry**	**3.10**	**1.05**	**3.13**	**1.18**		
C2.1	Technical knowledge and absorptive capacity	2.90	1.05	3.22	1.25	.227	-1.642 (.103)
C2.2	Lack of motivation	2.90	1.11	2.85	1.25	.222	.274 (.784)
C2.3	Attitude of industry	2.97	1.04	2.77	1.20	.222	1.070 (.286)
C2.4	Management barrier	3.66	1.03	3.68	1.02	.785	-.106 (.916)
C3	**Transfer Context and Organizational Structure**	**3.34**	**1.13**	**3.46**	**1.01**		
C3.1	University's Inadequate technical and information service	3.06	1.18	3.27	1.01	.027	-1.122 (.264)
C3.2	Lack of communication channels	3.61	1.02	3.75	0.98	.648	-.838 (.404)
C3.3	Lack of trust	3.07	1.18	3.27	1.18	.961	-1.013 (.313)
C3.4	Cultural differences	3.47	1.19	3.29	0.98	.081	.956 (.341)
C3.5	Inadequate infrastructure	3.52	1.08	3.66	0.89	.124	-.841 (.402)
C3.6	Inappropriate confidentiality	3.36	1.14	3.55	1.02	.362	-1.019 (.310)

Determinants of UIJRPTT

Using the data from the interviews, this section tried to empirically verify the importance of certain factors from the university, industry and transfer context as determinants that facilitated or hindered the technology development of technological development of the university and the photovoltaic manufacturers. Several questions used in the interview were designed to prompt the respondents' reflection and perspectives on key factors that they viewed affecting the growth of the UIJPTT and their extents. The data on the factors affecting growth and obstacles gained from the interview was grouped into the factors affecting growth of UIJRPTT in five levels and part which included technological efforts, technological adoption, technological adaptation, drive for creation and transfer and organization context. The data and insights from the qualitative data were presented as followed:

1. Technological Efforts

Government roles and policy supports were stated by the university and the industry as a major determinant in their technological efforts which determined the developing of technological activities and the UIJRPTT. The governmental role in implementing R&D strategy and appropriate funding in renewable energy and photovoltaic technology could expand the roles of the university and public research institutes in working with the industry. The role as market facilitator and developer by implementing policies support for domestic market expansion could affect the growth of the UIJRPTT. The market was the primary source of incentives for the manufacturers to invest in production and R&D. As the market growth, the production would increase and through learning and scales economy, the cost would reduce. The cost reduction would lead to more income and profit which could further to increase of R&D investment. One manufacturer stated that in principle the company set 1% of income for R&D project each year (I#12).

However, the government role and policy support in R&D were criticized as lack of clear vision and mission on photovoltaic technology development and the funding program given to the university to run the projects was much less than the research projects required and not compliment for long term R&D. As quoted by the interviewee "The government gave the money to build a house, but with that amount of money, only the toilet could be built. It was an unfinished house that people could not live in

(U#15)". The government roles as market facilitator and developer were criticized as lack of full political support for legitimization of photovoltaic industry and technology and lack of continuity for larger market development program. As an industry respondents stated: "The photovoltaic industry was not given the "key renewable industry and technology" as the technology was considered "too expensive" and "not worth for today investment and support (I#1)". The government was stated lacked of long term public commitment in building awareness on the importance of photovoltaic technology. The industry stated: "as far as there was no strong political support for the renewable energy, the retail price of the electricity was still low, and Thailand's energy security was still dependent on imports of oil, gas and electricity, the manufacturers stated that they were not confident enough in investing heavily in R&D in the photovoltaic technology (I#8)" Moreover, technology specific subsidies such as adders was viewed failing to cover the cost of investment (I#1, I#2), together with problems with licensing for solar farm that did not facilitate well to investor (U#15, I#1) and financial credit difficulties for household and large project related to photovoltaic solar farm (I#1).

The effect of the government roles and policy supports in R&D and market developing were high as: (1) R&D support from the government could direct (i) the R&D commitment in the university in developing the photovoltaic technology that served the country and industry need (I#11, U#10) and (ii) appropriate arrangement of funding scheme for the U-I joint research projects (U#24); and (2) marketing support from the government could expand the income base which led to profit and industry fund for R&D (I#8). The low support could affect to low motivation of both university and industry to make decision in conducting the U-I joint research.

2. Technological Adoption

Source of technology transfer of the industry and **the university capability** in building up technology influenced the decision in adopting the technology of the industry. For the industry, source of technology transfer in the form of turn-key projects, licensing of know-how and hiring of key personnel from the university was the source of the industry technological adoption of the silicon crystalline manufacturers and amorphous manufacturers. Turn-key project was the completed technology transfer Thai manufacturers acquired from technology providers, while licensing and hiring personnel was for technological improvement and development of manufacturing and process. Two manufacturers reported licensing sophisticated technology abroad for production improvement. The silicon based crystalline manufacturers stated that the crystalline silicon based technology was already a platform technology and from existing production line, the manufacturers could produce photovoltaic cells and modules as the other foreign companies due to the same source of machinery providers. Therefore, the industry revealed that they had no demand for adopting new technology from domestic source and more innovation research should rather be on the product and process improvement.

For the supply side, the **university capability in building up new technology** was in question. Due to the fact that the research work in developing new cell technology was in the early stage, the university could not provide technology for the industry to adopt the new technology (U#16, U#21). Therefore, the possibility for the U-I joint research was very low. However, from the interview, all manufacturers stated the necessity and need to adapt the technology to local conditions and to improve the product and process efficiency due to the fact that the technology and machinery the manufacturers bought could not reach the efficiency and performance as stated by the turn-key provider.

3. Technological Adaptation

Several universities such as NU, KMUTT, KMITL played adaptor role in technological development research. The collaboration with the industry would not only allow the academic and students to learn the real world problems, commercial aspects and gain experience that would benefit the academic education, but also improve the performance profile of the university and individual academics. For the industry, the status of exporter of cells and modules in the global market which needed to compete with the competitor from all other countries drove the industry in undertaking adaptation such as in cells, modules and system efficiency development. More efficiency meant lower cost and more profits the manufacturers would gain. The impact of the adaptation stage was important for learning and technological transition that the firm must go through. Customers also benefited from more product choices such as better system maintenance. It could be found that all joint research between the university and industry reported by the respondents and annual report were in the adaptation categories such as testing of modules, solar applications and BOS system efficiency improvement.

However, in terms of the cell development, there was obstacle in driving the adaptation of photovoltaic cell technology from the university. Due to the fact that three photovoltaic firms were assembling manufacturers, and the nature of their production line was to import cells and other components and assemble, the respondents from those companies revealed that there was no need for the joint research with the university in specific areas (I#16, I#17). For the company that manufactured thin film and silicon photovoltaic cells, the respondents stated that the major problems were that the research conducted in the university was not relevant to the industry technology and the university professionals lacked of knowledge in real production line (I#3, I#17, I#18). Moreover, the university capabilities and equipment in the silicon photovoltaic technology and knowledge and thin film were not enough to develop the industrial scale cell products (I#16, I#10).

The university attributes that considered facilitating the U-I joint research for photovoltaic technology transfer for adaptation of technology transfer included: possibility to pool experts from various faculty members (U#23, U#36), ownership of the equipment and facilities necessary for research works (U#24, U#20), and sources of funds from public organizations (U#23, I#13) and university credibility and capabilities (U#8, U#22). Despite favorable attribute, the respondents from the university and industry viewed that faculty time and university impeded decision of the university and the industry in conducting the U-I joint research for photovoltaic technology transfer in adaptation activities. It also affected the level of interaction between the university and the industry in working together.

Faculty time affected directly to the possibility of making contracting and conducting U-I joint research for technology transfer. Even though the universities such as KU, KMUTT, KMITL indicated the teaching and research load for at 50:50, the participants emphasized that, in practice teaching loads were too high. Besides teaching in classes, some indicated that they had to be responsible in advising students and administrative duties. There were no blocks of uninterrupted time during which to perform researches. Due to lack of time, some had to decline the opportunities in conducting U-I joint research or in consulting with the industry members and, as a result, the industry viewed that they could not access to the academicians. As an interviewee (U#7) stated that "Now I have students to take care of. I could not increase the number. I could not make it. Teaching load is also hard. I could tell that to achieve some quality of work, I could do at this level. If working too much, the quality and efficiency will be lower. I don't think it was good. For the time being, I do not have time".

As a result, the faculty members and students would lose the opportunities in learning new technological knowledge and skills, and in funding the students and further R&D. The industry could not acquire knowledge and learn from the adaptation projects. Moreover, in case that the joint project had been carried out, trouble of faculty time led to the expansion of the research projects, the phase out of the projects as the private sector many find other things more interesting and bad impression on the collaboration with the university and the individual academics and team.

Capabilities and credibility was an important attributor that seriously affected the UIJRPTT. The university capabilities addressed the proof of concept for technology and research possibilities to achieve and maximize the research results, while the credibility of the university was built on the capabilities through a period of time and success story to prove its brand in researching. The university credibility was valued by the participants from university and industry as the factor that brought the industry to work and conduct U-I joint research. As one university interviewee (U#14) stated: "We are standing here for a long time with continuous research works. This is why the industry came to us." However, in building the capabilities and credibility, the participants revealed obstacles the university faced that could impede the research cooperation such as the structure and main responsibility of faculty members were for teaching not for researching (U#36), deficiency in human resources, equipment and technology. Deficient human resource was the result of the restricted number of Ph.D. students (U#32), brain drain of specialists in photovoltaic technology (I#2), and lack of real professional and tenured researchers (U#36, U#14). Some laboratory reported deficiency of equipment due to lack of budget. One university participant accepted that the industry's technology progress and advancement was far from that of the industry (U#33). The university's obstacle in capabilities and credibility would not attract and allow the trust of the industry in being the partner in research work and conducting the U-I joint research for technology transfer (U#36).

The close geographical proximity of the university enabled the interaction and collaboration between the university and the industry. The proximity increased the potential for interaction because it could lower cost in transportation and increase potentials in learning and cooperation (I#13, U#13). Most of the manufacturers located in the central and eastern part of Thailand. However, some universities such as NU, KKU, and CCU were located far from the industry location.

Firm attributes facilitated and impeded the collaboration and level of interaction between the manufacturer and the university. The industry's skilled labor and capable engineers, entrepreneur spirit of the owner who was ready to invest and taking risks, industrial scale equipment and facilities facilitated the U-I joint research for photovoltaic technology transfer. However, the respondents from the university and industry viewed that in-house R&D, fear of leakage of trade secrecy, and limited fund mattered decision of the university and the industry in conducting the U-I joint research for photovoltaic technology transfer in adaptation activities (U#20, U#29,I#6).

From the interviews, the most obvious product and process development in the Thai photovoltaic industry had come from the in-house R&D, QA and QC departments not from academic research. Therefore, it would rather be a misperception for someone to view that (1) the photovoltaic industry did not conduct R&D and they did not need the UIJRPTT because the turn-key providers could solve the manufacturers' problems and (2) the industry did not need the advance research because the problems occurring in the manufacturers' factory were only the production equipment. In-house R&D for both big and small manufacturers played an important role in product and process development. The large scale industrial amorphous manufacturing firm, with long-term plan of key research projects, the manufacturer preferred conducting the R&D in in-house R&D. The benefit of the in-house R&D, QC and QA was wide ranges and relevant to others issues. Interestingly, the industry respondents (I#1, I#3, I#6, I#11,I#12) revealed that the by-products from the in-house R&D included: (1) lower cost of R&D activities as service and facilities fee charge of the university was high and save cost from buying some know how; (2) avoid leaking of trade secrecy as fear of leakage technological information and trade secrecy was strong among the Thai photovoltaic manufacturers and the university was considered not the best place to keep secrecy; (3) own the research results and intellectual property. As the result, the U-I joint research project that the industry collaborated with the university was rather considered "common" R&D project which required the university's facilities, equipment, human resource as well as long-term data collection. Several manufacturers indicated that they cooperate with the university only in some aspects such as verifying the data, issuing certificate that the TOR required and gaining credibility. The facility fee charge of the university which was considered very high had stimulated the firm conduct more test in their own premise.

Limitation of funds was identified by the industry participants as firm attribute that affected their R&D activities. Limited fund was the result and related with the size of the market and income (I#8, I#11). Moreover, credit constraints also another reason that reduced the demand by firms for R&D (I#13). Credit constraints for the R&D activities for photovoltaic firms and solar farm were limited by the fact that R&D was risky and traditional banks lending was unable to value intangible assets.

4. Drive for Creation

For the role as technology creator, the university stated that the key driver for developing technology was to own the technology and obtain the patents which could further lead to the financial benefit due to cost effectiveness and technology leadership (U#32). However, deficiencies in skilled resources such as researcher (U#36), lack of equipment (U#5), lack of funds for big and long term project (U#25, U#32), and early staged research results were indicated. It was also viewed that the basic research in laying the understanding of phenomena and knowledge and creating the new technology did not matched with the industry's core business in silicon based solar cell and selling of modules and applications with simple usages (U#33, U#18). For the industry, inventions and fundamental research were considered important to their competitiveness; however, there were several factors to be carefully considered. Those included: time consuming, benefit and cost of investment in research, and economic value of investment (I#2, I#3). Research investment, for the industry, involved large sunken costs which could and could not increase returns. One manufacturer viewed that increasing-returns-to-scale was major characteristics of the company's production process which meant if the inputs are increased; output should expanded more than proportionately. Moreover, as far as the role of external market was concerned, it was doubtful that new invention and technology would work for them due to reliability on technology and source of origin (I#1, U#36). The manufacturer viewed that funding the fundamental research was high and could not bring out profit. It was also viewed that, currently, the associated competitive pressure for the change of the technology was still in the early stages and it was not enough to force the industry to upgrade and change the technology (I#2). It should also be noted that, in order to conduct the invention and innovation activities, the collaboration with the university and the national institutes mattered. One of the manufacturers reported the problems and conflicts with the national research institutes that had led to the unfavorable impression in working with the institutes in the area of confidentiality and benefits arrangement from the research results (I12, I#13). This led the manufacturer prefer avoiding the cooperation with the other institutes. As a result of the mentioned factors, both university and industry revealed that they never established the U-I joint research for the photovoltaic technology transfer particularly in the projects that were relevant to technology innovation such as new type of photovoltaic cell development (I#11, I#18).

5. Transfer and Organization Context

Communication was seen as the key factor in contacting, gaining and sharing experience and practice between the university and industry that further developed framework for collaboration and joint research for technology transfer. The respondents agreed that there were more communication channels for the university, industry and government organizations to talk and discussed through the university promotion campaigns, the industry renewable energy industrial association and the venues organized by the government organizations. However, from the interviews, many participants revealed that there was a weak linkage, insufficient and inefficient communication between the university and the industry which depended on individual willingness and readiness to discuss. As university interviewees stated: "We are living in the different world. We live in our way. They live in another (U#7)". "I never contact with the industry (U#40)" "I will wait until the research results were in favorable results (U#17)". Lack of communication would lead to loss of opportunities for university and industry to talk (U#6,U#23) and to set research question that responded to the need and interest of both sides (U#29). While the industry stated that weak linkage was the results of the mismatch of the research results and industry technology need: "We went to many laboratories to look what they are doing, but the laboratory research results are not relevant to what we need and our technology (I#11)" "The university conducts the research as of the interest of the faculty member. It's not their faults. It is the way academic used to be. They rarely come to talk to us. They will come to us when the funding needs the joint action with the industry (I#2)"

The interesting thing was that the government venue that should be the venue for the university, industry and governmental organization to discuss about the development plan for photovoltaic and renewable energy technology and the research program and cultivating the linkage was considered problematic. The interviews stated: "The government organization limited the people participating in their meeting. They need the people who they can tell, turn left and turn right (U#7)" "I have been invited at the early stage, then after talking too much, they never sent me the invitation letter (U#23)" "I did not find any new faces in the meeting (I#1)"

Difficulties in practical incentive and bureaucratic system are among factors affecting the university individuals in driving the research activities and innovation. The university's competition in better international ranking through increasing publication was pointed as difficulty for academicians in some aspects (U#8, U#17). Many participants stated that this led the academician prioritization in only the academic paper publishing without paying much attention in development of research results for commercialization. Moreover, as far as the promotion of academic ranking of the faculty and incentive for researching was concerned, the faculty members viewed that conducting research related to commercialization may not help promote their academic career path (U#6). As normally academic ranking promotion was based on academic paper. Even though the U-I joint research could bring the researcher to write the research results in the paper or register the patents, but in practice, the researchers had to wait for sometimes until they could publish the research results due to confidentiality contract (U#27, U#28). This could have led to the out of date publication. It should also be further noted that some participants viewed that incentives or income from teaching was higher than that of researching (U#17).

Bureaucratic system affected the academician work in several ways. Some participants (U#7,U#10, U#12, U#13) viewed the inconsistent policies on incentive of the university due to change of administrative officer and administrative structure affected the motivation to conduct research and the U-I joint research. As university interviewees (U#10, U#12) stated: "The joint project is decreasing because they have in-house R&D. If the industry come to us and get stuck with the bureaucratic system which could delay their projects, they are not motivated to work with us". "In the past, the administrative officer supported the proactive role of the TTO by going to the industry, but now it was changed. Our role is changed." One blamed the changed of university administrative independency causing more inflexibility and bureaucratic system reducing the motivation of faculty member to conduct research. As a university interviewee (U#7) stated: "The autonomous did not make anything better but worst...Everything has to be depending on the Dean. New long procedures in decision making wasting time...I have to wait for the Dean to sign to bring out the research equipment. We have to pay for the cargo charge. Before, the faculty dean could sign and we can wait around 2-3 days only. The thing that motivated me to work on was only to teach". One blamed that the bureaucratic regulation that impeded the facilitation role of the TTO to the UIJRPTT. As an interviewee (U#15) stated that: "Our people fear of violating the regulation. Nobody wants to take risks".

6. University and Industry Conflicts

Conflicts from different perceptions most cited by the interviewee were: (1) conflict in research motivation, (2) conflict of commitment, and (3) conflict in time. Those conflicts affected the decision and impression in formulating and conducting the research between the university and industry. Conflict in research motivation occurred when the university valued cooperation in the forms of co-funding, sharing ideas and co-working with the university and the industry viewed that cooperation could begin once the university could prove successful results, or invent the prototype or finished products (U#3, U#6, I#1, I#2).

Conflict of commitment occurred when the industry hiring university consultant to work for them which was cheaper than conducting U-I joint research (I#2). The university was not content with the role of academic consultant privately (U#25, U#29). They viewed that the university would lose benefit it should gain by rules. Academic also felt guilty of being consultant, as they viewed that it took their times of teaching and taking care of students (U#23).

Conflict in time existed as university viewed that they could wait for trial and errors until the researcher could prove the experiment results but the industry could not wait and extend the projects duration (U#3, U#24, U#9). The extension and unpunctuality could lead to loss of opportunities in selling the products and expanding marketing (I#16).

In sum, the data from the interviews verified the importance of certain factors from the university, industry and transfer context as determinants that facilitated or hindered the decision of the university and industry in various aspects. The qualitative data highlighted the importance of the government's roles and support policy as technology and market facilitator in driving the technological efforts. For technological adoption, industry source of technology transfer such as turn key projects and licensing technology and doubt in university capabilities in building up new technology led to no demand and supply for adopting new technology domestically. Faculty time, capabilities and credibility, close geographical proximity, firm attributes and limitation of fund affected the decision of both university and industry in adapting technology from UIJRPTT. Drive for technology creation was impeded by university roles as technology creator and industry economic value perception in research investment. Finally, transfer and organization context including communication channel, difficulties in practical incentive and bureaucratic system and conflicts between university and industry were determined to the growth of the UIJRPTT. Table 24 summarizes the determinants of the UIJRPTT from the qualitative data in this section.

Table 24 Summary of Determinants of Growth, Issues, Obstacles and Their Effects

Determinants	Issue	Obstacle	Effect
Technological Efforts			
Government role and policy support as technology and market facilitator	Lack of vision and mission	- Lack of policy to support technology development domestically	-Low fund for R&D to university and research institutes
	Lack of full support for legitimization of PV industry	- Lack of R&D commitment in university - Inappropriate arrangement of funding scheme	-Lack of R&D direction to streamline PV technology development projects
	Lack of continuity for larger market development program	-Perspectives on low value and cost cover for R&D development for commercialization	-Recognition for R&D in the industry is low or none
	Lack of long term public commitment in building awareness on PV importance	- Low market support and problems in specific subsidies	-Limited market growth and volume which affect the income of industry
Drive for Technological Adoption			
Source of technology transfer in industry	No demand for adopting new technology as industry acquire technology abroad		- Industry did not support new technology invention
University capabilities in building up new technology	Research works in early stage and not corporate with industry technology		- Early stage for commercial technology for the industry
Drive for Technological Adaptation			
University's attribute	Pool experts Equipment Source of funds Capabilities and credibility	Lack of knowledge in real production line and irrelevance of skills and knowledge in technology in need	- Industry could not acquire knowledge and learn from adaptation projects
		Deficiencies in human resources, equipments due to lack of budget	- Not allow industry trust to work with the university
Faculty time	No time for researching due to overload work	Inadequacy of specialists and tenured researchers and teaching load	- Faculty members lose opportunities in learning new knowledge, skills and funds
			- Expansion of projects led to bad impression of industry to university

Table 24 (cont.)

Determinants	Issue	Obstacle	Effect
Close geographical proximity	Location of university near industry		+ Location could reduce cost in transportation and increase potential learning
Firm's attributes	Skilled labors and capable engineers		+ Industry could conduct research without problem of human resources capabilities
	Entrepreneur spirits		+ Industry could take more risks in conducting research
	Equipments		-/+ Industry full of equipment required could support the research work
	In house R&D	Industry aim for low cost	- Industry preferred to work in in-house R&D.
		Fear of leakage IP ownership	
Industry Limitation of Funds	Small income		- Limited capabilities in investing in research.
	Credit constraints		
Drive for Technological Creation			
University role as technology creator	Infrastructure	Deficiency in skill resources Lack of equipment Lack of funds Early stage research results	- Insufficient infrastructure affecting the ability in conducting research and technology development
Industry attitude in research investment	Benefit and cost	Large sunk cost, not increase return Reliability on technology and source of origin	- Value of research not well recognized
	Management	Conflict with government institutes	- Unfavorable experiences in working with others
Transfer and organization context			
Communication	Opportunities in contacting, gaining, and sharing experience and practice	Weak linkage insufficient and inefficient communication channel	- Loss of opportunities for both to talk and set research question that respond their needs

Table 24 (cont.)

Determinants	Issue	Obstacle	Effect
Difficulties in practical incentive and bureaucratic system	Incentive Problem	Academic ranking based on paper not research for commercialization	- Motivation for research work related to commercialization were not well valued
		Incentive for teaching higher than researching	-University emphasized teaching rather than researching
	Bureaucratic system	Too restricted regulation	- Discomfort in UIJR working for both academics and industry
		Inconsistency of policies and incentives	- Discontinuation of policy support and favorable incentives for UIJR
University and industry conflicts	Conflicts of interest	Conflict in research motivation Conflict in commitment and Conflict in time	- Unfavorable situation before and during working in UIJR that could affect motivation and continuation in working in next project

Note: means negative impact and + means positive impact

Discussion

From the research results, the answer for the question of why there is little number of UIJRPTT in Thailand depended on various factors. The analysis in potentials and gaps of the context related to the promotion of photovoltaic technology and U-I linkages revealed that there were potentials and gaps in government support on the photovoltaic technology, the university and industry characteristics and the linkages between university and industry. The questionnaire results indicated barriers to the UIJRPTT including factors related to characteristics of university and industry and the transfer and organization context. Eleven out of fourteen of the items rated influencing negative impact to the UIJRPTT formulation. Those five key barriers included industry management barriers, lack of communication channels, inadequate infrastructure, university difficulties with negotiation and managing collaboration and inappropriate confidentiality and intellectual management. The results supported that there was gaps perceived by the respondents in the three factors and they could impede the formulation and growth of the UIJRPTT. The results validated the significant focus of technology transfer literature and U-I collaboration (BHEF, 2001; Casey, 2004; Szulanski, 1996, 2000; TDRI, 1992).

The interview results highlighted the importance of determinants in technology development. Those included: (1) the government's roles and support policy in the university and industry technological efforts; (2), the industry source of technology transfer and university capabilities in building up new technology in technological adoption; (3) faculty time, capabilities and credibility, close geographical proximity, firm attributes and limitation of fund in adapting technology from UIJRPTT; (4) university inadequacy infrastructure and industry economic value perception in technology creation; and (5) transfer and organization context in determining the growth of the UIJRPTT. The roles of government in determining the UIJRPTT was in line with the research work on the innovation system in Thailand such as Monaiyapong (2004) and Brimble and Doner (2007). Those works state that the government and the government agencies are the key player in supporting activities and tasks of the university and industry. The government policies and fragmented Thai bureaucracy could hinder U-I linkage and university-industry-government linkages. It could be found that the photovoltaic technology was lack of the legitimacy from the government to prioritize it as key technology. As a result, this could affect to insufficiency of support policies and strategies to encourage the R&D, market development and financial funding and credits.

Industry source of technology transfer, firm attributes and limitation of fund which included credit constraints and skilled labor and capable engineer, entrepreneur spirits, and equipment as determinant of the UIJRPTT was clearly in line with the work of Szulanski (1996, 2000), indicating that the transferee characteristics such as knowledge, motivation, and enthusiasms were essential element of transferee in technology transfer. TDRI (1992) also indicates that entrepreneur spirits could affect the collaboration. University capabilities and credibility, faculty time, close geographical proximity revealed as determinant of the UIJRPTT supported the work of Szulanski (1996, 2000), Santoro and Gopalkrishnan (2001). Transfer and organization context which included communication, difficulties in practice and bureaucratic system and conflict of interest were confirmed in this research as the determinants of the growth of the UIJRPTT. The interview results revealed the weak linkages of the university and industry and limited circles in the governmental venues. This support the work of Casey (2004), stating that the university and industry often have stereotypical visions of the others and that hampers communication effective project finalization and execution. From the research, it explained that the vision could affect the cultivation and beginning of the UIJRPTT between the two sides. Difficulties in practice and bureaucratic system reflected that university lack of consistency and other bureaucratic perspectives that did not facilitate the work of UIJRPTT was in line with the work of Casey (2004) and Brimble and Doner (2007). Moreover, as far as the conflict of interest was concerned, BHEF (2001) stated that there was conflict of interest in financial, commitment as anything that might interfere with the faculty full time duties The conflicts stated in this study expanded the nature of conflict from the study of BHEF (2001) by revealing the attitude of working between university and industry as university needed the industry to work with them since the beginning of the project whereas the industry needed the proven technology. The conflict in commitment and time that may arise from the organizational culture difference as the industry expected that the commitment and time frame of the UIJRPTT should be as stated in the contract.

The results from three methods yielded several answers of why there was little number of the UIJRPTT which were discussed as followed:

First, the characteristics of the university were confirmed as the root cause of the situation. The descriptive results revealed that the possibility for the university to work with the industry in terms of technology creation and adoption was rather small due to the fact that limited capability and funds, early stage of research for new photovoltaic technology as well as the limited support from the government. Therefore, the UIJPRTT mostly related to technology adaptation such as standard test, and solar application development. However, the UIJRPTT in the case of technology adaptation was still limited because of, according to the research results, the university system and individual related matter of the university professionals. The data analysis provided evidence that despite the university was potentially capable as technology transferor, the university still faced the problem of deficiencies in skilled resources such as researchers and research equipment, and lack of funds for big and long term project that were necessary for conducting the knowledge intensive research and formulation of trust and credibility of the university to the industry. This was partly because the university individually and collectively did not have the concrete plan and support for photovoltaic technology development. Moreover, it was also obvious that the university system of pooling experts within and outside the university to work together was problematic

Secondly, individual related matter of the university professionals was confirmed impeding the UIJRPTT growth. From the interview, some universities professionals indicated that they would wait until they were successful in research results before contacting with the industry. This reflected the behavior and characteristics of the university professionals that were separated and largely isolated from the market and the industry according to the traditional linear model of innovation. The individual obstacles related to the isolation may come from the incentive structure of the university in motivating the faculty to work with the industry, which was also confirmed by descriptive results. The interview results also revealed that university and faculty members mostly concentrated on teaching and training human resources. This could affect the faculty members and researchers' time and limit the understanding in economic competence and to reorient their R&D activities towards potential market demands. Moreover, from the interview results, the process to higher academic ranking may be problematic due to the fact that the professorship and university ranking was depended on articles published, teaching classes, and administrative roles. Successful commercialization and involvement in technology development can do little help in developing the profession. Moreover, as confirmed by descriptive results, they were concerned on potential impact of publication on faculty and students. As a result, the research projects that were largely academically oriented and efforts to pursue research results to upper stage were rarely.

Second, characteristics of the industry were confirmed by as the root cause of the little number of the UIJRPTT. In conducting the research, the photovoltaic firms were largely locked into the attitude of the industry management team on the value of research collaboration and investment cost and time spending evaluation and market incentive. This was confirmed by the statistical results and interview. The interview data reflected in the decision in adopting source of technology transfer in the form of importing turn-key projects, licensing of know-how and hiring of key personnel from the university, but pay less attention to successful innovation. The firms were more flexible in expanding their production capacity by importing advanced technology and partly because in Thailand there was no such technology provider. Moreover, as the market abroad expanded and competition was also fiercer, most Thai photovoltaic firms responded to the competition by updating the manufacturing facilities and techniques rather than R&D capabilities to defend market position. Several reasons were indicated such as time consuming, benefit and cost of investment in research, and economic value of investment and market capabilities. Research investment involved large sunken costs, returns-to-scale led to consideration that output should expand more than input proportionately and role of external market was concerned as it was doubtful that new invention and technology would work for them due to reliability on technology and source of origin. Moreover, due to limited market capabilities and funds from profit margin and since most aspects of production would be internalized and involved with trade secret and IP ownership, and limited university's capabilities, the photovoltaic firms viewed that they could not catch up the technology and market from domestic research and importing technology was the flexible choice. However, some efforts in in-house R&D and in QC and QA departments in adaptation and assimilation could be found due to the fact that this might lead to reduction in technology purchase from licenses and loyalty. Most of their efforts were concerned with increasing the efficiency with existing technologies. Some UIJRPTT in adaptation as seen today, therefore, limited to the test of the products, materials, module system that related to the manufacturing process and market support, rather than photovoltaic innovation. The understanding of this phenomenon led to one of the answers that the industry did not lack of technical knowledge and capacity and did not lack of motivation to learn new things, as confirmed by questionnaire respondents, but the choice of photovoltaic firms in Thailand to conduct the joint research or not mainly depended on the attitude of industry management on value of the research and cost and benefit.

Third, transfer context and organizational structure was confirmed as the factor affecting the growth of UIJRPTT. The interview reported that the industry had established linkages through inter-personal contact and site visit to search information on new knowledge with the university and maintain at least one link with a university both in terms of official such as joint projects in testing and of unofficial such as free advice and recommendations to solve some problems without establishing the official research projects. It was important that university-generated knowledge is diffused both in direct or indirect way as much as possible within the industry. The mismatch of university technology and industry need reflected the lack of communication between the two parties. As shown in the statistical results, lack of communication channel significantly mattered the growth of the UIJRPTT. The results of lack of communication led to the situation that the basic and applied research was obviously not related to the industry and therefore the R&D results could not applied and be used for commercialization of the industry. According to the interview results, the Thai governmental organization established the venue of meeting and discussion on policies and research program. However, there appeared hardly to be the true open venue as the circle was still limited and not open for new.

For knowledge and technology diffusion, the other transfer context and organizational structure such as technical and information service, trust, cultural differences and IP management were significantly rated as impacting the growth of the UIJRPTT as barriers. They were confirmed by the interview data analysis that affected the driver of technology transfer under the UIJRPTT. With the perception of the respondents, inadequate technical and information service reflected in making access to information of the university projects and research results was difficult and lack of adequate standard of test relevant to the need of the industry and certification as well as integration of knowledge. Time and trust was lost as the key researcher had no time to concentrate and conduct the research and staffs was unaware of the nuances associated with project. In effect, many things "went on hold" and delay in coordination and distribution of funding could exist which may lead to the conflict in time, commitment and interest. The cultural difference could have made the conflicts deeper as culture difference could bring on a behavior and unfavorable attitude to the current and future UIJRPTT.

It was worth noting that the obstacles, impediments and barrier discussed above reflected the weakness of the university in lacking of long term policy support for the photovoltaic technology development, lack of personnel management related to research and development, lack of knowledge integration, and weak performance of coordination office in support and enhance the university and industry research.

Fourth, from the gap analysis and interview results, it confirmed that the photovoltaic technology was lacking of critical actors such as the government in legitimizing the technology and market development which made the system incomplete in its functionalities. Carlsson (1995), in Zhineng, 2001, stated that "to exploit technological opportunities certain actors have to be included and connected with each others. Those included active customers, innovator who integrate technology, entrepreneurs who identify profitable innovation, competent venture capitalists who recognize and finance the entrepreneurs, exit markets that facilitate ownership change and industrialists who take successful innovation to industrial scale production." It could be considered that for the photovoltaic technology development, Thailand lacked of those critical actors.

To establish and enable the network actors to work efficiently, in developing countries like Thailand, the government was the key player in supporting those actors. The activities and tasks of the actor related most with the government fundamental policy and supports. The main obstacle that could impede the photovoltaic technology development, as confirmed by the interview, was that the technology was never received legitimacy from the government as key technology for the country. In terms of S&T, the Thai government had established the policies and strategies to encourage the R&D, they were criticized as lack of clear vision and mission on photovoltaic technology development in the long term period. Moreover, irrational institution system including separation of the conflict roles of funding organizations, and unplanned specialization of research institutes and universities could affect the photovoltaic technology development. As a result, the photovoltaic technology development conducted in the research institutes and the university was rather like "working on their own" and focused on stimulating the supply of technology rather than stimulating the demand for technology development of industrial firms. There were very few evidences indicating that the research institutes, university and industry worked together continuously and indicated technology needed for the country and the integration of photovoltaic related technology. Moreover, most financial resources continued to be concentrated on the capabilities and resources of scientific, technological build-up which were undertaken under the Ministries' jurisdiction and specialized agency such as NSTDA. On the other hand, there was less resources allocation of mechanism designed to increase firms' abilities to implement their own technological learning, strengthening their own design, engineering and other technological development capabilities or undertake their own innovative activities that they could work with the university.

In terms of market and industry development, Ministry of Industry, Ministry of Science and Technology, Ministry of Energy played their roles lower than their expected capabilities in directing policy and institution support for industrial technology development and market development. As confirmed by the interview, Thailand still lacked of concrete policy support in build up the sustainable domestic market, insufficiency of export promoted policy and financial support scheme for industry and customer investment in photovoltaic products. As a result, the photovoltaic firms faced limited market capabilities which lead to low profit margin which could bring to low demand of technology development and investment. Therefore, in the system, it could be said that it was hardly to find the entrepreneurs who could identify profitable innovation, competent venture capitalists who could recognize and finance the entrepreneurs, and industrialists who could take successful innovation to industrial scale production and exit markets that could facilitate ownership change.

Summary of Part Two

This part employed the qualitative and quantitative approaches to acquire the data. This part presented the research results in three parts: data search and interview, questionnaire results and interview results. From the data search and interview, the analysis in potentials and gaps of the context related to the promotion of photovoltaic technology and U-I linkages revealed that there were potentials and gaps in government support on the photovoltaic technology, the university and industry characteristics and the linkages between university and industry.

The identification of the variables affected the formulation and growth of the UIJRPTT namely: characteristics of university (C1), characteristics of industry (C2) and transfer and organization context (C3) were rated in Likert scale as barrier of the UIJRPTT. Those key barriers included industry management barriers, lack of communication channels and university difficulties with negotiation and managing collaboration. This supported that there was gaps perceived by the respondents in the three factors and they could impede the formulation and growth of the UIJRPTT. All of the items rated influencing negative impact to the UIJRPTT formulation.

The data from the interview highlighted the importance of determinants in technology development. Those included: (1) the government's roles and support policy in the university and industry technological efforts; (2), the industry source of technology transfer and university capabilities in building up new technology in technological adoption; (3) faculty time, capabilities and credibility, close geographical proximity, firm attributes and limitation of fund in adapting technology from UIJRPTT; (4) university inadequacy infrastructure and industry economic value perception in technology creation; and (5) transfer and organization context in determining the growth of the UIJRPTT.

The research results yielded several answers of why there was little number of the UIJRPTT. First, the photovoltaic technology and market development was lacking of critical actors such as the government in legitimizing the technology and market development which made the system incomplete in its functionalities. Second, various universities are still separated according to the traditional linear model of innovation and largely isolated from the industry and the market. Moreover, the structure of university in focusing on teaching and producing human resources limited the faculty members and researchers to understand economic competence and reorient their R&D activities towards potential market demands. Third, the photovoltaic firms were largely locked into the attitude of the industry management team on the value of research collaboration and investment cost and time spending evaluation and market incentive. Fourth, the transfer and organization context were problematic due to inadequate technical and information service, staff's unawareness of the nuances associated with project, conflict in time, commitment and interest derived from cultural difference and IP management.

PART THREE Analysis of Factor Affecting the Effective U-I Joint Research for Photovoltaic Technology Transfer

Introduction

This part presented the results of the qualitative and quantitative data from the research instruments. The aim of this part was to answer the research question of what were the factors affecting the effective UIJRPTT and the extent of the factors and how to improve the situation. The hypothesized factors and variables related to characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) and conceptual framework of the model of effective UIJRPTT developed from Chapter Two were tested and confirmed whether they were the factors affecting the effective UIJRPTT and their extents. This part was organized into three sections. The first section detailed the evaluative results of the factors affecting the effective UIJPRTT agreed by the respondents and the development of the effective UIJRPTT model, which included a number of enabling and outcome factors. Construct reliability and validity from confirmatory factor analysis were assessed, followed by path analysis using SEM method. The model development and the specification of goodness of fit index were described. The qualitative data from descriptive statistics and interviews were then used to evaluate the current status of the model factors. The practical issues and actions in the model's variables were also discussed to develop and refine the effective UIJRPTT model.

Factors Affecting the Effective U-I Joint Research for Photovoltaic Technology Transfer and the Model Development

1. Rating of Enabling and Outcome Factors and Variables

The survey respondents (n=150) were requested to provide rating for the variables in two separate columns (A and B) that were measured on a five-point Likert scale. Column A asked the respondents whether they viewed the variables in the key factors were essential for the effective UIJRPTT in Thailand. The results were used to determine the importance or significance of each factor and variable as essential enabling factors and variables. Column B requested the respondents on the potential impact of the factors and their variables to the effective UIJRPTT. The data set acquired from column B was utilized for the evaluation of the effective UIJRPTT model construct and determining casual path to identify the extent of the factors' impact. The key hypothesized factors as described in the conceptual model in Chapter II were: characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2), joint research mechanism (D3); and 12 observed variables: university's capability in receiving and transferring technology in terms of technique and funds (D1.1), university's adequate specialists, researchers and students (D1.2), university's adequate research tools and equipment (D1.3), potential impact on faculty and students to work with industry (D1.4), industry's capability in receiving and transferring technology in terms of technique and funds (D2.1), industry's willingness and motivation in working with university with shared value (D2.2), industry's perspectives on worthiness and value of joint research in terms of economic and intelligence value (D2.3), industry's understanding culture differences (D2.4), communication effectiveness (D3.1), management of coordination office and joint research program (D3.2), IP management (D3.3), incentive system for joint research (D3.4). The respondents were also asked to rate their opinions on the extents that the three key factors (D1, D2, D3) enhance the effective UIJRPTT (D4) which were identified as the growth of the U-I joint research (D4.1), joint research project performance (D4.2) and economic performance from joint research (D4.3). All mentioned observed variables were measured through five-point Likert scale rating.

The descriptive statistics used in this part included: (1) mean and standard deviation for each enabling and outcome variables. The main reason for evaluating mean and standard deviation was to confirm the respondents' perspective on the factors and their variables and to assist with factor analysis decision making; (2) t-test for university and industry comparison. The t-tests were performed to test whether there was any significant difference in the mean value of each item was similar and there was any significant difference when the rating results of the university and industry respondents were compared.

1.1 Mean and Standard Deviation

The mean and standard deviation value of the factor and variables for both column A and B are displayed in Table 25. Mean scores of each factor are computed by equally weighting the mean scores of all variables in the factor. The mean value for all variables detailed in column A that was greater than three (3.0) indicating that the respondents perceived that the entire set of variables contained in the questionnaire were important.

Drawn from the data results in column A, all respondents agreed that all enabling factors were essential to the effective UIJRPTT. Joint research mechanism (D3) was rated highest with the average mean value of 4.17, followed by characteristics and perspectives of university (D1) with the average mean value of 4.12 and characteristics and perspectives of industry (D2) with the average mean value of 4.05. The standard deviation of the three enabling factors in column A averaged 0.81, 0.76 and 0.73, suggesting that the respondents had similar perception. In terms of variables, the respondents agreed that all variables were enabling factors for the effective UIJRPTT because the range of the mean values was from 3.91-4.32. Incentive system (D3.4) with the average mean value of 4.32 were rated highest, followed by IP management (D3.3), industry perspectives on worthiness and value of joint research (D2.3) with the average mean value of 4.27 and 4.26 respectively.

As for the impact of the factor affecting to the effective UIJRPTT (Column B), the respondents rated all factors had high impact to the effectiveness UIJRPTT with the average score higher than 3.80. Joint research mechanism (D3) was rated highest with the mean value of 4.08, followed by characteristics and perspectives of university (D1) with the mean value of 4.05 and characteristics and perspectives of industry (D2) with the mean value of 3.97. Incentive system (D3.4) was rated highest impact to the effective UIJRPTT with the mean value of 4.21, followed by and IP management (4.15) and adequate research tools and equipment (4.14). The other variables within all constructs were considered important and had high impact to the effective UIJRPTT. The standard deviation of the three enabling factors in column B averaged 0.74, 0.75 and 0.75, suggesting that the respondents had similar opinion.

The results of the mean value and standard deviation in column A and B suggested that the majority of the respondents identified these three factors and variables important and influential in describing the effective UIJRPTT in Thailand. Moreover, the descriptive results of the outcome factor with the average mean of 4.14 and low standard deviation of 0.66 indicating that majority of respondents agreed these variables as the outcome factors of the effective UIJRPTT and the mean value indicating the possible high degree impact from the enabling factor to the outcome factor.

Table 25 Factor and Variable Mean and Standard Deviation

Code	Descriptions	Column A Mean	Column A S.D	Column B Mean	Column B S.D
	Enablers				
D1	**Characteristics and perspectives of university**	**4.12**	**0.81**	**4.05**	**0.74**
D1.1	Capability in receiving and transferring technology in terms of technique and funds	4.09	0.83	4.02	0.73
D1.2	Adequate specialists, researchers and students	4.13	0.79	4.06	0.72
D1.3	Adequate research tools and equipment	4.20	0.81	4.14	0.77
D1.4	Willingness and motivation for teamwork and shared value	4.06	0.81	3.99	0.74
D2	**Characteristics and perspectives of industry** technique and funds	**4.05**	**0.76**	**3.97**	**0.75**
D2.1	Capability in receiving and transferring technology in terms of technique and funds	4.01	0.75	3.99	0.71
D2.2	Willingness and motivation in working with university with shared value shared value	4.02	0.78	3.98	0.78
D2.3	Perspectives on worthiness and value of joint research in terms of economic and intelligence value	4.26	0.79	4.12	0.80
D2.4	Understanding Cultural Difference	3.91	0.73	3.81	0.71
D3	**Joint Research Mechanism**	**4.17**	**0.73**	**4.08**	**0.75**
D3.1	Communication effectiveness	4.04	0.73	4.00	0.74
D3.2	Management of coordination office and joint research program	4.06	0.70	3.96	0.74
D3.3	IP management	4.27	0.69	4.15	0.80
D3.4	Incentive System	4.32	0.81	4.21	0.73
	Outcome				
D4	**Effective U-I joint research for photovoltaic technology transfer**			**4.14**	**0.66**
D4.1	Growth of U-I joint research for photovoltaic technology			4.06	0.66
D4.2	Quality performance from joint research			4.18	0.67
D4.3	Economic performance from joint research			4.19	0.67

1.2 Comparison of Rating between University and Industry

In order to identify the similar and different opinions while rating the factors affecting the effective UIJRPTT of the university and industry respondents, the author compared the scores the respondents from the two sides rated by drawing the data from column B to test if there was a significant difference in mean value in a particular variable. The data from column B were used to calculate the CFA, path analysis and to develop the model of the effective UIJRPTT in the next section. The significance differences in the mean value for a particular variable could provide the hint on the different perception of the university and industry respondents on the current situation and variables. Table 26 illustrates the significance similarity and differences of descriptive statistics in each variable.

The mean value comparison between the university and industry using the Levene's Test for Equality of Variance showed no significant difference for all variables at the confidence level of 95%. The value of all variables in the Levene's Test was higher than 0.05 indicating that the university and industry respondents rating estimated having equal variance. Using the t-test for Equality of Means, the significant differences of the mean value rated by the university and industry on the impact of the variables to the effective UIJRPTT was obvious for the majority of variables, because the results from the calculation of Sig.(2-tailed)/2 <0.05 and $t > 0$. Despite the differences of the mean value of variable D3.3 and the outcome factor (variable D4.1, D4.2, D4.3) were not significant, the mean value difference could also be seen easily high. Therefore, the results showed that it could be assumed that the university respondents viewed that the impact of most variables to the effective UIJRPTT were rated higher than the industry respondents perceived.

Table 26 Factor Mean Comparison from Column B

Code	Descriptions	University (n=96)		Industry (n=54)		Levene's Test	t-value
		Mean	S.D	Mean	S.D	Sig.	Sig. (2-tailed)
D1	**Characteristics and perspectives of university**	**4.19**	**.70**	**3.79**	**.74**		
D1.1	Capability in receiving and transferring technology in terms of technique and funds	4.16	0.70	3.75	0.72	0.49	3.36 (0.001)
D1.2	Adequate specialists, researchers and students	4.17	0.69	3.87	0.75	0.50	2.51 (0.013)
D1.3	Adequate research tools and equipment	4.33	0.70	3.79	0.78	0.36	4.29 (0.000)
D1.4	Willingness and motivation for teamwork and value	4.11	0.72	3.77	0.74	0.38	2.70 (0.008)
D2	**Characteristics and perspectives of industry**	**4.12**	**.77**	**3.69**	**.73**		
D2.1	Capability in receiving and transferring technology in terms of technique and funds technique and funds	4.10	0.70	3.79	0.78	0.06	2.46 (0.015)
D2.2	Willingness and motivation in working with university with shared value shared value	4.14	.75	3.68	0.74	0.89	3.60 (0.000)
D2.3	Perspectives on worthiness and value of joint research in terms of economic and intelligence value	4.31	0.71	3.79	0.85	0.06	3.94 (0.000)
D2.4	Understanding cultural difference	3.96	0.73	3.51	0.57	0.85	3.95 (0.000)
D3	**Joint Research Mechanism**	**4.18**	**.74**	**3.91**	**.73**		
D3.1	Communication effectiveness	4.12	0.72	3.77	0.71	0.76	2.81 (0.06)
D3.2	Management of coordination office and joint research program	4.09	0.74	3.72	0.71	0.67	2.99 (0.003)
D3.3	IP management	4.22	0.81	4.10	0.76	0.09	1.55 (0.122)
D3.4	Incentive System	4.29	0.70	4.07	0.77	0.97	1.74 (0.083)
	Outcome						
D4	**Effective U-I joint research for photovoltaic technology transfer**	**4.17**	**.64**	**4.07**	**.71**		
D4.1	Growth of U-I joint research for photovoltaic technology	4.09	0.65	4.00	0.70	0.72	0.82 (0.411)
D4.2	Quality performance from joint research	4.22	0.62	4.07	0.77	0.83	1.33 (0.183)
D4.3	Economic performance from joint research	4.21	0.66	4.14	0.68	0.79	0.616 (0.539)

2. Data Preparation for Model Development

2.1 Normal Distribution Test

The robustness of the estimation in the SEM depended on the normal distribution of variables. The univariate and multivariate normality was assessed by analyzing skewness and kurtosis of the data from column B. For the univariate normality test, with values of Z-score skewness and Z-score kurtosis ranging between 0.000-1.834 as well as 0.618-7.667 respectively, slight to moderate univariate normality was established. However, D4.2 had Z-score skewness of 3.505 and D1.3 had Z-score of kurtosis of 10.341. This may be problematic as it is suggested that only values exceeding a skew index of 3 and kurtosis index of 10 may create a problem (Kline, 1998). The results of the test of multivariate normality showed that the Z-score skewness value was 7.884 and Z-score kurtosis was 6.299. The values exceeding of univariate and multivariate results may be suggested the potential affect of non normality. Therefore, a range of fit indexes was used for the analysis of model including the recommended Normed Fit Index (NFI) and Comparative Fit Index (CFI) and chi-square to confirm the validity.

2.2 Correlation Analysis

The correlation analysis was conducted to meet the requirement of the factor analysis which stated that data should be in the form of correlations. To test whether a set of data can be used to conduct factor analysis, the correlation matrix representing all pairs of variables should be firstly analyzed to provide the correlation coefficient between each variable and each of the other variables. Each variable should have a large correlation than 0.30 with at least one of the other variables (Angsuchoti, Wijitwanna, and Pinyopanuwat, 2008). From the results, most observed variables had medium to large correlation ($.4<r<.6$ and $.6<r<.8$) Two statistical indices namely Kaiser's-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity also used to test appropriateness of set of data for factor analysis. KMO tests whether the partial correlations among variables are small. Bartlett's test of sphericity tests whether the correlation matrix is an identity matrix, which would indicate that the factor model is inappropriate. The KMO measures the sampling adequacy which should be greater than 0.5 for a satisfactory factor analysis. From the results, the KMO measure was 0.913. From the same table, the Bartlett's test of sphericity is significant (0.00). That is, its associated probability is less than 0.05. This meant that the correlation matrix is not an identity matrix which indicates the correlations of the variables (Child, 2006).

Table 27 KMO and Bartlett's Test

Test Item		Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.913
Bartlett's Test of Sphericity	Approx.Chi-Square	1253.263
	df	105
	Sig.	.000

Table 28 Correlation Matrix

	D1.1	D1.2	D1.3	D1.4	D2.1	D2.2	D2.3	D2.4	D3.1	D3.2	D3.3	D3.4	D4.1	D4.2	D4.3
D1.1	1	0.596511	0.557284	0.488286	0.500487	0.478586	0.436774	0.349617	0.380516	0.353664	0.279159	0.485587	0.229332	0.219737	0.154624
D1.2	0.596511	1	0.64595	0.469132	0.518428	0.485056	0.499587	0.408323	0.359553	0.360663	0.235168	0.422025	0.225858	0.20561	0.123997
D1.3	0.557284	0.64595	1	0.603092	0.672493	0.601333	0.56117	0.419955	0.488738	0.424165	0.342726	0.544085	0.281005	0.181517	0.127589
D1.4	0.488286	0.469132	0.603092	1	0.638525	0.6789	0.615696	0.39855	0.557608	0.479276	0.529724	0.575223	0.310497	0.318305	0.229895
D2.1	0.500487	0.518428	0.672493	0.638525	1	0.609836	0.593359	0.310855	0.545486	0.467282	0.496022	0.59959	0.283568	0.239299	0.176411
D2.2	0.478586	0.485056	0.601333	0.6789	0.609836	1	0.654901	0.388238	0.532689	0.468398	0.434218	0.531204	0.143808	0.207807	0.071277
D2.3	0.436774	0.499587	0.56117	0.615696	0.593359	0.654901	1	0.50568	0.56181	0.586561	0.521564	0.507595	0.397642	0.350379	0.239538
D2.4	0.349617	0.408323	0.419955	0.39855	0.310855	0.388238	0.50568	1	0.340292	0.347672	0.295434	0.392352	0.303511	0.312876	0.297694
D3.1	0.380516	0.359553	0.488738	0.557608	0.545486	0.532689	0.56181	0.340292	1	0.663647	0.565096	0.551568	0.270921	0.304684	0.188327
D3.2	0.353664	0.360663	0.424165	0.479276	0.467282	0.468398	0.586561	0.347672	0.663647	1	0.580598	0.512755	0.299691	0.328204	0.255017
D3.3	0.279159	0.235168	0.342726	0.529724	0.496022	0.434218	0.521564	0.295434	0.565096	0.580598	1	0.546307	0.296523	0.282532	0.293632
D3.4	0.485587	0.422025	0.544085	0.575223	0.59959	0.531204	0.507595	0.392352	0.551568	0.512755	0.546307	1	0.273386	0.35221	0.281402
D4.1	0.229332	0.225858	0.281005	0.310497	0.283568	0.143808	0.397642	0.303511	0.270921	0.299691	0.296523	0.273386	1	0.683346	0.646395
D4.2	0.219737	0.20561	0.181517	0.318305	0.239299	0.207807	0.350379	0.312876	0.304684	0.328204	0.282532	0.35221	0.683346	1	0.657166
D4.3	0.154624	0.123997	0.127589	0.229895	0.176411	0.071277	0.239538	0.297694	0.188327	0.255017	0.293632	0.281402	0.646395	0.657166	1

3. Confirmatory Factor Analysis (CFA)

The CFA method was used to confirm if the observed variables based on previous researches were defined in each intended constructs (factors) of the proposed model of effective UIJRPTT in Thailand. First, the individual constructs of characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2), joint research mechanism (D3) and effective UIJRPTT (D4) and their items were defined. The measurement model of the constructs was specified to represent the relationships between items and the constructs. LISREL 8.8 program was used in conducting the CFA by generating factor loading for each item in relation to the construct and indicating the model fit by comparing the theoretical measurement model with the sample model. The factor loadings which are the product of matrix of regression coefficient were used to assess the validity of the measurement model because they reflect the items contribution to their latent construct. This research valued that the item with the factor loading greater than 0.30 was considered acceptable. The reliability of the measurement model was assessed by square multiple correlation coefficient (R^2) which provided information on how much variance the factors accounted for in the observed variables, as well as construct reliability (ρ_c) and average variance extracted (ρ_v). Others indices used to test the fit of constructs in the measurement model included chi-square (X^2) Goodness of Fit Index (GFI), and Root Mean Square Error of Approximation (RMSEA).

The measurement model of the four constructs: characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2), and joint research mechanism (D3) and the effective U-I joint research (D4) firstly appeared bad fit (Chi-square=147.62, df=84, p-value=0.000 RMSEA=0.071). After many modifications including adding constraints, modifying constraints and fixing constraint coefficients, as a result, the revised model had acceptable goodness-of-fit indices: RMSEA=0.016 Standardized RMR =0.052 GFI=0.92 AGFI=0.90 CFI =1.00. While the Chi-square was reduced to 91.39 with df =88 and p-value=0.38 as well as the X^2/df values were situated below 2. All indices offered evidence that the model fit the data well. The results indicated that the observed variables in each factor were representative of its factor. Most of them had the estimated factor loading (regression weight) from 0.40 to 0.62 but not higher than 0.7, which was considered weak to moderate indicator of the factor, with significant t-value at the 0.01 level. The variables namely D2.2, D2.3, D2.1 and D4.2 had highest factor loadings of 0.62, 0.62, 0.60 and 0.60 respectively whereas D2.4, D1.1, and D1.2 had low factor loadings, 0.40, 0.45 and 0.45 respectively, indicating weak indicator of its factor. The revised model was utilized for path analysis of the model in the next section. Figure 12 illustrates the revised outcome from the CFA of the 4 factors and 15 associated variables with factor loadings.

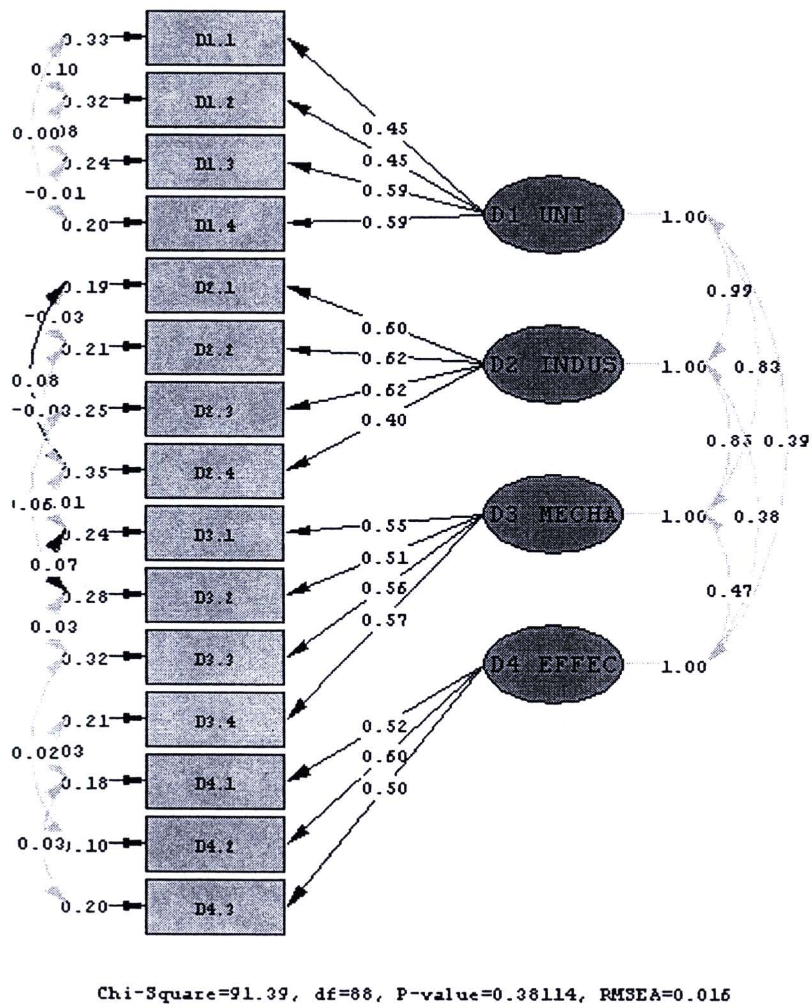

Figure 12 Confirmatory Factor Analysis with Estimated Results

Table 29 Analysis Result of Confirmatory Factor Analysis of Three Constructs of Measurement Model

Variables	Parameters of Matrix									R^2
	D1			D2			D3			
	λ	SE	t	λ	SE	t	λ	SE	t	
D1.1	0.45 (0.62)	0.05	8.21***							.38
D1.2	0.45 (0.62)	0.05	8.39***							.39
D1.3	0.59 (0.77)	0.05	11.23***							.59
D1.4	0.59 (0.80)	0.05	11.90***							.64
D2.1				0.60 (0.81)	0.04	12.12***				.66
D2.2				0.62 (0.80)	0.05	11.91***				.64
D2.3				0.62 (0.77)	0.05	11.45***				.60
D2.4				0.40 (0.55)	0.05	7.10***				.31
D3.1							0.55 (0.75)	0.03	10.28***	.56
D3.2							0.51 (0.69)	0.03	9.24***	.48
D3.3							0.56 (0.70)	0.05	9.48***	.50
D3.4							0.57 (0.78)	0.05	10.90***	.61
	D4									
	λ	SE	t							
D4.1	0.52 (0.77)	0.04	10.62***							.60
D4.2	0.60 (0.88)	0.04	12.39***							.78
D4.3	0.50 (0.74)	0.05	10.01***							.55

Note: λ = factor loading (standardized factor loading) SE=standard error (<0.03 preferable), t-value >1.96, p<.05 (*), t-value>2.58, p<.01 (**), t-value>3.29, p <0.001(***) R^2= (>0.50 preferable)

Under the Measurement Equations heading, the estimated loadings appeared along with standard errors, t-values, and squared multiple correlation coefficients (R^2). In this case the entire factor loading estimates was significant. The estimated weights are highly sensitive to model constraints, whereas the standardized regression weights provide more intuitive information about the loadings. The squared multiple correlations (R^2) provided information on how much variance the factors account for in the observed variables. D1.1, D1.2, D2.4, and D3.2 had a low R^2 of only 0.38, 0.39, 0.31 and 0.48 and most of standard error number were higher than 0.03.

Therefore, the analysis and summary should be more careful in applying the data results. The remaining R^2 statistics of each variable were higher than 0.50 which were acceptable which indicated that the construct could well explain the variance of observed variables. Table 29 and 30 shows the CFA analysis results of the measurement model of the four construct and their construct reliability and the average variance extracted.

Before further analysis, an assessment of the reliability and validity of construct was required. Reliability refers to the absence of random errors in the measurement (Zikmund, 2003) that ensures consistent, accurate and predictable findings (Kinnear, et al., 1993). Reliability was assessed by means of Cronbach's alpha and composite reliability. Construct reliability is estimated using information on item loadings and error variances (Diamantopoulos and Siguaw, 2000). Convergent validity refers to the correlation between different measurements for the same phenomenon (Kinnear, et al.,1993) which was determined by means of the average variance extracted. The score indicate the items account for a considerably larger degree of variance than the measurement error (Diamantopoulos and Siguaw, 2000). The construct reliability (ρ_c) and the average variance extracted (ρ_v) of the measurement constructs namely characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2), joint research mechanism (D3) was above 0.60 and above 0.50, indicating that the constructs were highly reliable. Table 30 presents the analysis results of the four constructs of measurement model under confirmation factor analysis. Therefore, the CFA confirmed the conceptual model construct of the three enabling factors and outcome factors and their fifteen variables. The following section provided the structural path analysis of the model to confirm the model causal paths between the factors.

Table 30 Construct Reliability and Average Variance Extracted of Measurement Model

Variables	Construct Reliability (ρ_c)	Average Variance Extracted (ρ_v)
D1	0.797	0.500
D2	0.827	0.550
D3	0.821	0.535
D4	0.842	0.641

Note: The construct reliability (ρ_c) greater than 0.60 and the average variance extracted (ρ_v) greater than 0.50 are acceptable (Angsuchoti, Wijitwanna, and Pinyopanuwat, 2008).

4. The Path Model

As subset of SEM, path analysis is the statistical technique used to examine causal relationship between two or more variables and understand comparative strength of direct and indirect effect among a set of hypothesized variables. However, the "causal" or path way in the model represent the hypotheses of researchers and if the result from the technique supports the propositions, it does not prove that the causal assumptions are correct. Rather, the result from path analysis is the test of validity of the model construct that indicates whether the data collection supports the hypotheses or not (Angsuchoti, Wijitwanna, and Pinyopanuwat, 2008). The principle of path analysis is the construct of the structural model and tests it with the collection of data to evaluate the hypothesized relationships in the model by examining the significance of the path loadings among the constructs.

From the CFA results in the previous section, the structural model for further path analysis were constructed with the observed variables (indicating in square), latent variables (indicating in circle), and arrows that show assumed causal relations. The independent (X) variables are called exogenous variables. The dependent (Y) variables are called endogenous variables. In the path model, characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) were exogenous variables and the effectiveness of U-I joint research (D4) was endogenous factor. The other sub-factors were observed variables. Error terms ("disturbances" for latent variables) are included in the SEM diagram, represented by "D's" for X variables and "E's" for Y variables. The error terms represent residual variances within variables not accounted for by pathways hypothesized in the model. The parameters indicating direct effects are the variances, regression coefficient and covariance among variables. Regression coefficients are represented along single-headed arrows that indicate a hypothesized pathway between two variables. Covariance is associated with double-headed, curved arrows between two variables or error terms and indicates no directionality.

The structural model appeared bad fit (Chi-square=143.96, df=84, p-value=0.000 RMSEA=0.071). After many modifications including adding constraints, modifying constraints and fixing constraint coefficients, the revised structural model showed an acceptable fit based on the given goodness-of-fit criteria: RMSEA=0.020 Standardized RMR =0.055 GFI=0.92 AGFI=0.90 CFI =1.00. All indices offered evidence that the model fit the data well. The Chi –square test yielded a value of 100.84 with df = 95, X^2/df values =1.06 and a corresponding p-value of 0.32, higher than 0.05 indicating non significance. Considering the standardized path coefficient which indicated the direct effect of a variable assumed to be a cause on another variable (Foster, Barkus, and Yavorsky, 2006), the results showed that characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) exerted an effect on effective UIJRPTT (D4) indicating the relationship between the factors and the outcome factor. The path from D1 to D4 was a direct effect with a standardized path coefficient of 0.47. The path from D2 to D4 was a direct effect with a standardized path coefficient -0.60. The path from D3 to D4 was a direct effect with a standardized path coefficient of 0.62. Figure 13 illustrates the path diagram of the effective UIJRPTT structural model.

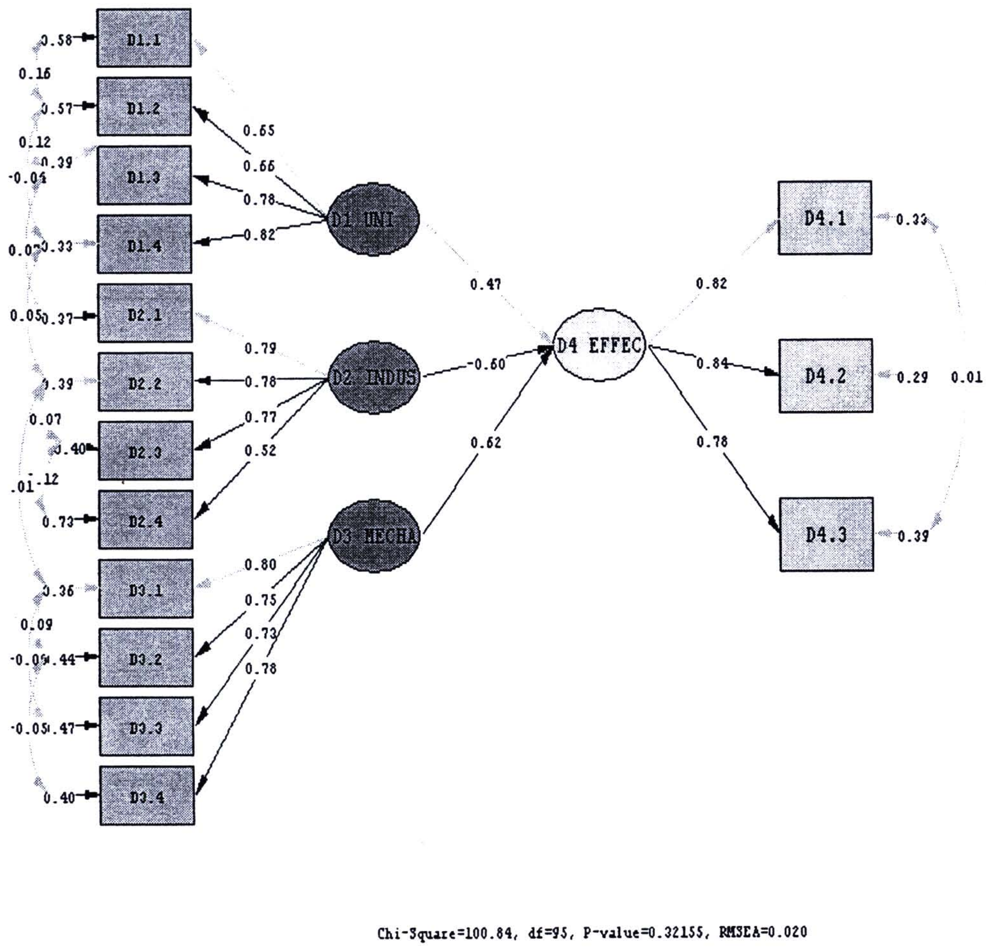

Figure 13 Final Model of Effective UIJRPTT with Standardized Factor Loading and Path Coefficient

All paths had path coefficient at the significant level of 0.05 for D1 to D4 and D2 to D4 and of 0.01 for D3 to D4. This meant that the effective UIJRPTT(D4) was significantly influenced or affected by the three factors. The direct effect mostly was from joint research mechanism (D3) followed by characteristics and perspectives of the industry (D2) and characteristic and perspectives of the university (D1). Therefore, in order to promote the effective UIJRPTT, the three factors and their variables should be supported. From the R^2, it meant that the three factors could explain the variances of the effective UIJRPTT with the prediction power of 23%. The summary of the path coefficient and significance level is provided in Table 31. The effective UIJPRTT model could be specified by the following path equations:

$$Y = .26(D1)+-.33(D2)+.34(D3)+0.23 \quad (1)$$

$$Z_Y = .47(Z_{D1})+-.60(Z_{D2})+ .62(Z_{D3}) \quad (2)$$

where Y is the effective UIJRPTT (D4).

Table 31 Estimated and Standardized Path Coefficient and Significance Level

Paths	Structural Equation (standardized structural equation)	Path Coefficient (standard coefficient)	t-value	R^2
DI to D4	.26(D1) [.47(Z_{DI})]	0.26 (0.47)	-2.16*	0.23
D2 to D4	-.33(D2) [-.60(Z_{D2})]	-0.33 (-0.60)	2.16*	
D3 to D4	.34(D3) [.62(Z_{D3})]	0.34 (0.62)	5.59***	

Note: t-value >1.96, p<.05 (*), t-value>2.58, p<.01 (**)t-value>3.29,p<0.001(***)

5. Model Development and Hypotheses Support

The conceptual model and related hypotheses, developed on the literature review, were tested by utilizing the result and analysis of the CFA and path analysis in the previous section. As a result, the model of effective UIJRPTT was developed. As shown in Table 29 and 31, the CFA and path analysis provided support for the research hypotheses. The hypothesized relationship and linkages between the factors: characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) and the effective UIJRPTT (D4) as outcome factor and all 15 variables were confirmed. The effective UIJRPTT was found to be significantly influenced by the three factors. Joint research mechanism (D3) appeared to have rather strongest direct impact on the effective UIJRPTT. All factor loadings of each 15 observed variables had significant level of 0.001. The detailed elaboration of the findings which support the model development and hypothesis was as followed:

Characteristics and perspectives of university (D1): The results showed that characteristics and perspectives of university (D1) significantly influenced the effective UIJRPTT ($p<0.05$), providing support to the conceptual model. The estimated direct effect of D1 to D4 revealed a standardized coefficient of 0.47, but weak estimated coefficient of 0.26. The university' willingness and motivation to work with the industry with shared value (D1.4) was the most influential factor from D1 to the effective UIJRPTT with standardized factor loading of 0.82, followed by the university's adequate tools and equipments (D1.3) with standardized factor loading of 0.78, adequate specialists, researchers and students (D1.2) with standardized factor loading of 0.66, and the university capability in receiving and transferring the knowledge and technology in terms of technique and funds (D1.1) with standardized factor loading of 0.65.

Characteristics and perspectives of industry (D2): The results showed that characteristics and perspectives of industry (D2) significantly affect the outcome factor ($p<0.05$), confirming the hypothesized conceptual model path, with the standardized path coefficient of -0.60 and estimated path coefficient of -0.33. The negative influence of the D2 on the outcome factor could be explained with the behavior of the industry. Negative and low level of the characteristics and perspectives of the industry could reflect to the level and degree of cooperation. The negative perspective of the industry on the joint research, the low degree of commitment of the industry could affect the effective UIJPRTT. From the results, the industry's capability in receiving and transferring technology in terms of technique and funds (D2.1) was significantly essential to the effective UIJRPTT with the standardized factor loading of 0.79, followed by the willingness and motivation in working with the university with shared value (D2.2) with the standardized factor loading of 0.78, the perspectives on worthiness and value of joint research in terms of economic and intelligence value (D2.3) with the standardized factor loading of 0.77 and industry's understanding of cultural differences (D2.4) with the standardized factor loading of 0.52.

Joint research mechanism (D3): The results showed a positive influence of joint research mechanism (D3) on the outcome factor ($p<0.001$). The direct standardized path coefficient was 0.62 and estimated path coefficient was 0.34. The results confirmed that joint research mechanisms including, communication effectiveness (D3.1) was significantly influential to the effective UIJRPTT with the standardized factor loading of 0.80, followed by incentive system from the government and university (D3.4) with the standardized factor loading of 0.78, management of coordination office and joint research program (D3.2) with the factor loading of 0.75, and IP management (D3.3) with the standardized factor loading of 0.72. The mechanism involved all stakeholders – university, industry and government, to create robust bonds in improving and enhancement the performance of mechanisms.

Effective UIJRPTT (D4): The results showed that the effective UIJRPTT could be achieved through the three factors namely: characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3). The effective UIJRPTT could create the growth of the UJRPTT, and enhance the quality performance (i.e less rework, innovation production and process, better quality of research results) and economic performance (i.e. less investment in resources, less time in conducing research and IP rights).

In sum, the final model of effective UIJRPTT was formed to help the university and industry as well as the government and stakeholders to better understand the factors and variables and their interrelations and significance. The results of the model development could be further used to point out the existing status and identify the possibility in developing the factors in the model which was conducted in the next section.

Evaluating Current Status of Factors in the Effective UIJRPTT Model

In order to evaluate the current status of the model variables related to characteristics and perspectives of the university and industry and the joint research mechanism, the respondents were asked in the questionnaire to rate their view on the current status of the variables in those factors in five Likert scale. Overall respondents rated all factors in moderately satisfactory/adequate status. The highest average mean values among the three factors was characteristics and perspectives of industry (D2) with average of 3.38 scores, followed by the characteristics and perspectives of university (D1) with average of 3.34 score and joint research mechanism (D3) with average of 3.16 scores. The highest and lowest scored variables were summarized as followed:

1. The three highest scored variables were:

1.1 University willingness and motivation to work with industry (D1.4) with the average mean of 3.52;

1.2 Industry capabilities and funds (D2.1) with the average mean of 3.46;

1.3 Industry willingness and motivation (D2.2) with the average mean of 3.42.

2. The three lowest scored variables were:

2.1 Incentive system (D3.4) with the average mean of 3.10;

2.2 IP management (D3.3) and Management of coordination office and joint research program (D3.3) with the average mean of 3.12;

2.3 Adequate research tools and equipment (D1.3) with the average mean of 3.15.

The respondents viewed that university had willingness and adequate specialists, researcher and students working on photovoltaic technology while the industry was equipped with capabilities, fund and willingness to work together despite there were other obstacles impeding the cooperation for U-I joint research. However, the perception on current status of the joint research mechanism may be problematic because overall respondents evaluated the variables in this factor as low satisfactory status. The incentive system was rated lowest despite in the satisfactory status, followed by the IP management and coordination office and joint research program. The university appropriate tools and equipment was rated lowest among all university variables. The results supported the quantitative results in part two by which the interviewees cited that the university lacked of tools and equipment due to lack of funds.

University respondents rated all factor variables in the adequate/satisfactory status. Interestingly, the characteristics and perspectives of university (D1) was rated highest with the average score of 3.44 and the characteristics and perspectives of industry (D2) was rated lowest with the average score of 3.27. All variables from twelve variables were rated in adequate/satisfactory status with the average mean value range of with the range of 3.17-3.64. The highest and lowest scored variables rated by the university respondents were summarized as followed:

1. The three highest scored variables were:

1.1 University willingness and motivation to work with the industry (D1.4) with the average mean of 3.64;

1.2 Adequate specialists, researchers and students (D1.2) with the average mean of 3. 50;

1.3 University capabilities and funds (D1.1) with the average mean of 3.40.

2. The three lowest scored variables were:

2.1 Industry's understanding of differences in culture (D2.4) with the average mean of 3.17;

2.2 Adequate research tools and equipment (D1.3) with the average mean of 3.21;

2.3 IP management (D3.3) with the average mean of 3.22.

The results reflected the university had adequate knowledge base and adequate specialists, researchers and students and was ready for working with the industry through its capabilities and funds. The university respondents rated lowest scores to the characteristics and perspectives of industry. However, interestingly, the university respondents rated low score also to the industry understanding of differences in culture which could reflect the blame game between the university and industry.

The industry rated all factors in adequate/satisfactory status. The characteristics and perspectives of industry (D2) was rated with the average highest mean scores of 3.56, while characteristics and perspectives of university (D1) and joint research mechanism (D3) were rated unsatisfied with the mean scores of 3.16 and 2.91. Nine variables from twelve variables were rated in adequate/satisfactory status with the average mean value range of 3.03-3.64 whereas three variables were rated in adequate but relatively poor status with the range of 2.61-2.94. The highest and lowest scored variables rated by the industry respondents were as followed:

1. The three highest scored variables were:

1.1 Industry capabilities and funds (D2.1) with the average mean of 3.64;

1.2 Industry willingness and motivation in working with university (D2.2) with the average mean of 3.6;

1.3 Industry perspectives on worthiness and value of joint research (D2.3) with the average mean of 3.44;

2. The three lowest scored variables were:

2.1 Incentive system (D3.4) with the average mean of 2.61;

2.2 Management of coordination office and joint research program (D3.2) with the average mean of 2.80;

2.3 IP management (D3.3) with the average mean of 2.94.

The results reflected that the industry was willing to work with the university. It also had adequate knowledge base and viewed the importance of the U-I joint research. The industry respondents were rated the lowest scores to the variables in the joint research mechanism particularly from the university and government incentive and support. This may reflect the industry's perceptions that the effective UIJRPTT required the government roles in supporting incentive funds in forms of policy and funds, that they viewed inadequate. Moreover, the management of coordination and joint research program and IP management may be viewed by the industry respondents that they should be improved. The results were presented in Table 32.

From the results, it could be noticed that the university and industry respondents commonly perceived that: (1) most variables were evaluated in moderately satisfactory/adequate status; (2) most variables in joint research mechanism was rated by the university and industry lower than other variables in other two factor groups showing that the factor was in relatively low satisfactory status and could be problematic; (3) both university and industry evaluated they had capabilities and willingness to work with each others which was the good qualification that should be further developed; (4) some variables such as IP management, incentive system, management of coordination office and joint research program and adequate research tools and equipment were rated as lowest scored variables, therefore, all stakeholders should find the way to improve the situation; and (5) the different perceptions on the current status of incentive system could be worth to mention. The mean value of incentive system by university and industry was 3.38 and 2.61. This meant that the industry viewed that the variables was unfavorable and should be improved whereas the university may not take more intensive roles in lobbying for more incentives system for the conduct of UIJRPTT. The following section detailed the confirmation of the model factors and discussed the practical issues and action related to each variables to refine the effective UIJRPTT model.

Table 32 Comparison of Mean in Evaluating the Current Status of Model Factor

Code	Descriptions	University (n=96)		Industry (n=54)		Overall (n=150)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
	Enabler						
D1	**Characteristics and perspectives of university**	**3.44**	**.94**	**3.16**	**.77**	**3.34**	**.89**
D1.1	Capability in receiving and transferring technology & funds	3.4	.82	3.1	.63	3.33	.77
D1.2	Adequate specialists, researchers and students	3.5	.98	3.2	.80	3.40	.93
D1.3	Adequate research tools and equipment	3.21	.97	3.03	.91	3.15	.95
D1.4	Willingness and motivation in working with industry	3.64	.99	3.29	.76	3.52	.93
D2	**Characteristics and perspectives of industry**	**3.27**	**.77**	**3.56**	**.80**	**3.38**	**.79**
D2.1	Capability in receiving and transferring technology & funds technique and funds	3.36	.69	3.64	.70	3.46	.71
D2.2	Willingness and motivation in working with university with shared value	3.32	.81	3.61	.78	3.42	.81
D2.3	Perspectives on worthiness and value of joint research	3.25	.80	3.50	.88	3.34	.84
D2.4	Understanding cultural difference	3.17	.79	3.51	.86	3.3	.83
D3	**Joint Research Mechanism**	**3.31**	**.90**	**2.91**	**.90**	**3.16**	**.92**
D3.1	Communication effectiveness	3.38	.88	3.20	.91	3.32	.89
D3.2	Management of coordination office and joint research program	3.25	.89	2.8	.94	3.12	.92
D3.3	IP management	3.22	.93	2.94	.76	3.12	.88
D3.4	Incentive System	3.38	.91	2.61	.99	3.10	1.0

Practical Issues and How to Improve the Factor in the Effective UIJRPTT

The in-depth interviews focused primarily on the factors highlighted by asking the question of: What are the factors affecting the effective UIJRPTT in Thailand? What are needed from the industry or the university or the government? What should be changed? The interview findings clearly substantiated the importance of the given factors in the effective UIJRPTT model and the discussion on practical issues and actions in each factor to develop and refine the effective UIJRPTT model.

1. Characteristics and Perspective of University

1.1 University Extensive Capabilities and Fund

University extensive capabilities and fund was confirmed by the interview data as an essential element that could lead to the effective UIJRPTT. This was consistent with the quantitative data results and literature. The university knowledge and expertise could immensely benefit the industry in many aspects. In photovoltaic cell development, the discovery of new material or breakthrough to increase the efficiency of the photovoltaic cells and system even 1% could trade off between efficiency and cost (I#1, I#3). The university's knowledge on basic research, nature of physics and materials could help solve the industry problems (I#6, I#12). The ability of the university in testing and BOS system development could help the industry reduce cost and increase efficiency (I#5, I#11). The acquisition of the technology, from the Thai university, was viewed that could be cost-effective for the industry. The university extensive knowledge base was influencing the effective UIJRPTT in the way that the industry which would decide to invest in the UIJRPTT would consider whether the university had enough knowledge and credibility. Moreover, in achieving the quality of the UIJRPTT, the ability of the university to integrate the knowledge in the fields related to photovoltaic technology and system and to specialize in key specific area was necessary (I#1, I#3, I#4, I#9).

However, according to the industrial interviewees, as discussed before in part two, there were obstacles to enhancing the capabilities and extensive knowledge of the university such as the inability of the university in integrating the knowledge within the university faculties and laboratory and other university (I#3), lack of experience specialists and technology developers (I#1), and insufficiency of university knowledge on specific area due to limited human resources (I#4). Moreover, the potential of the university knowledge and research results conducted were largely undermined and unexploited at least in practice (I#6, I#13). The important issue was how to exploit those research results to be benefited to both university and industry (I#6, I#13) and how to attract both university and industry to work together since the beginning to satisfy the research and development objective of both sides (I#1).

In order to develop the effective UIJRPTT, the interviewees viewed the need to improve the university knowledge which was the basis for further effective UIJRPTT that could be done by:

1.1.1 Implementing human resource development plan detailing how many of faculty members, researchers and students needed for the photovoltaic research and development in the country and university level (U#45);

1.1.2 Developing and upgrading the capabilities of the faculty members, researchers and students by supporting research and utilize their knowledge for technology transfer (U#33,U#36);

1.1.3 Increasing courses in renewable energy and photovoltaic technology to increase the number of students and enhance faculty members' knowledge base (U#26, U#43);

1.1.4 Pooling resources and research efforts within the university faculty and between the university and government institutes to allow opportunities of academics to gain more experience in researching (I#3);

1.1.5 Supporting research in specific part/area of photovoltaic which could respond to the need of the industry (U#15, I#1). Those areas included: heat transfer, polymer, vacuum, chemistry which needed the multi-field of specialists in machinery engineering, chemistry, physics, and material sciences.

Besides the extensive knowledge of the university, it was obvious that university with funds could influence the increase of the effective UIJRPTT. University respondents confirmed that the criteria of the funding agency such as TRIF, NRTC and NSTDA could encourage the UIJR. The development of photovoltaic technology in the university was largely undertaken with assistance and funds from the

NRTC and the NSTDA. But, as discussed in the previous part, the problem was that the fund was scattered and too little in conducting the large scale research. The interviewees stated that there was thus a need for the government funding agencies to substantially increase their funding support. Many faculty members accepted that they had to write many proposals to various organizations to apply for grants. Special collaborative program funding of TRIF, NRTC and NSTDA and other governmental ministries concerned should be more available to encourage the effective UIJRPTT and monitor the funds granted to university projects with streamline directions and technology roadmap (U#43, U#45, I#6).

1.2 Adequate Human Resources

Qualitative data confirmed that the UIJRPTT required an adequate human resource base. This was consistent with the quantitative data and the literature. The impact of adequate human resources in university was pointed high. The interviewees stated that some laboratories were facing insufficiency of manpower with long term experience in specific area of research (I#7, I#13, I#11). As discussed in the previous part was that the faculty did not have adequate time to conduct research due to the fact that there was limited number of key persons in the research laboratory and there was little number of professional researcher and students. Without adequate human resource, research teamwork could not be established and the ability of the research team could not be utilized in the larger scale research.

Realizing the importance of human capital, and adequacy of human capital base in the university, the interviewees proposed that the university should:

1.2.1 Produce and recruit more scientists, capable engineers and technology developer in the photovoltaic related technology to work as faculty members and researchers to build up capable human resources with long term plan (I#6);

1.2.2 Promote the awareness and interest of public and students in learning and studying the photovoltaic technology which would allow people to interest more in studying and researching photovoltaic technology and as a result would enhance the support from the university and government (U#33,U#36);

1.2.3 Increase number of professional researcher (U#19, U#24) to work with the faculty members who lacked of time;

1.2.4 Improve the career path and working condition of the professional researchers to attract more scientists and researchers to work with the university in long term to solve the problem of inadequate specialist in the university (U#19, U#21, U#22, U#24). Moreover, some research ranking attached to the TTO should be given to the researcher in the laboratory or research units. The TTO staff ranking should be reconsidered as administer (U#45).

1.3 Adequate and Appropriate Tools and Equipment

Strong evidence from the interview data supported the importance of the adequate and appropriate tools and equipment. The industry interviewees stated that they needed tools and equipment of the university because it was not worth investing buying an equipment for only one purpose but they could gain advantage from the fund of the university in buying the equipment. The university could gain benefit from those equipment for teaching and instructing. However, the university either had the problem of lacking fund to buy equipment and sometimes it viewed that it was not necessary to buy machinery. The improvement was suggested by the interviews that:

1.3.1 Pool resources and equipment of university-university, university-industry, university-government institute-industry should be supported to allow more opportunities to invest and reduce the repetition in equipment purchase. Each side should be more open minded in allowing and facilitating using research equipments (I#9, I#10).

1.3.2 Collective long term planning of research work and projects related to photovoltaic technology among universities should be supported. The long term plan would identify the research plan, allocation and division of research work and indicate tools and equipments needed for research investment in systematic way (I#6, I#17);

1.3.3 Tools and equipment in the university should be appropriate for producing the research prototype. The pool equipment may allow opportunity for university to upgrade larger scale equipment and tools that benefit the work of the industry (U#36, I#1);

1.4 Willingness and Motivation of the University

The university respondents stated that the relationship between the faculty and industry was built between people. The importance of the willingness and motivation for the effective U-I joint research which emerged from the interview data validated the conceptual framework of the model. The interviewees defined qualification that individual university academics should have for the effective UIJRPTT which included (1) everybody should help each others to accomplish a project to the end (U#6) , (2) having passion for research work (U#1, U#7), and (3) believing in what they want to do (U#1). Those were the energy source of relationship and commitment. The interviews revealed evidence that the university individuals were willing to work with the industry but also required the ability to work with freedom in promoting their idea, project or relationship (U#23, I#12). The findings substantiated that the mentioned issues affected highly to willingness and motivation that was important for the effective U-I joint research.

2. Characteristics and Perspectives of Industry

2.1 Adequate Knowledge Bases and Funds

Adequate knowledge base and funds of the industry was confirmed by the qualitative data analysis as the key factor for the effective UIJRPTT. The investment in R&D to be profitable embodied industry's human knowledge base and capital. In the workplace, capable and skillful engineers, scientists and staffs could enhance technological progress in the factory in adapting the sophisticated photovoltaic technology for product and process development (I#5, I#12). The capabilities, skills and experience of the industry staffs could be utilized in the process of setting up research question, and conducting the research (I#9). Some industry respondents revealed that the research question, normally, came out from the analytical skills and capabilities of industry staffs in evaluating of the necessity of the research work and where to conduct the research (I#11, I#12). In case that the firm needed to conduct research outside the factory, the R&D team would search out university research works and proposed the management team whether the university knowledge, equipment and funds were appropriate.

In respect of human capability build-up, the photovoltaic firms motivated their human resources to pursue higher studying, researching and training to acquire additional cognitive and adaptive skills (I#10, I#14). Some firms supported their staffs to study further to gain PhD and conduct the research theme that relevant to the firms needs to find solutions viewing the benefits from the research results and the cooperation with the university' faculty experience and equipments (I#14). The need for special vocational course (I#10, U#17), technical training (U#23, I#7), subsidies and grants for industry research (I#13, U#23) was indicated by both university and industry interviewees that could help increase the level of their staffs' knowledge base and capabilities that needed for further conducting research.

The level of fund was indicated by the industry interviewees (I#11,#12, I#13) that it was depended on the necessity of the research. If the research was needed and firms had the income, the firm would allocate some funds for the research works possibly preferred to conduct in the factory. If the research needed a huge of investment, it would consider conducting joint research with the university or institutes that could raise funds. Grants from the government were therefore needed to decrease the risk for the industry's research investment and cover the sunk cost.

2.2 Willingness and Motivation of Industry

The industry revealed that they had willingness to work with the university. The willingness and motivation of the industry was based on two factors. First, when the owner of the firm or the CEO viewed that the research work was needed after considering benefit and cost (I#2, I#3). Second, when the R&D team proposed that the research works was necessary for the problem solving and improve the efficiency of the cells and module. The R&D team would propose the short and long term research plan to the CEO for decision (I#12). The industrial visionary leader was therefore confirmed by an industry interviewee as crucial. The leader should look outward and view the importance of research to own technology. The role of the CEO was important as one interviewee summarized: "The owner and CEO should be a visionary leader. If the owner and CEO view that once they find the problem, they look at the list of experts and specialist in the university and go to meet them. The cooperation would be higher. But in Thailand, they try to solve their own problems. (U#10)".

To increase the effectiveness of the UIJRPTT, the following issues related to the willingness and motivation of the industry should be focused:

2.2.1 Perception of pool risks by the industry and university would motivate the industry to work more with the university because it could share the investment risk and risk from the research failure. University was also viewed that it should not think of gaining profit from research (I#3, I#4);

2.2.2 Increase of personal relationship between university and industry that pave the way for future collaboration in U-I joint research (I#9);

2.2.3 Support from the visionary industrial leader in motivating the U-I relationship and working (I#3, I#12).

2.3 Perspectives on Worthiness and Value of Joint Research

Perspectives on worthiness and value of joint research from the industry side were confirmed as key driver for the effective UIJRPTT. The industry interviewees stated that the drive for the R&D was the competitiveness and the survival of the photovoltaic firms. The decision to undertake R&D rested largely on whether or not the firm's profit can be improved by the R&D results (I#3, I#11). The interviewees viewed that the firm invested in R&D if there was a great risk that not doing so may lead to a loss in profit (I#3, I#4). However, in the presence of positive externalities from the R&D such as in the form of the U-I joint research, purely private decision from the photovoltaic firms may result in underinvestment due to lack of funds and motivation. Moreover, small firms cannot afford the R&D that entailed huge financial outlays (U#45). Sunken cost such as cost of experiments, testing and instrumentation laboratory may not be recovered while the success of the experiment was not guaranteed and proven credibility. Therefore, the industry interviewees (I#15) viewed that the government should intervene by providing funds, subsidizing or co-financing through R&D support scheme to help ensure adequate investment in new products and process they viewed necessary in increasing the competitiveness and survival. Moreover, support from the government in large scale deployment of photovoltaic was the way for the survival of the business which could bring income and profit that could motivate the industry to work harder for the UIJRPTT (I#8, I#9, I#10).

2.4 Understanding of Cultural Differences

Various respondents agreed that organizational culture differ between university and industry partners that reflected their specific environments of operation. Results thus supported the current literature on university-industry linkages and the quantitative results stressing the effect of a clash of cultures on the relationships, conflicts and barriers and finally affected to the effective UIJRPTT. Therefore, some respondents stated that the industry and university should learn to understand and adjust the organization compatibility regarding goals and objective as well as the similarity in operating philosophy (U#13,U#29,U#43,). The industry should adjust the way they work to be long term plan with specific and clear time frame. The adjustment would help two sides in working together more effectively and contently and in reducing any conflicts from different organization culture. The university should understand the limitation of the industry. The extension and unpunctuality of the project schedule could lead to the loss of market such as the government project and private customer deals that need certificates and test from the university. As a result, it could lead to the industry's bad impression to the university. The university should adjust the way they work to be more business like that focused on quick, flexible and efficient. But still remain the university entity of non profit organization.

3. Joint Research Mechanism

3.1 Adequate and Effective Communications

Communication emerged from the qualitative data as highly important factor for the effective UIJRPTT, confirming the quantitative results in model constructs. The qualitative data analysis clearly underlined the importance of communication, but the communication between the university and industry was viewed not interactive enough to successfully link them together. The respondents viewed that frequent interactions, participation and involvement in interaction and R&D activities of the university and industry was the key for the success of UIJRPTT (I#6, I#10, I#11, I#14). Some industry respondents revealed that classroom communication channel could be the key channel for both university and industry to get acquaintance and learning the area of expertise of the university (I#2, I#3). This process was time consuming but it was considered effective way to learn each other and finally lead to the possibility to work with each other finally. Site visits allowed university researchers to understand the process and production line of the factory (I#9, I#10). The discussion during the site visits could lead to the research question for the two sides to co-work in the future. Some indicated that communication channels allowed opportunities for both university and industry to discuss on what activities they need to do together before conducting UIJRPTT, to discuss what went on, what problems should be solved during the UIJRPTT, and to share lessons learnt after finishing the projects (U#16, U#17, U#18, U#25).

From the qualitative data, university interviewees asserted increase in communication channel and interaction integration to promote the linkage between the university and industry such as:

3.1.1 Create more communication channels and interactions (U#3, U#16, I#11);

3.1.2 Support informal linkages through recreation activities such as sports activities. Acquaintance and informal long term contact would lead to trust and future collaboration (U#7, U#20);

3.1.3 Develop a website that could provide updates on university research theme and success story on photovoltaic technology development and R&D projects as well as list of equipments. Industry needs on R&D should also be posted in the website (U#23);

3.1.4 Encourage training of industry staffs in university and university site visits to industry factory for learning and building of social ties and network (U#22, I#9, I#10).

3.1.5 Continuation of keeping contacts and communications between each side to maintain linkage between each others after the research completion (U#25);

3.2 Adequate and Appropriate Coordination Office and Joint Research Program

The efficient facilitation was cited as necessary for UIJRPTT. It involved the research handling since the beginning, middle, ending and post ending. The adequate and appropriate coordination and working with the TTO through well TTO management had led to the satisfaction and motivation of both university and industry in conducting UIJRPTT. Unfortunately, some firms and faculty members expressed dissatisfaction with the TTO and their personnel by pointing out that the bureaucracy and inflexibility (U#7,U#15,U#23, I#3, I#4). As pointed by the respondents, this had led some faculty avoiding conducting research projects. Some faculty who work in the project felt irritating with the bureaucratic and financial control regulation and system. Some industry mentioned that to avoid any bureaucratic system of university system, they preferred to engage in more informal such as private consulting. The TTO that the author visited were clearly not understaffed, many were busy collecting data needed by several government organizations in funding schemes and university R&D promotion activities but the personnel who directly work with the industry and market the technology and cooperation with the industry was observed understaffed.

From the qualitative data, the respondents expressed the improvement of the TTO and arrangement of the coordination between the university and industry that reflect the importance of TTO roles and management to the effective UIJRPTT as followed:

3.2.1 TTO should have enough human resources in marketing the technology development and activities of the university. The personnel should also be equipped with the data and be friendly and well motivated to service (U#3, U#8).

3.2.2 TTO should work as one stop service to provide information for the industry related to contract arrangement, and IP management and facilitate the work of industry and the university faculty. Too much bureaucratic system and regulation should be removed (U#11,U#15,U#25).

3.2.3 TTO and organization concerned in the university system should consult with the faculty on their needs and how to facilitate more to faculty members in conducting and motivating them to and in conducting the research. TTO also should discuss more with the industry to improve their service (U#7).

3.3 Appropriate IP Management

Confidentiality and IP management was confirmed as a key factor for effective UIJRPTT. Since R&D involved capital costs and increasing returns, if the photovoltaic firms had to invest in R&D with the university under joint research, they needed the mechanism that provide a legal and judicial system for contract performance and adjudication of any contractual disputes. The major issues in IP management related to: (1) the publication of the faculty, students and researcher that should avoid leaking of confidentiality and trade secrecy, (2) intellectual property and benefit allocation should be "fair" for all, and (3) equipment and research results should be clearly indicated the ownership (U#29, I#2). The respondents (U#29, U#43) indicated that, with respect to the good and proper IP management, university and industry would work together with trust and confidence. Many respondents (I#1, I#2, I#17, U#11,U#12, U#13, U#29) viewed that the IP management was well arranged and this matter was clearly written in the research agreement. If the two sides agreed and followed the agreement, the work would be smoothly done. Moreover, the government had provided a legal system and law implementation to protect the IP of the patent holder and licensees (I#2, U#11).

3.4 Adequate Scheme of Incentive System

Many respondents asserted adequate scheme of policy framework and incentive system from the government had a great impact on the effective UIJRPTT. The industry respondents discussed the important roles of the government to facilitate technological progress under the effective UIJRPTT. Beginning with (1) its science and technology plan; (2) industrial policy and foreign investment; and (3) renewable energy market development.

The interviewees (U#23, U#36, I#1, I#8, I#11) viewed that in developed countries namely Germany and the United States of America the photovoltaic industrial technology development was delegated to the industry with and without the support of the government. The government would focus more on R&D projects involving large capital investment. However, in Thailand the photovoltaic industry was relatively incapable in developing its own technology and lack of access to finance. Therefore, the government and university could play a leading role in R&D and technology development. One industrial interviewee (I#14) pointed out the importance of establishing a "national institute for solar cell" in Thailand. The institute should play a crucial role in promoting photovoltaic technology, conducting R&D, providing funds for others organization and promote the usage and application of photovoltaic technology. It was viewed that leadership in innovation, in basic and development research finally could establish the technological and industrial superiority of the country which needed the cooperation of the government, university and industry.

Other interviewees (U#23, I#11, I#13) stated that the R&D activities of NREL, the US national laboratory related to solar energy research, could be a best practice model for Thai government, university and industry to work together for effective technology transfer. The US has invested heavily on photovoltaic R&D and has produced many important photovoltaic related technological breakthroughs. The strength of the US solar R&D program was due to many research strands and full range of R&D from basic to manufacturing researches and focus on collaboration between industry, university and NREL as national laboratory, which included public and private partnership with cost sharing.

Foreign direct investment (FDI), as viewed by the industry and university interviewees, could play an important role in introducing new technology, strengthening technological capabilities, training and development of human resource and increasing export learning. FDI could also bring with it R&D and technology. The interviewee stated that the government should create an attractive environment for the FDI and photovoltaic technology transfer in Thailand (U#7, I#8). However, in order to stimulate the FDI, the domestic market development should be strengthened so that it was attractive enough for production and R&D investment.

The policy designed for demand side to create market need for photovoltaic needs were most cited as crucial in increasing the effective UIJRPT. It was viewed that with the market expansion meant more profits and more R&D development. To accomplish the task, several interviewees (U#15, I#1, I#2, I#8, I#11) strongly stated that the government should consider the issues of environmental degradation and sustainable energy management and implement the long term market-friendly and outward-oriented policies for renewable energy and photovoltaic technology that could provide a stable, predictable environment for the photovoltaic firms and all stakeholders which included customers. The renewable energy market development program in Thailand included the mandatory renewable energy target under the 15 years plan introduced in 2008 and the SPP and VSPP program. It was criticized from the industry interviewees that the target was not ambitious enough to achieve significant production from the photovoltaic. Although the Ministry of Energy plan to increase the proportion of renewable energy usage to 20% in 2022, but the proportion given to the electricity generation from renewable energy which including biomass, hydro, waste, wind, solar and hydrogen was only 2.1% whereas the proportion for NGV usage which had to import and not considered renewable energy was targeted in the renewable energy plan around 8.2%. It was viewed that the government plan in importing energy was a major concern of the interviewees in terms of national energy security despite Thailand was equipped with the energy sources such as sun light and photovoltaic technology and industry support. For the national market development schemes under the SPP and VSPP, it was viewed that the grid-connected incentive had been too short term (10 years), too small for self-sustaining market (with 8 baht/kWh adder) and the process for applying for grid connected was found difficulty in contacting with eight organizations and approved grid-connected projects were not operated. The respondents (I#8, I#14)) viewed that the government should increase the adder for VSPP especially the household unit to attract them to use the photovoltaic roof top and the VSPP household owner should be allow to use tax credit to reduce the income tax that they had to pay. This would help stimulate the market expansion and public awareness on renewable energy. In addition, the industry support policy such as substantial tax and non tax incentive programs, subsidy and loan for photovoltaic market stimulus, government procurement and export support program such as road show were also cited as important to expanding the business and market development that could affect the effective cooperation in UIJRPTT (I#3).

4. Outcome Factors

The purpose of establishing the U-I joint research for photovoltaic technology transfer, as described in the literature, was growth of the U-I joint research, the creation and enhancement of quality performance and economic value; and thus to achieve relationship success. Given the importance of mutual benefits, the data reflected the highly complex nature of value and variety of benefits that might determine perceived value and satisfaction in the U-I joint research for photovoltaic technology transfer. Aiming at the determination of value in the given context, interview findings revealed that the two sides perceived different outcomes as beneficial, confirming the appropriateness of employing quality performance and economic value.

For technology development, there were possibilities that the industry would collaborate more with the university partly because the industry could not conduct the research in all parts by them. In terms of the benefit from the effective UIJRPTT, the respondents viewed that the extensive knowledge base of the university in those relevant parts could increase the overall energy produced, shorten energy pay-back time of the system and enhance flexible design of the application works of photovoltaic.

With regard to the likelihood that the U-I joint research would be renewed at the end of the current contract and led to further growth of the UIJRPTT, the interviewee, for example, described the intention to stay in and continue the relationship as the most cited outcome for the university respondents. The industry also named the continuation of a relationship as important, which was based on familiarity, plan for investments and capabilities of the university.

In sum, this section provided the data and highlights of the interviews related to the factors and how to improve the factors in the effective UIJRPTT model. The results revealed that the interviewees confirmed the importance of the factors and variables in the effective UIJRPTT model. Moreover, they identified the practical issues and actions to enhance the effective collaboration under the U-I joint research for photovoltaic technology transfer through each variable. Due to the fact that the actions and practical issues derived from the qualitative data could be beneficial to all stakeholders and could help equip the quantitative effective UIJRPTT model with concrete guidance and suggestions from the university and industry respondents, the summary of the actions and practical issues was added into the table with all the model factors and variables. Table 33 shows all the detail of the refined effective UIJRPTT model.

Discussion

From the quantitative and qualitative results, characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) were confirmed as primary factors affecting the effective UIJRPTT. The results validated the significant focus of technology transfer literature and U-I collaboration. Despite rated in the adequate status; the qualitative data analysis indicated there were more rooms to improve the adequacy and reduce the deficiency of the variables. The following was the discussion of the research results on each factor.

1. Characteristics and Perspectives of University and Outcome Factor

Characteristics and perspectives of university (D1) were confirmed as the predictor of effective UIJRPTT and exhibited the relatively moderate effect throughout the data analysis. The quantitative results indicated the relationship between characteristics and perspectives of university and the effective UIJRPTT with positive standardized path coefficient of 0.47 at the significant level of 0.05 and the qualitative results confirmed the influences of the factor variables which supported the thesis hypothesis. The factors included four variables, namely: capabilities in receiving and transferring technology in terms of technical and fund (D1.1), adequate specialists, researchers, and students (D1.2), adequate and appropriate tools and equipment (D1.3), and willingness and motivation in working with the industry (D1.4). The variables of the factor were necessary to the research and development in practice and in theory, and this may explain the significance of characteristics and perspectives of university well as a key driver of the effective UIJRPTT.

The high capabilities in receiving and transferring technology in terms of technical and funds significantly influence the effective UIJRPTT with standardized coefficient of 0.65. Such capabilities meant the university and their professionals such as faculty members, researchers and students posses extensive knowledge base and skills and equipped with resources, basic skills and low gap between knowledge level and the level required utilizing the technology (Szulanski, 1996, 2000; Miesing, Krieger and Slough, 2007; Fontana, Geuna and Matt, 2006) Moreover, sufficient fund and efficient budget was also the prerequisite for the university to start and continue the research work and cooperation with other organizations including the UIJRPTT with the industry. From the interview results, the university knowledge and expertise could immensely benefit the industry from the discovery of new material and technology breakthrough to increase the efficiency of the photovoltaic cells and system, solving the industry problems and testing and BOS system development. If the university posses extensive knowledge base that was relevant to the need of the industry, the industry would likely to decide to invest and work for the UIJRPTT. Due to the fact that the photovoltaic products such as cells and modules was the combination of sciences and engineering, therefore, the ability of the university to integrate the knowledge in the technology and basic research was necessary. Despite rated with satisfactory status, it was concerned that the university still lacked of adequate and integrated knowledge in conducting research related to photovoltaic technology for commercialization. From the results, the respondents indicated that the capabilities of the university could be improved by implementing human resource development plan, upgrading faculty and academic capabilities in science and engineering, increasing course in photovoltaic technology related. While university funds related to risks in research and development investment through failure and cost and benefit basis, therefore, to reduce such risks university, university could pool resources and research efforts with the industry and government research institutes, research in special parts and encouraging more funding scheme support from the government. The results are relevant to the study of Szulanki (1996, 2001) which state that lack of perceived reliability of source can affect the technology transfer and the study of Miesing, Krieger, and Slough (2007) which indicate that successful knowledge transfer depends on collective creation of knowledge throughout the organization.

Adequate human resources such as specialists and researchers were also confirmed by quantitative and qualitative data as variables influencing effective UIJRPTT with the factor loading of 0.66. This meant that the university which was equipped with adequate knowledgeable and experienced specialists and adequate teamwork from faculties such as Science, Engineering, and Materials also could work together could influence the effective UJRITT in the way that it could make the UIJRPTT more attractive for the industry to work with the university and could make the research results successful. From the qualitative data, the university and industry expressed their needs to conduct UIJRPTT, however, despite rated in adequate status, problems arose when academics sometimes lacked of time; when the research team lacked of extensive knowledgeable and experienced specialists and researcher to conduct the research; and when it was found difficult for faculty members from different faculties and laboratories to work together due to different personal interest and organization culture. It was suggested that the deficiency of human resources could be reduced by producing and recruiting of more scientists and engineers, promote public awareness and interest in photovoltaic technology, increase number of professional researchers and improve their career path and working condition of the professional researchers. This could also support the university teaching priorities. The results were relevant to the work of TDRI (1991) which stated that shortage of scientific and engineers in Thailand affect the technology push of many technology development.

Adequate equipment was essential for conducting research and effective UIJRPTT with the factor loading of 0.78. The interview results revealed that the industry needed tools and equipments from the university because it was not worth investing and buying such equipments but the university could benefit from the equipment for teaching and instructing. If the university had the appropriate equipment and tools needed for the research, the industry would likely to conduct the UIJRPTT with the industry and the results of the UIJRPTT would likely be successful and reduce time in researching. The result was relevant to the study of TDRI (1991) which stated that university's lack of consultancy and technical services and research tools and equipment affect the research and technology transfer. However, the low rated score status of the current situation of the variable and risk in purchasing expensive equipment and return were the issues to be considered. Pool resources and equipment, and long term planning for research and equipment purchase of the university could reduce the financial risk. Moreover, in order to comply with the need of the industry, the university should consider upgrading tool and equipment appropriate for research prototype.

Additionally, the university willingness and motivation to implement and cooperate with industry in teamwork with shared value was needed to achieve technology transfer process (Malik, 2002). This reflected the effort to formulate, maintain and stimulate the effective UIJRPTT in terms of relationship and performance development. Without commitment derived from willingness and motivation of the university, it was not sufficient for relationship and performance development under UIJRPTT. The university willingness and motivation to work with the industry was proven in the model that had significant impact to the effective UIJRPTT among the variables in the characteristics and perspective of university with the standardized factor loading of 0.82. It was also confirmed that the university had very high willingness and motivation to work with the industry. Therefore, this variable should be further promoted. From the interview results, the academic therefore needed to have passion and commitment in working in the UIJRPTT project and have freedom in promoting idea and projects. The university academic and researchers as well as students in the UIJRPTT should also understand the photovoltaic technology development, new technology and economic value of technology needed for future research and increase communication with the industry.

2. Characteristics and Perspectives of Industry and Outcome Factor

The results showed characteristics and perspectives of industry (D2) as influencing effective UIJRPTT based on the model analysis. Its relevance in the effective UIJRPTT was not surprising given that the factor has been established in the past and existing literature of technology transfer and U-I collaboration (Szulanski, 1996, 2000; BHEF, 2001; Siegel, et al., 2004; Casey, 2004; Fontana, Geuna, and Matt, 2006). The model measurement in this research entailed four variables: capabilities in receiving and transferring technology in terms of technique and fund (D2.1), willingness and motivation to work with university with shared value (D2.2), perspectives of management on worthiness and value of joint research (D2.3) and understanding cultural differences (D2.4). With standardized coefficient of -0.60, the fundamental influence of characteristics and perspectives of industry was clearly established with significant level of 0.05. The negative coefficient may indicate that the negative perspective of the industry on the joint research and low degree of commitment of the industry could affect the lower degree of effective UIJRPTT.

The importance of characteristics and perspectives of industry was anchored in the relevance of capabilities to receiving and transferring technology in terms of technique and funds of the industry with factor loading of 0.79. The high capabilities of the industry which meant the knowledge base and ability of the industry as transferee to conduct the UIJRPTT and be transferred the technology (Szulanski, 1996, 2000) affected high degree of the effective UIJRPTT. This was because the capabilities of the industry in terms of technique and funds could indicate the ability level of firms to conduct the joint research and collaboration with other organizations. The results evidenced the adequacy status and important roles of the skilled and capable engineers and R&D staffs in searching knowledge, research question setting, and evaluation of research possibility which affected the formulation of the UIJRPTT and the effective technology transfer and collaboration between the university and industry. The selection and acquisition of technology required a high level of expertise and long experience. The development of the capability of the industry is also recommended. Co-learning program, special courses, site visits to university and vice versa could reflect the technical assistance meeting and events which could foster an environment of information sharing, and problem solving. Such cooperation should be supported by both industry and university by viewing that that is the responsibility of each side to work on it. Funds were important for conducting research and level of fund would be allocated due to necessity of the research. The up-gradation of imported technologies and adaptation of technology from UIJPRTT required adequate technological capabilities at the firm level and provision of funds. The results were relevant to the previous literature which indicated that transferee capabilities could increase the success of technology transfer through quick problem solving; choosing technology that fits the projects (Miles, 1998) and high degree of working experience would help tackle problem solving in the appropriate way (Kippenberger, 1997). Therefore, to support staffs for further study, training and participate in vocational courses could help the industry staffs to increase their knowledge and reduce time and cost in technology development process. Grants for industry research could also help the industry to conduct research on their demand and the experience of the staffs from research could increase the capabilities of the industry.

Willingness and motivation to learn, work and develop new technologies and product with the university with shared value was shown having impact on the effective UIJRPTT in the model with standardized factor loading of 0.78. The quantitative results strongly indicated that the industry had high willingness and motivation to learn and work with the university and this willingness and motivation affected high degree of effective UIJRPTT. Qualitative data supported that the willingness and motivation of the industry was based on the CEO initiatives, leadership and vision and R&D team confirmation that the research work was necessary for the company. The collaboration with the university such as system testing was necessary in reducing cost before sending the system to be proven abroad. However, the data revealed that firms preferred to work in in-house much more than working with the university considering lower cost and keeping the trade secrets and IPs management. Therefore, to reach the effective UIJRPTT, it was needed to promote to firms to realize the importance and benefit of UIJRPTT. The willingness and motivation to learn would lead to the commitment of the industry to work with the university in setting goal and mission with the common purpose. The research result is relevant to the work of Fontana, Geuna, and Matt (2006) which state that the willingness and motivation of firm significantly affect the development of R&D projects and the study of Levy and Samuels (1992) which state that firms evaluate the feasibility before conducing U-I research projects.

Perspectives of management team on worthiness and value of joint research in terms of economic and intellectual values affected the effective UIJRPTT with the factor loading of 0.77. This meant that the negative perspectives of the industry management team on the benefit and cost could affect the lower degree of commitment and value on the UIJRPTT. The research results revealed that the photovoltaic firms would invest in R&D if it considered that without R&D it could lead to loss in profit, and when they need to share the risk and cost because it was viewed that sunken cost could occur and may not be recovered as the success of the experiments could not be guaranteed and proven credibility. The perspectives of the management team on the UIJRPTT also depended on the long-term strategy of the industry and on visionary leader. It was also observed that large firm with high investment and having record of continuous working on R&D particularly in increasing efficiency would likely to conduct more research and search for university to work with whereas small and medium firm appeared to be happier with immediate outputs and clearer evidence of financial returns. To reduce risks in R&D investment, government support for industry to conduct research and market stimulation would encourage the decision of the management in UIJRPTT. The result is relevant to the study of BHEF (2001) which indicate that the understanding and appreciation of the value each partner brings to the U-I technology transfer can affect the effective U-I collaboration.

Understanding of cultural differences, from the quantitative and qualitative data, had an impact on the effective UIJRPTT. The research results revealed that both university and industry had different organizational culture. Therefore, both sides should learn to understand each other and adjust the organization compatibility regarding goals and objectives and similarity in operating philosophy. The industry should work with long term plan and digit time frame whereas the university should understand the limitation of the industry such as the effect from the extension and unpunctuality of the projects. If so, the high understanding of cultural differences could affect the high degree of effective UIJRPTT which could be seen from the satisfaction of both parties in working together. The research results were relevant to the study of Siegel, et al. (2004; Casey, 2004; BHEF, 2001) which state that cultural misunderstanding reduces the effectiveness of the industry's efforts to market university technology and of Severson (2005) which states that there are different perspectives related to the university and industry as non-profit and non profit organization and bureaucratic and entrepreneurial system. The understanding of differences in cultures of the industry significantly affected the effective UIJRPTT in Thailand with the factor loading of 0.52. However, due to the fact that in practice conflicts could arise from the differences in organization culture such as time horizon and commitment conflicts, it was therefore needed that both university and industry should consider develop a mechanism such as a peer to follow the contracted contribution to the progress of the project whether it met the objectives, and quality service standard.

3. Joint Research Mechanism and Outcome Factor

The research results showed a significant influence of joint research mechanism (D3) on the effective UIJRPTT based on the model analysis. A moderately strong impact emerged in the final model with standardized path coefficients of 0.62 with significant level of 0.001. The model measurement in this research entailed the variables: communication effectiveness (D3.1), management of coordination office and joint research program (D3.2), IP management (D3.3) and incentive system (D3.4).

Communication effectiveness showed significant effect on the effective UIJRPTT in quantitative data with the factor loading of 0.80. The results from the qualitative data also supported the association of communication effectiveness and trust. This meant that the industry communicated with the university to acquire the university information, knowledge and technology when they search and site visits. After discussing with the university and considering the capabilities of the university, the industry would believe and trust in the ability of the university in conducting the UIJRPTT. Communication therefore was the prerequisite for further activities and UIJRPTT as both parties had a chance to talk and discuss. Some respondents therefore recommended that there should be venues for the university and industry to discuss, interact, make connections and know more to familiarize each other to break the ice and to develop interpersonal relationship and shared value which was proved as the basis to the start of the trust and collaboration. Once both side agreed to work together on the UIJRPTT, the project mission, partnership approach, collaboration and ownership, recognition of contributions of each partners, and projection of self-interest and grants should be discussed. After the project was started, regular meetings should be conducted to help facilitate information sharing, solving problems and finding conflicts resolution. The result is consistent with the study of Anderson and Weitz (1989) suggesting that high interaction effectiveness based on increased experience and familiarity with other party and the study of Grayson and Ambler (1999) stating that relationship is associated with interaction and involvement. Another aspect of communication effectiveness is the communication and interaction between university, industry and government organization that should be encouraged to be the forum for discussion on policy and research development program for photovoltaic technology development. The venue should be regularly organized and all stakeholders from the university, industry and government agencies should be sincere and seriously intended. As the matter of fact that the meeting organized by the government agencies which were the funding agencies and policy makers selected only the persons that the agencies wished them to participate, therefore, it was recommended that once the name of the stakeholders were known, they should continue to be included in invitations and in reports.

The results also showed that management of coordination office and joint research program had a significant effect on the UIJRPTT. The qualitative results from the previous part and this part indicating the problem of coordination office as lack of staffs who could handle with the industry in terms of marketing and promotion, problem with commitment and support policy change due to the change of university TTO senior management and bureaucratic system and inflexibility. The bureaucratic and inflexibility in administrative procedures could rise the tension and reduce motivation of the university and industry in participating the UIJRPTT and could lead to delay in executing contracts, issuing reimbursement, and straining the cash flow of the project. From the qualitative results, it reflected the importance of TTO roles the management of coordination office and joint research program and management to the effective UIJRPTT. Recommendations from the respondents such as increasing of human resources in marketing the technology development and activities of the university; improve the TTO work as one stop service to provide information for the industry related to contract arrangement, IP management, and conflict resolutions, and to facilitate the work of industry and the university faculty; and consulting and discussion with the faculty and the industry to improve their service. The result is in line with the studies of BHEF (2001; Siegel, et al., 2004) and Santoro and Gopalakrishnan (2001) which suggest that the structure to find partners, management of collaboration and coordinating support service and commitment of the senior management correlate with the growth and effectiveness of technology transfer.

IP management showed an effect on the effective UIJRPTT model. The results underlined the importance of the IP management and supported the past and existing studies (BHEF, 2001; Casey, 2004; Santoro and Gopalakrishnan, 2001; Lockett and Wright, 2005; Thursby and Thursby, 2004). The studies indicate that there are positive correlation between U-I formation and university IPRs and IPRs protection for promising discoveries is critical to success of technology transfer process. From the qualitative analysis, confidentiality and the sharing of the IP and ownership emerged as the concern of the industry in the preliminary step for the UIJRPTT. A university was considered that it was not a best place to keep secret, there was high risk for the industry to share information and knowledge to the university counterpart. The results of the research at the end of the UIJRPTT were industry as problems from benefit allocation, technology and equipment ownership, and publication of university paper could be problematic. Therefore, the appropriate IP management to be fair for all and IP agreement needed technical, commercial and legal expertise was considered necessary for the effective UIJRPTT and could reduce the uncertainty and risks from disagreement. In this regard, the university and industry should indicate clear project goals and emphasize the clarified contribution, roles, and ownership in the contracts and bylaws. The inclusion of the contract and bylaw provision for sharing, confidentiality, IRPs management and conflict resolution was an important step to help both side gain trust from each others.

The results also showed that incentive from the university and government had a significant effect to the effective UIJRPTT. In university jurisdiction, incentives such as grants and rewards were viewed motivating the faculty members, researchers, and students in conducting the effective UIJRPTT. This is relevant to the work of Siegel, et al. 2004 stating that the university reward system affect the U-I collaboration and Miesing, Krieger, and Slough (2007) stating that incentive and rewarding are the condition for successful technology transfer and cultivation of collaboration. In the Thai context, the university's academic promotion and tenure system for researchers tends to reward basic research and publications, whereas the opportunities for service and community oriented are more limited. This should be resolved to create research for community and industry environment. More interestingly, from qualitative analysis, the results revealed that the policy and support from the government could affect the effective UIJRPTT greatly in many aspects. For the industry, it is widely recognized that, in the cycle, the importance of technological progress is important for the industry long-term economic growth. Such progress mainly depends on the generation of new knowledge which derived from research and development. Selling innovative technology could lead to more income and profit which motivate individual firm to further invest in R&D. Due to the fact that the photovoltaic industry was not a big and sustainable industry, it still needed the support from the government in creating the profit and income so that part of the profit could be divided for the R&D for technological development. The role of the government was therefore very important. The government role in market and technology facilitators was recommended by the respondents. Suggestions included (1) providing a policy recommended by the respondents. Suggestions included (1) providing a policy environment conducive to photovoltaic technology and market development which included trade, investment, finance, and science & technology, (2) assisting enterprises in the integration and commercialization on new technologies, (3) promoting FDI and (4) supporting various research activities of the industry due to the fact that the knowledge that could lead to new invention and innovation was beyond the capabilities of the photovoltaic firms due to limited knowledge and finance. The supports could raise the industry's motivation in conducting the R&D by its own and with the university in the area that the industry lacked of knowledge. To avoid underinvestment in new knowledge, the government could play role in supporting various research activities in the university. Those included (1) strengthening basic research and technology development; (2) raising quality of education and research related to photovoltaic technology at all level; (3) strengthening the scientific and engineering manpower base; and (4) arrangement of funding in governmental ministries concerned. As a result, the capabilities and the infrastructure for research activities of the university would be increased and could affect the formulation of the UIJRPTT and increase of quality and economic performance of the research results. Last but not least, several respondents mentioned about the development of photovoltaic technology through the task of NREL in the US. Therefore, the government agencies, the university and the industry should search and study the best practices of collaborations and organization structure management from others to improve the process to develop photovoltaic technology in Thailand.

Summary of Part Three

This part presented the research studies in three major sections. The first section was related to the factors affecting to the effective UIJRPTT and the development of the model of effective UIJRPTT. From the quantitative data analysis, hypothesized factors and variables were tested and confirmed. The model of effective UIJRPTT was then developed as the results of the CFA and path analysis. The hypotheses on the factors and the linkages between the factors and their variables namely: characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) and outcome factor (D4) were confirmed. Moreover, the effective UIJRPTT as outcome factor was found significantly influenced by the three enabling factors. Among the factors, joint research mechanism was the most influential factors to the effective UIJRPTT.

The second section was the evaluation of the current status of each factor viewed by the university and industry respondents. Similarity and difference perception of the current status by the two respondent groups was identified. However, for overall results, all factors and variables in the effective UIJRPTT model were rated at the adequate/satisfactory status. Both university and industry respondents viewed that the two sides had willingness and motivation and capabilities in terms of technique and funds to work together. However, some variables, despite rated in satisfactory status, such as IP management, incentive system, management of coordination office and joint research program and adequate research tools and equipment were among the variables rated with lowest scores. Those variables were proven necessary to the effective UIJRPTT; therefore, all stakeholders should consider finding the ways to improve the situation.

The third section was the qualitative data analysis by which its results confirmed the importance of variables in each factor and highlighted what action and practice the university, industry and government should consider enhancing the performance of each factor variable. From this part, the effective UIJRPTT model was refined. The model was therefore equipped with the guidance and suggestions that were beneficial to the collaboration under the U-I joint research for photovoltaic technology transfer.

The effective UIJRPTT model was still an idealistic model, but some of the guidance and suggestions in the model could be easily done and be used as the benchmark for all stakeholders to conduct in order to better improve the current situation where there was little number of the U-I joint research. Some of the suggestions which involved the support of the government, the university and industry administrative officer could be more difficult in brining into practice and it was necessary to evaluate the appropriate cost and benefit of such investment and sacrifices.

Table 33 Summary of Issues and Action in the Model of UIJRPTT from Respondents

Issues and Recommended Actions	Variables	Factor
Issues: Relevant knowledge base to the industry needs, Ability to integrate knowledge in technology and science, Ability to provide and link to fund resource **Actions:** Implementing human resource development plan Upgrading faculty and academic capabilities in science and engineering Increasing courses in photovoltaic technology related Pool resources and research efforts with industry and govt. institute Researching appropriate and special part/ area of PV technology Encouraging collaborative funding scheme	University capabilities and fund	Characteristics and perspectives of university
Issues: Adequate experienced specialists and researcher, teamwork from faculties within and outside university **Actions:** Produce and recruit more scientists and engineers in photovoltaic related technology Promote public awareness and interest in photovoltaic technology Increase number of professional researchers Improve career path and working condition of researchers	Adequate human resources	
Issues: Adequate and appropriate tools and equipment related to research need **Actions:** Pool resources and equipments of U-I, U-I, U-G-I University collective long term planning for research Upgrade tools and equipments appropriate for research prototype	Adequate and appropriate tools and equipment	
Issues: Efforts to formulate, maintain and stimulate UIJRPTT, Commitment of university professional **Actions:** Willingness and passion of individual researchers Freedom in promoting idea and projects	Willingness and motivation of university	
Issues: Ability of skilled and capable engineers and R&D staffs, Ability of management to raise funds and acquire research grant **Actions:** Support staffs for further studying and training Special vocational course and technical training Grants for industry research	Industry capabilities and fund	Characteristics and perspectives of Industry
Issues: Management initiative and leadership in R&D, Commitment to work with the university **Actions:** Visionary leaders Pool risk with the university in research Increase personal relationship with university	Willingness and motivation	

Table 33 (cont.)

Issues and Recommended Actions	Variables	Factor
Issues: Long term strategy in R&D, Perspectives on positive value of R&D **Actions:** Govt. funding, subsidizing and co-finance through R&D support scheme to cover sunk cost	Perspectives on worthiness and value of joint research	
Issues: Understanding of working style, obstacles and commitment of each side **Actions:** Organization compatibility by adjusting goals and objective and operating philosophy	Understanding of cultural difference	
Issues: Communication for UIJRPTT formulation, maintaining and post project, and Increase of venue for communications among govt., university and industry **Actions:** Create more communication channels and interactions among govt., university and industry Support informal linkage through recreation activities Keeping contacts after research completion Develop websites that provide updates on research work and industry needs and interface Encouraging training of industry staffs and university factory site visits	Communication effectiveness	Joint Research Mechanism
Issues: Adequate staffs for marketing, promotion and policy supports, Flexibility **Actions:** Increase number of human resources in TTO in marketing technology One-stop service office with less bureaucratic system, more flexibility and continuation of policy and management More consultation with researchers in the university and with the industry to improve service	Management of coordination office and joint research program	
Issues and Actions: Well management for IP issues such as publication to avoid leaking IP, IP benefit allocation, and equipment and research results ownership	IP management	
Issues: Appropriate university incentive and rewards, Policy and support from government **Actions:** Strengthen government policy support on S&T, industry and foreign investment and renewable energy market development Establish of "national institute of solar cell" to promote, conduct, funding photovoltaic R&D NREL model application University incentive for social and industry cooperation as KPI for career promotion	Incentive system	

PART FOUR Model Implementation and Validation

Introduction

From the previous part, the effective UIJRPTT model was developed by employing the SEM method. The factors and variables in the model were confirmed by the CFA and interview results and the significant interrelationship between the factors, their variables and outcome factors in the model were established by the path analysis. In a subsequent study, this part aimed to implement the model and to validate the developed path model through investigations on three case studies where the UIJRPTT projects were implemented. This part was organized into three sections. The first section detailed how factor variables in the model were broken down into the indicators to accurately indicate the performance levels of the previously developed path constructs. The second section described the three UIJRPTT projects used as case studies. The third section reported the descriptive statistics value of the variables and the indicators to the effective UIJRPTT on the three projects. Three significant paths in the model were validated namely: characteristics and perspectives of university (D1) to outcome factor; characteristics and perspectives of industry (D2) to outcome factor, joint research mechanism (D3) to outcome factor.

UIJRPTT Indicator

Drawn from the qualitative results and the discussion in Part Three and from the literature, the UIJRPTT indicator of the each factor variable in the effective UIJRPTT model could be identified as followed:

1. Characteristics and Perspectives of University (D1)

Characteristics and perspectives of university (D1) included four variables, namely: capabilities in receiving and transferring technology in terms of technical and funds (D1.1), adequate specialists, researchers and students (D1.2), adequate research tools and equipments (D1.3) and willingness and motivation for team work with the industry with shared valued (D1.4). Table 34 lists the derived indicators, description and supported references for each factor variables.

From the qualitative results, several points could be used to define the university capabilities in receiving and transferring technology in terms of technical and funds (D1.1). Those included: university knowledge base and credibility that were extensive and relevant to the industry needs, the university capability in integrating knowledge in technology and science from various sources in partial and holistic for technology and product commercialization and the university ability that could support funds and access to the other funding sources. The first two indicators were in line with the studies of Szulanski (1996, 2000), Miesing, Krieger, and Slough (2007) and Fontana, Geuna, and Matt (2006) which state that the knowledge base of the faculty members, researchers and staffs and gaps between knowledge level and level required affect the effective UIJRPTT and collective creation of knowledge can generate the effective knowledge transfer and the study of Liefner and Schiller (2008) which state that sufficient funds are the prerequisite for university to carry out academic research. Funding for securing and developing future research has been indicated as the motivator and benefits for university professional to engage with industry (Lee, 2000). Such funds can also benefit to students and researchers in working in the projects (Santoro and Chakrabarti, 2002).

Adequate specialists, researchers and students (D1.2) simply could refer to, as stated by the interview results, the adequacy of specialists and researcher who are capable and experienced in conducting the research work and can devote time in research project and the university ability in setting up teamwork from faculties within and outside the university to collectively work in the research work. This was in incorporated with the study of Siegel, et al. (2004) which states that insufficiency of university human resources can impede the UITT and of Gray, Lindblad, and Rudolph (2001) which states that professional networking benefits, satisfaction with

Table 34 Indicator for Characteristics and Perspectives of University

Variables	Description	References
Capabilities in receiving and transferring technology in terms of technical and funds (D1.1)		
Relevant and extensive knowledge base and credibility	Concerned with the degree that university knowledge base and credibility are extensive and relevant to the industry needs	Interview Results Szulanski (1996, 2000) Miesing, Krieger, and Slough (2007) Fontana, Geuna, and Matt (2006) Lee (2000) Santoro and Chakrabarti (2002) Liefner and Schiller (2008)
Capability in integrating knowledge	Concerned with the degree of the university capability in integrating knowledge in technology and science from various sources in partial and holistic for technology and product commercialization	
Ability to provide and access to funding resource	Concerned with the degree of the university ability that can support funds and access to the other funding sources	
Adequate specialists, researchers and students (D1.2)		
Adequate experienced specialists and researchers	Concerned with the degree of the adequacy of specialists and researcher who are capable and experienced in conducting the research work and can devote time in research project	Interview Results Siegel, et al. (2004) Gray, Lindblad, and Rudolph (2001)
Teamwork from faculties within and outside university	Concerned with the degree of the university ability in setting up teamwork from faculties within and outside the university to collectively work in the research work	
Adequate research tools and equipment (D1.3)		
Adequate and appropriate tools and equipment related to research need	Concerned with the degree the university has adequate tools and equipment that can own and collaborate with other universities and research institutes domestically and abroad to facilitate the research need	Interview Results
Willingness and motivation for teamwork with shared value (D1.4)		
Efforts to formulate, maintain and stimulate UIJRPTT	Concerned with the degree of the university and its professionals' efforts by viewing the importance of UIJRPTT and put their efforts in formulating, maintaining and stimulating the collaboration	Interview Results Barnes, Pashby, and Gibbons (2002) Irwin, More, and McGrath (1998) Santoro and Chakrabarti (2002)
Commitment of university and professionals	Concerned with the degree of the university and its professionals having passion and commitment in starting and accomplishing the UIJRPTT with the industry	

The relevance of research, and satisfaction with administrative operations could predict the firm retention in relations to the U-I research collaboration

The university should have adequate research tools and equipment (D1.3). In this connection, the interview results indicated that the university should try to find the way to own and collaborate with other universities and research institutes domestically and abroad to facilitate tools and equipment related to the research need. This ability is beneficial for the university to offer technical services and conducting research related to the UIJRPTT requirements.

The indicator of willingness and motivation for teamwork with shared value (D1.4) could define, as summarized from the interview, as the degree of the university and their professional efforts by viewing the importance of UIJRPTT and put their effort in formulating, maintaining and stimulating the collaboration. The university and its professionals should also have passion and commitment in starting and accomplishing the UIJRPTT with the industry. Barnes, Pashby, and Gibbons (2002) and Irwin, More, and McGrath (1998) confirm that commitment is essential characteristics of innovation and technology and can create climate for communication and success of UI interaction. The studies of Santoro and Chakrabarti (2002) also indicate that the willingness and ability of individuals to build relationships, enthusiasm and intrinsic motivation to succeed and the talent to promote and to influence and ideal, project or relationship can influence the relationship development and success of collaboration.

2. Characteristics and Perspectives of Industry (D2)

Characteristics and perspectives of industry (D2) included four variables, namely: capabilities in receiving and transferring technology in terms of technical and funds (D2.1), willingness and motivation to work with university with shared value (D2.2), perspectives on worthiness and value of joint research in terms of economic and intellectual value (D2.3) and understanding cultural difference (D2.4). Table 35 lists the indicators, description and supported references for each factor variables.

To achieve the effective UIJRPTT, capabilities in receiving and transferring technology in terms of technical and funds (D2.1) is needed. From the interview results, the respondent identified that the ability of the industry skilled and capable engineers and R&D staffs in setting up research questions, searching and conducting research was necessary. Moreover, the industry should have the ability in providing funds for the projects and acquiring research grants. This is in line with Fontana, Geuna, and Matt (2006) which state that determinant of research cooperation depending on the level of firm's intense R&D activities, in seeking, screening and signaling the scientific and technology development as well as participating in the government-funded projects.

The industry should also have willingness and motivation to work with university with shared value (D2.2). The qualitative results indicated that the willingness and motivation could come from the management who has the initiatives and leadership by viewing the research work was necessary for the company. The industry should also indicate its commitment to work with the university in setting goal and mission with common purpose. According to Gummesson (2002), the relationship requires mutual value or the creation of a win-win situation to be successful and each party involved should perceive the relationship and working beneficial. Mora-Valentin, Montoro-Sanchez, and Guerras-Martin (2004) also indicate that commitment in the U-I cooperation include the commitment of senior executives and technician, emotional commitment, prospects of continuity and positive attitude towards investing in the relationship. According to Barrett and Weinstein (1998), senior management is responsible for creating an organization or group capable of creating committed and successful UIJRP. Management must thus acknowledge, and act towards, creating an organizational culture supportive of relationship.

Perspectives on worthiness and value of joint research in terms of economic and intellectual value (D2.3), according to the qualitative results, related to the long term strategy in R&D development of the industry to survive in the market and how the industry has perspectives on the positive value of R&D and UIJRPTT. That value involved the issue of whether the industry can gain benefit from technology development and technology advancement, if the research results could also cover the investment cost and the degree that it can acquire research grants from the government to reduce research and financial risks. Long term strategy and the perspectives on the value of technology development can lead to long term continuation of relationship and time and financial efforts that can be provided to a relationship and contribution (Plewa, 2005).

It is generally understood that differences in organization culture could lead to the development of different view (Lewis, 1996). From the research results, understanding cultural difference (D2.4) was necessary for the effective UIJRPTT. The interview results also indicated that to avoid any unfavorable situation such as misunderstanding and misperception, it was important the industry and the university should understand each other's working style, possible obstacles and commitment of each side and try to discuss together in adjusting organization compatibility regarding goals, objectives and time frame for research results. This is in line with the studies of Chatterje, et al. (1992) and Fralicx and Bolster (1997) which state that the harmony of values and styles of working was seen as a key to success in large number of merger and acquisitions and the study of Dyer and Singh (1998) which states that organizational compatibility may be necessary to gain relationship benefit.

Table 35 Indicator for Characteristics and Perspectives of Industry

Variables	Description	References
Capabilities in receiving and transferring technology in terms of technical and funds (D2.1)		
Ability of skilled and capable engineers and R&D staffs	Concerned with the degree of the ability of the industry skilled and capable engineers and R&D staffs in setting up research questions, searching and conducting research	Interview Results Fontana, Geuna, and Matt (2006)
Ability of management in funds and acquiring grants	Concerned with the degree of the industry ability in providing funds for the projects and acquiring research grants	
Willingness and motivation to work with university with shared value (D2.2)		
Management initiative and leadership in R&D	Concerned with how the management has the initiatives and leadership by viewing the research work was necessary for the company	Interview Results Gummesson (2002) Mora-Valentin, Montoro-Sanchez, and Guerras-Martin (2004) Barrett and Weinstein (1998)
Commitment to work with the university	Concerned with the degree of the industry having commitment to work with the university in setting goal and mission with common purpose	

Table 35 (cont.)

Variables	Description	References
Perspectives on worthiness and value of joint research in terms of economic and intellectual value (D2.3)		
Long term strategy in R&D	Concerned with the long term strategy in R&D development of the industry to survive in the market	Interview Results Plewa (2005).
Perspectives on positive value of R&D and UIJRPTT	Concerned with how the industry has perspectives on the positive value of R&D and UIJRPTT as it can gain benefit from technology development, the results could cover the investment cost and the degree that it can acquire research grants from the government	
Understanding cultural difference (D2.4)		
Understanding of working style, obstacles and commitment of each side	Concerned with the degree of understanding of working style, obstacles and commitment of itself and the university and trying to discuss together in adjusting organization compatibility regarding goals, objectives and time frame for research results	Interview Results Chatterje, et al. (1992) Fralicx and Bolster (1997) Dyer and Singh (1998)

3. Joint Research Mechanism (D3)

Joint research mechanism (D3) included four variables, namely: communication effectiveness (D3.1), management of coordination office and joint research program (D3.2), IP management (D3.3), and incentive system (D3.4). Table 36 lists the derived indicators, description and references for each variable.

From the interview results, two indicators could be identified to communication effectiveness (D3.1): First, communication system at the level of U-I project which included the three major steps that were communication for UIJRPTT formulation, for maintaining-during project and for post project. Groenroos (2000) described bilateral communication as creating a bond between parties which could lead to trust (Morgan and Hunt's, 1994) and Anderson and Weitz (1989) state that the sharing of information protects the relationship from misunderstandings and potential conflicts. Second, communication at the level of policy which included the regular venues for communication are set among government, university, and industry for discussing and implementing plan for photovoltaic technology and market development that are open for all stakeholders to share their view.

Based on the qualitative data, it was found that deficiency of staffs who could facilitate the U-I collaboration and inflexibility of bureaucratic system were problematic in supporting the work of university and industry professional. Siegel, et al. (2003) state that deficiency of human resource and inflexibility of technology transfer office relating to the bureaucratic nature of university's organizational culture affect the effective UIJR. In Plewa (2005), flexibility can be defined from an attitude or behavioral perspectives as either the willingness to "respond to changes and accommodate partners as the need arise" (Johnson, 1999) or as "smooth alterations in practices and polices by trading partners in light of unforeseen or changing conditions (Boyle, et al., 1992). From the qualitative data concerned with Management of coordination office and joint research program (D3.2), the respondents suggestion concerned the issue of adequate staffs of the TTO in marketing, promotion and working in continuation of policy support for UIJRPTT and the flexibility of bureaucratic system in facilitating the working process of the university and industry professional which could be defined as the performance indicator of the variable.

The results from the qualitative data and analysis confirmed that for IP management (D3.3), the issue on how the university and industry manage and satisfy with the issues such as publication to avoid leaking IP, IP benefit allocation, and equipment and research results ownership to be fair to all parts to reduce uncertainty and risk is essential. Based on qualitative data, the concern on confidentiality was recognized as the primary factor of risks in the UIIJRPTT, which could increase the uncertainty of research. Risk may be reduced by detailed contract, which aim at establishing a common ground for operations and deal with intellectual property in the collaboration. According to Bedapudi and Berry (1997), the flexibility in operation and information exchange and providing the discovery and successful research could increase trust and reduce perceived risk and higher level of satisfaction.

The qualitative results drew the conclusion that incentive system (D3.4) can be simply defined as the degree of appropriate university incentive and rewards for university professionals particularly in the work for community and commercialization projects. Cohen (2004) underlined the existence of two parties at the university namely administration and faculty should be motivated by financial contribution, administration being interested in revenue and faculty being interested in research support and personal income. Faculty was described as searching for financial support in order to achieve a higher-order incentive, namely academic eminence. Secondly, it can be defined by the degree of the legitimacy and the policy and support from the government in the area of photovoltaic technology and market development, human resources, trade and R&D and financial support. According to Calantone, et al. (1988), the government polices and enforcement practices can encourage technology transfer. The government's policies, regulations and enforcement practices can impact greatly on the effectiveness of technology transfer initiatives.

Table 36 Indicator for Joint Research Mechanism

Variables	Description	References
Communication effectiveness (D3.1)		
Communication for UIJRPTT formulation, maintaining-during project and post project	Concerned with the degree of communication channels and mechanism that allow the university and industry to communicate in the process of UIRJPTT formulation (familiarization), maintaining-during project (project mission, contract, sharing of information and solving problems and conflicts) and post projects (information sharing and keep contacts)	Interview Results Groenroos (2000) Morgan and Hunt's (1994) Anderson and Weitz (1989)
Venue for communications among government, university and industry	Concerned with how the regular venues for communication are set among government, university, and industry for discussing and implementing plan for photovoltaic technology and market development that are open for all stakeholders to share their view	
Management of coordination office and joint research program (D3.2)		
Adequate staffs for marketing, promotion and policy supports	Concerned with the degree of adequate staffs of the TTO in marketing, promotion and working in continuation of policy support for UIJRPTT	Interview Results Siegel, et al. (2003) Plewa (2005) Johnson (1999) Boyle, et al. (1992)
Flexibility	Concerned with the degree of flexibility of bureaucratic system in facilitating the working process of the university and industry professional	
IP management (D3.3)		
IP management	Concerned with how management for IP issues such as publication to avoid leaking IP, IP benefit allocation, and equipment and research results ownership are set to be fair to all parts	Interview Results Bedapudi and Berry (1997)

Table 36 (cont.)

Variables	Description	References
Incentive system (D3.4)		
Appropriate university incentive and rewards	Concerned with the degree of appropriate university incentive and rewards for university professionals particularly in the work for community and commercialization projects	Interview Results Cohen (2004) Calantone, et al. (1988)
Policy and support from government	Concerned with the degree of the legitimacy and the policy and support from the government in the area of photovoltaic technology and market development, human resources, trade and R&D and financial support.	

4. Effective UIJRPTT

The effective UIJRPTT (D4) as outcome factor included three variables, namely: Growth of UIJRPTT (D4.1), Quality performance from joint research (D4.2), and Economic performance from joint research (D4.3). Quantitative and Qualitative results identified and confirmed that overcoming the barriers and implementing of factors related to characteristics and perspectives of university and industry and joint research mechanism can stimulate growth and performance of the UIJRPTT which could be defined as the indicator of effective UIJRPTT. Moreover, as discussed in Chapter Two, the study of Faems, Van Looy, and Debackere (2005) confirmed that through collaboration, the U-I partners can improve capabilities through learning and consequently improve the innovation capacity and product development. Technology and product development can also bring the financial results such as IP rights (Dasher, 2005; Kazuyuki, 2004) and gain benefit in terms of time, cost reduction and quality of the product (Waroonkun, 2007). Table 37 lists the derived indicators, description and supported references for each factor variables.

Table 37 Indicator for Effective UIJRPTT

Variables	Description	References
Growth of UIJRPTT (D4.1)		
Growth of UIJRPTT and collaboration	Concerned with the degree of higher growth of the collaboration under UIJRPTT	Interview Results
Quality performance of Joint research (D4.2)		
Improved product and process development	Concerned with the improved product and process development that the UIJRPTT brings	Interview Results Faems, Van Looy, and Debackere (2005)
Improved Quality of research results	Concerned with the degree of quality of research results improved	
Economic performance from joint research (D4.3)		
Less investment in resources and less time	Concerned with the degree of less investment and time consuming that university and industry benefit from UIJPRTT	Dasher (2005) Kazuyuki (2004) Waroonkun (2007)
Income from research results	Concerned with the degree of income from the research results	

Case Study

According to the information from the respondents stated in Part One, three cases studies on UIJRPTT projects related to sponsored research, and consortia were conducted. The projects involved SERT and three companies. Those case studies consisted of: (1) Project 1: joint project (consortia) between SERT and Thai Agency Engineering Co., Ltd. related to photovoltaic cell and equipment test and application development; (2) Project 2: joint project (sponsored research) between SERT and Bangkok Solar related to grid connected photovoltaic demonstration system; and (3) Project 3 joint project (sponsored research) between SERT and Ekarat Solar related to solar cell for sprinkler system. It should be noted that only basic details of the case studies and their respective participants are provided due to confidentiality requirements.

1. Photovoltaic Cell and Equipment Test and Application Development Project

The joint research was initiated by the SERT and Thai Agency Engineering. The two parties had developed the cooperation from contacts at the personal level between SERT lecturers and high ranking staffs for the company. In May 2003 this cooperation was formalized into an academic joint research. The memorandum of understanding (MOU) on the technical cooperation and photovoltaic technology development between SERT and Thai Agency Engineering Co.,Ltd. and Solar Power Technology Co.,Ltd. was signed. The project areas were in the following areas: (1) photovoltaic application development for commercial purposes; (2) establishment of photovoltaic cell standard test by which equipments were facilitated by Solar Power Technology Co.,Ltd; (3) cooperation with SERT and Council on Renewable Energy in the Mekong Region-CORE for photovoltaic system and equipment certification; (4) education and human resources training services; (5) establishment of joint foundation for supporting the R&D related to photovoltaic cells and (6) cooperation for photovoltaic technology R&D. The sub-projects of the photovoltaic application development that SERT and Thai Agency Engineering cooperated together during the couple of years included the solar cell submersible aerator project with the value of the project of 150,000 baht and solar cell for street light and commercial advertisement board with the value of the project of 100,000 baht. Photovoltaic cell and equipment test project had been continuously conducted since the MOU was signed.

2. Grid Connected Photovoltaic System Demonstration Project

In 2008, SERT and Bangkok Solar started a joint research project titled "grid connected photovoltaic system demonstration project". The objectives of the project were to set up and the photovoltaic system to demonstration how the system works was installed. The project would help SERT professionals and interested people to learn more about grid connected photovoltaic system and to solve the problems that may arise such as power quality and power fluctuation due to weather conditions. It was also expected that SERT could gather valuable operating experience about both integrating the intermittent power provided by the photovoltaic system and about the operation of distributed generation system with the grid.

The system was located in the Energy Park of SERT with the total area of 61 square meters. Bangkok Solar contributed photovoltaic cells (BS40) as in-kind to the project and the company's technicians carried out installation of the project. The system utilizes 3 kW of photovoltaic module constructed from amorphous silicon cells on the fixed array frame and are electrically configured to feed DC power to the grid tied inverter. The power output from the inverter is connected via conductor (frequency and voltage range limited) for utility protection. Various electrical parameters were measured and demonstrated such as DC and AC voltage, current, power and energy production, cumulated AC energy supplied to grid, utility grid impedance and frequency, and resistance of isolation of PV array. Moreover, Bangkok solar also set up an area for outdoor exhibition informing on photovoltaic cell production process and the company's products.

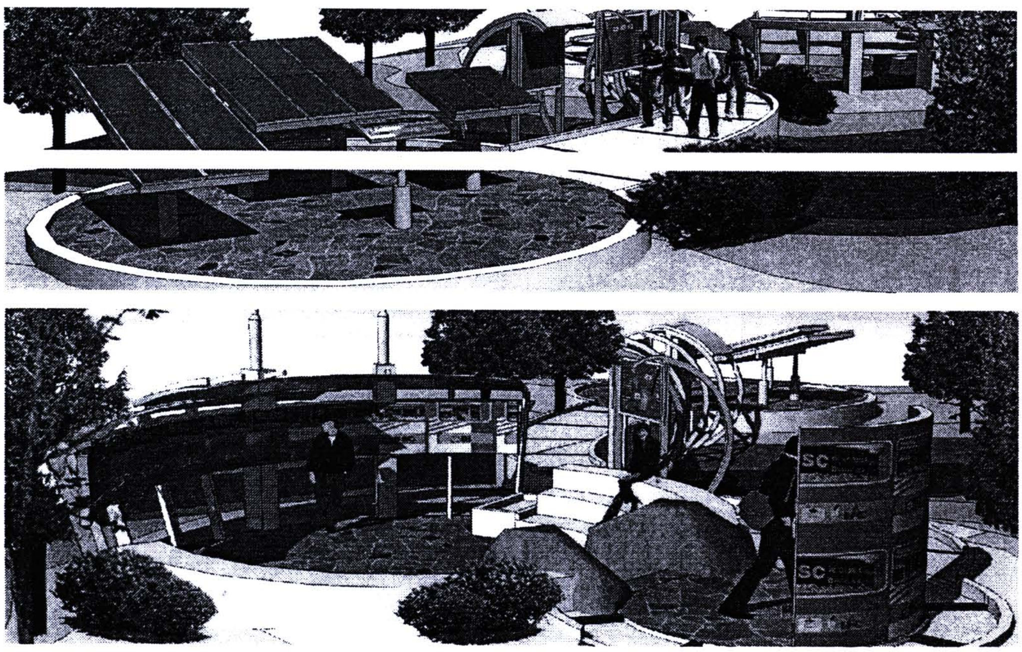

Figure 14 Grid Connected Photovoltaic System Demonstration Project at SERT

3. Sprinkler System Project

NU initiated the project titled "photovoltaic applications for agricultural process and sufficient residential project" with the objectives to be the model for the self-sufficient economic community by demonstrating the application of renewable energy. The project involved various areas including: (1) community house sub-project; (2) agricultural system sub-project; (3) renewable energy system sub-project which related to photovoltaic cell application (sprinkler system for watering vegetables, crops and herbs, fogging system for reducing temperature, electrification system for household, solar system for street light, etc.), biomass and biogas system, solar thermal system. SERT took responsible for the photovoltaic cell application in terms of studying, designing system, running and evaluating the project. For this part, Ekarat Solar collaborate with SERT by supporting 5 kW photovoltaic cell as in-kind contribution to the activity in 2009.

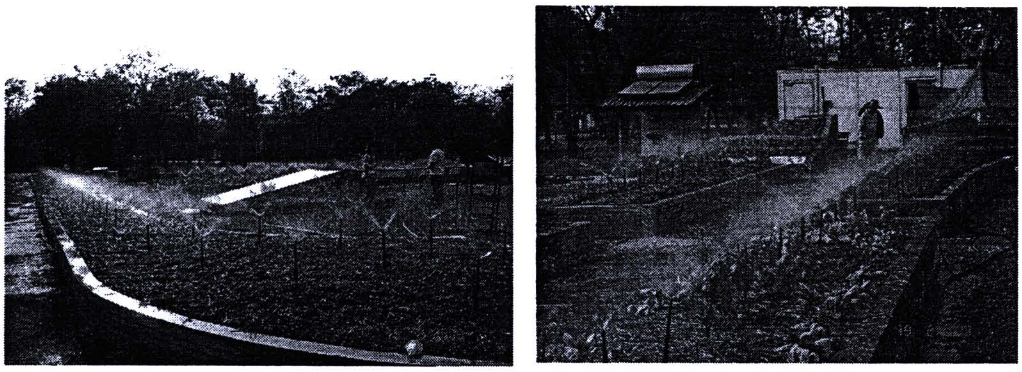

Figure 15 Sprinkler System Project at SERT

Model Validation

As discussed in Chapter III, the case study respondents comprised of university and industry professionals who involved in the joint research projects and TTO administrative officers and some company staffs. The case study for model validation was carried out in January 2010. The questionnaire was designed to be based on the factor variables in the effective UIJRPTT model that had the significant path coefficient to the outcome factor. Moreover, a series of variable indicators drawn from interview results and further literature review were added in the questionnaire. The results of the questionnaire survey from the three case study projects to validate the path determined from SEM, namely (1) characteristics and perspectives of university (D1), (2) characteristics and perspectives of industry (D2), and (3) joint research mechanism (D3) to outcome factor, the effective UIJRPTT (D4). The idea to achieve this was to utilize the developed structural equations from the path model to predict the effective UIJRPTT on the case projects. Actual performance score were then compared against predicted values to reinforce the validity of the path model. The result could finally help predict the future achievement of the UJIRPTT effectiveness. The results were as followed.

1. Mean and Standard Deviation

The mean value and standard deviation for the factors and variables, and the variable and indicators are detailed in Table 38 and Table 39. The mean scores of all factor variables were computed by equally weighting the mean score of all indicators. For example, the mean for capabilities in receiving and transferring technology in terms of technical and funds (D1.1) was computed by equally weighting the mean score of relevant and extensive knowledge and credibility (D1.1.1), capability in integrating knowledge (D1.1.2), and ability to provide and access to funding sources (D1.1.3). The mean of characteristics and perspectives of university (D1) then was computed by equally weighting the mean score of capabilities in receiving and transferring technology in terms of technical and funds (D1.1), adequate specialists, researchers and students (D1.2), adequate research tools and equipments (D1.3), and willingness and motivation for teamwork with share value (D1.4). Examining the mean score for each factor individually, the results were detailed as followed:

1.1 Characteristics and perspectives of university (D1) mean value calculated from the three projects comprised of 4.07, 4.14 and 3.92, indicating that the respondents from SERT, TTO administrative office and three industrial professionals perceived that the factor was essential to the effective UIJRPTT. The actual mean values in the factor and variables (D1.1, D1.2, D1.3 and D1.4) of the three projects and of the primary study were slightly different. Among variables of D1, willingness and motivation for teamwork and shared value (D1.4) and adequate specialists, researchers and students (D1.2) was rated highest item for projects 1, project 2 and project 3 respectively. Moreover, the results revealed that the mean values of the indicators under D1 ranged from 3.4 to 4.4 for project 1; from 3.5 to 4.4 for project 2 and from 3.6 to 4.3 for project 3.

1.2 Characteristics and perspectives of industry (D2) mean value calculated from the three projects was 3.93, 3.58 and 3.77, indicating that the respondents perceived that from their experience, the factor had an high impact to the effective UIJRPTT. The actual mean values in the factor and variables (D2.1, D2.2, D2.3 and D2.4) of the three projects and of the primary study were slightly different. Among variables of D2, perspectives on worthiness and value of joint research in terms of economic and intelligence value (D2.3) was rated highest for project 1 and 3 whereas capabilities in receiving and transferring technology in terms of technical and funds (D2.1) was rated highest for project 2. The results showed that the mean value of the indicators under D2 ranged from 3.7 to 4.2 for project 1, 3.6 to 4 for project 2 and 3.4 to 4.1 for project 3, indicating that the respondents agreed that all indicators were supportive to the effective UIJRPTT.

1.3 Joint research mechanism (D3) mean value calculated from the three projects was 3.97, 3.70 and 3.98, indicating that the respondents perceived that the factor had a bearing on the effective UIJRPTT. The actual mean values in the factor and variables (D3.1, D3.2, D3.3 and D3.4) of the three projects and of the primary study were slightly different. Among variables of D3, IP management was rated highest for all projects. The results showed that the mean value of the indicators under D3 ranged from 3.8 to 4.1 for project 1, 3.2 to 4 for project 2, and from 3.8 to 4.3 for project 3.

1.4 Effective UIJRPTT (D4) mean value calculated from the three projects was 4.1, 4.06 and 4.13 respectively, indicating that the effective UIJRPTT could enhance growing number, the quality performance, and economic performance of the UIJRPTT. The actual mean values in the factor and variables (D4.1, D4.2, and D4.3) of the three projects and of the primary study were not much different. Among variables of D4, growth of the UIJRPTT (D4.1) was rated highest for all projects. The results showed that the mean value of the indicators under D4 ranged from 3.8 to 4.3 for project 1, 3.8 to 4.3 for project 2 and from 3.5 to 4.4 for project 3.

Table 38 Mean and Standard Deviation of Variables and Indicators in Case Studies

Code	Description	Project 1		Project 2		Project 3	
		Mean	SD	Mean	SD	Mean	SD
Characteristics and perspective of university							
D1.1	**Capabilities in receiving and transferring technology in terms of technical and funds**	**3.83**	**0.78**	**3.96**	**0.87**	**3.86**	**0.77**
D1.1.1	Relevant and extensive knowledge and credibility	4.1	0.56	4.4	0.84	4.3	0.67
D1.1.2	Capability in integrating knowledge	4	0.94	4	0.81	3.7	0.67
D1.1.3	Ability to provide and access to funding sources	3.4	0.84	3.5	0.97	3.6	0.96

Table 38 (cont.)

Code	Description	Project 1		Project 2		Project 3	
		Mean	SD	Mean	SD	Mean	SD
D1.2	**Adequate specialists, researchers and students**	**4**	**0.93**	**4.25**	**0.55**	**4.15**	**0.83**
D1.2.1	Adequate experienced specialists and researchers	4.1	0.99	4.3	0.48	4.1	0.87
D1.2.2	Teamwork from faculties within and outside university	3.9	0.87	4.2	0.63	4.2	0.78
D1.3	**Adequate research tools and equipments**	**4.1**	**0.99**	**4.1**	**0.99**	**3.7**	**0.67**
D1.3.1	Adequate and appropriate tools and equipment related to research need	4.1	0.99	4.1	0.99	3.7	0.67
D1.4	**Willingness and motivation for teamwork with share value**	**4.35**	**0.76**	**4.25**	**0.89**	**4**	**0.71**
D1.4.1	Efforts to formulate, maintain and stimulate UIJRPTT	4.3	0.82	4.4	0.69	4.2	0.63
D1.4.2	Commitment of university and professionals	4.4	0.69	4.1	1.1	3.8	0.78
Characteristics and perspectives of industry							
D2.1	**Capabilities in receiving and transferring technology in terms of technical and funds**	**3.9**	**0.69**	**4**	**0.65**	**3.85**	**0.93**
D2.1.1	Ability of skilled and capable engineers and R&D staffs	3.7	0.82	4.1	0.56	4	0.81
D2.1.2	Ability of management in providing funds and acquiring grants	4.1	0.56	3.9	0.73	3.7	1.05
D2.2	**Willingness and motivation to work with university with shared value**	**3.8**	**0.67**	**3.9**	**0.98**	**3.85**	**0.95**
D2.2.1	Management initiatives and leadership in R&D	3.7	0.48	4	0.94	3.8	0.91
D2.2.2	Commitment to work with the university	3.9	0.87	3.8	1.03	3.9	0.99
D2.3	**Perspectives on worthiness and value of joint research in terms of economic and intellectual value**	**4.15**	**0.68**	**3.9**	**0.98**	**4**	**1.04**
D2.3.1	Long term strategy for R&D	4.2	0.63	4	0.94	4.1	1.10
D2.3.2	Perspective on positive value of R&D and UIJRPTT	4.1	0.73	3.8	1.03	3.9	0.99
D2.4	**Understanding cultural difference**	**3.9**	**0.87**	**3.6**	**1.17**	**3.4**	**1.07**
D2.4.1	Understanding of working style, obstacles and commitment of each side and organization compatibility	3.9	0.87	3.6	1.17	3.4	1.07
Joint research mechanism							
D3.1	**Communication effectiveness**	**4**	**0.87**	**3.75**	**1.06**	**3.9**	**0.72**
D3.1.1	Communication channel and mechanism	4.1	0.87	3.8	0.78	3.8	0.78
D3.1.2	Regular venue for communications among govt., university and industry	3.9	0.87	3.7	1.33	4	0.66
D3.2	**Management of coordination office and joint research program**	**3.9**	**0.87**	**3.4**	**1.15**	**3.95**	**0.79**
D3.2.1	Adequate staffs for marketing, promotion and policy supports	3.9	0.87	3.2	1.13	3.7	0.67
D3.2.2	Flexibility	3.9	0.87	3.6	1.17	4.2	0.91

Table 38 (cont.)

Code	Description	Project 1		Project 2		Project 3	
		Mean	SD	Mean	SD	Mean	SD
D3.3	**IP management**	**4.1**	**0.87**	**4**	**0.81**	**4.1**	**0.87**
D3.3.1	Fair IP management	4.1	0.87	4	0.81	4.1	0.87
D3.4	**Incentive system**	**3.9**	**0.86**	**3.65**	**1.21**	**4**	**0.94**
D3.4.1	Appropriate university incentive and rewards	3.8	0.91	3.6	1.26	3.7	0.94
D3.4.2	Legitimacy, policy and support from government	4	0.81	3.7	1.15	4.3	0.94
D4.1	**Growth**	**4.3**	**0.67**	**4.3**	**0.94**	**4.4**	**0.51**
D4.1.1	Growth of UIJRPTT and collaboration	4.3	0.67	4.3	0.94	4.4	0.51
D4.2	**Quality performance**	**4.1**	**0.73**	**4.1**	**0.93**	**4.3**	**0.46**
D4.2.1	Improved product and process development	4.1	0.73	4.1	0.87	4.4	0.51
D4.2.2	Improved quality of research results	4.1	0.73	4.1	0.99	4.2	0.42
D4.3	**Economic performance**	**3.9**	**0.86**	**3.8**	**0.85**	**3.7**	**0.54**
D4.3.1	Less investment and time	4	0.81	3.8	0.91	3.5	0.52
D4.3.2	Income from research results	3.8	0.91	3.8	0.78	3.9	0.56

Table 39 Mean and Standard Deviation of Factors and Variables

Code	Descriptions	Primary		Project 1		Project 2		Project 3	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
D1	**Characteristics and perspectives of university**	**4.05**	**0.74**	**4.07**	**0.86**	**4.14**	**0.83**	**3.92**	**0.74**
D1.1	Capability in receiving and transferring technology in terms of technique and funds	4.02	0.73	3.83	0.78	3.96	0.87	3.86	0.77
D1.2	Adequate specialists, researchers and students	4.06	0.72	4	0.93	4.25	0.55	4.15	0.83
D1.3	Adequate research tools and equipment	4.14	0.77	4.1	0.99	4.1	0.99	3.7	0.67
D1.4	Willingness and motivation in working with industry with shared value	3.99	0.74	4.35	0.76	4.25	0.89	4	0.71

Table 39 (cont.)

Code	Descriptions	Primary		Project 1		Project 2		Project 3	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
D2	**Characteristics and perspectives of industry**	**3.97**	**0.75**	**3.93**	**0.73**	**3.85**	**0.95**	**3.77**	**1.00**
D2.1	Capability in receiving and transferring technology in terms of technique and funds technique and funds	3.99	0.71	3.9	0.69	4	0.65	3.85	0.93
D2.2	Willingness and motivation in working with university with shared value shared value	3.98	0.78	3.8	0.67	3.9	0.98	3.85	0.95
D2.3	Perspectives on worthiness and value of joint research in terms of economic and intelligence value	4.12	0.80	4.15	0.68	3.9	0.98	4	1.07
D2.4	Understanding cultural difference	3.81	0.71	3.9	0.87	3.6	1.17	3.4	1.07
D3	**Joint Research Mechanism**	**4.08**	**0.75**	**3.97**	**0.87**	**3.7**	**1.06**	**3.98**	**0.83**
D3.1	Communication effectiveness	4.00	0.74	4	0.87	3.75	1.06	3.9	0.72
D3.2	Management of coordination office and joint research program	3.96	0.74	3.9	0.87	3.4	1.15	3.95	0.79
D3.3	IP management	4.15	0.80	4.1	0.87	4	0.81	4.1	0.87
D3.4	Incentive System	4.21	0.73	3.9	0.86	3.65	1.21	4	0.94
	Outcome								
D4	**Effective UIJRPTT**	**4.14**	**0.66**	**4.1**	**0.57**	**4.06**	**0.68**	**4.13**	**0.38**
D4.1	Growth of UIJRPTT	4.06	0.66	4.3	0.67	4.3	0.94	4.4	0.51
D4.2	Quality performance from joint research	4.18	0.67	4.1	0.73	4.1	0.93	4.3	0.46
D4.3	Economic performance from joint research	4.19	0.67	3.9	0.86	3.8	0.85	3.7	0.54

2. Determining Actual Mean Equivalent and Predicted Scores

A comparative analysis between the collected actual mean scores for each factor and the predicted scores derived from the path standardized prediction equations of the effective UIJRPTT model was conducted to reinforce the validity of path model and to predict the expected outcome factor on the projects. From SEM analysis in Part Three, the developed standardized equation was $Z_Y = .47(Z_{D1}) + -.60(Z_{D2}) + .62(Z_{D3})$.

The actual scores obtained from the case studies in each projects were converted to an equivalent Z score on the original Thai UIJRPTT distribution. To clarify this, the calculation process was, for example, to obtain the actual mean equivalent Z scores for characteristics and perspectives of university (D1) of project 1 (PJ.1) were $Z_{PJ.1,\ D1}$ = (4.07-4.05)/0.74) = 0.027. Z score for characteristics and perspectives of industry (D2) of project 1 were $Z_{PJ.1,\ D2}$ = (3.93-3.97)/0.75) = -0.053. Z score for joint research mechanism (D3) of project 1 were $Z_{PJ.1,\ D3}$ = (3.97-4.08)/0.75) = -0.14. The calculation of Z score for project 2 and 3 were similar to that of project 1. In order to obtain the predicted Z scores for each factor of each project, the Z scores were utilized in the appropriate standardized equation from the primary study. For example, the actual $Z_{PJ.1,\ D1}$ score of 0.027, was substituted into the D1 prediction equation to establish a predicted D1 factor score for project 1 (predicted $Z_{PJ.1,\ D1} = 0.47\ Z_{PJ.1,\ D1}$ = 0.47 x 0.027 = 0.01). The predicted $Z_{PJ.1,\ D2} = -0.60\ Z_{PJ.1,\ D2}$ = -0.60 x-0.053 = 0.03. The predicted $Z_{PJ.1,\ D3} = -0.62\ Z_{PJ.1,\ D3}$ = 0.62 x -0.14 = -0.08. Table 40 shows the actual mean equivalent for each factor from the case study projects and the predicted z scores for each factor in each project.

Table 40 Actual Mean Equivalent and Predicted Z-scores

Title	Descriptions	Factors D1	D2	D3
Results from Primary Study	Mean	4.05	3.97	4.08
	SD	0.74	0.75	0.75
Project Code (case study)	PJ.1 (mean)	4.07	3.93	3.97
	PJ.2 (mean)	4.14	3.85	3.70
	PJ.3 (mean)	3.92	3.77	3.98
Actual mean equivalent Z-score from case study	$Z_{PJ.1}$	0.027	-0.053	-0.14
	$Z_{PJ.2}$	0.12	-0.16	-0.50
	$Z_{PJ.3}$	-0.17	-0.26	-0.13
Predicted Z-scores (standardized)	$Z_{PJ.1}$	0.01	0.03	-0.08
	$Z_{PJ.2}$	0.05	0.09	-0.31
	$Z_{PJ.3}$	-0.08	0.15	-0.08

3. Comparing Actual and Predicted Mean Value

From Table 40, the actual mean values of each factor in each project were then computed and compared against the predicted mean values to reinforce the validity of the path model. For example, the predicted D1 mean value of project 1 was calculated based on the mean D1 value from the primary study and the predicted Z score of D1 from project 1 and multiplied by standard deviation from this mean (i.e. 4.05+0.01*0.74=4.05). The comparison of actual and predicted mean value difference was conducted to provide the evidence that the factor were essential for enhancing effective UIJRPTT.

Table 41 Comparison of Actual and Predicted Mean Value of Model Factor

Project	Predicted Value	Actual Mean Value	Mean Difference	Percentage Difference
Characteristics and perspectives of university (D1)				
Project 1	4.05	4.07	-0.02	-0.49
Project 2	4.08	4.14	-0.06	-1.44
Project 3	3.99	3.92	0.07	1.78
Characteristics and perspectives of industry (D2)				
Project 1	3.99	3.93	0.06	1.52
Project 2	4.03	3.85	0.18	4.67
Project 3	4.08	3.77	0.31	8.22
Joint research mechanism (D3)				
Project 1	4.02	3.97	0.05	1.26
Project 2	3.84	3.70	0.14	3.78
Project 3	4.02	3.98	0.04	1.00

From the results as shown in Table 41, the predicted mean values for characteristics and perspectives of university (D1) from the three case studies were slightly different from the actual values with the ranges of -0.49 to 1.78 percent. This indicated that the path equation from D1 to effective UIJRPTT (D4) appeared to be reliable for the prediction of the effective UIJRPTT. The analysis confirmed that the characteristics and perspectives of university based on the capability of university in terms of techniques and funds, adequate human resources, adequate tools and equipment and willingness and motivation for teamwork and shared value of university professionals were necessary for enhancing the effective UIJRPTT.

The predicted mean values for characteristics and perspectives of industry (D2) from the three case studies were different from the actual values with the ranges of 1.52 to 8.22 percent. This indicated that the path equation from D2 to effective UIJRPTT (D4) appeared to be reliable for the prediction of the effective UIJRPTT.

The results determined that the characteristics and perspectives of industry which comprised of the capability of industry in terms of capability in terms of techniques and funds, willingness and motivation in working with the university with shared value, perspectives on worthiness and value of joint research in terms of economic and intelligence value as well as understanding cultural differences were essential for enhancing the effective UIJRPTT.

The percentage difference of predicted and actual mean values for joint research mechanism (D3) was very close, ranging from 1.00 to 3.78 percent. The result indicated that the path equation from D3 to effective UIJRPTT (D4) was highly reliable for the prediction of effective UIJRPTT. Communication effectiveness, management of coordination office and joint research program, IP management, and incentive system from the university and the government were essential for developing the effective UIJRPTT. In sum, the low percentage differences of the actual and predicted mean value of the three factors confirmed that the three factors were essential for achieving and evaluating the effective UIJRPTT.

Summary of Part Four

The case studies were conducted by selecting three UIJR with an aim to validate the relationship, drawn from the path model, between the three factors namely: characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3), to the effective UIJRPTT (D4) as outcome factor. 30 questionnaire surveys from university and industry professionals were used for the validation analysis. The analysis included mean and standard deviation, determining actual mean equivalent and predicted scores and comparing actual and predicted mean value. From the analysis, the significant path and the standardized path coefficient from the three factors to the outcome factor derived from the SEM equation were determined reliable for evaluating the degree of effective UIJRPTT.

Summary

This chapter presented research results in three parts. First part provided the data on characteristics and background of the respondents as well as their common perspectives toward the UIJRPTT. The second and third parts were the analysis of factors affecting the growth of the UIJRPTT and the analysis of the factors influencing the effective UIJRPTT and the development of the model of the effective UIJRPTT which detailed the research results of the primary study. The first part revealed that in total there were 150 questionnaire respondents, by which 96 were university respondents (64%) and 54 were industry respondents (36%). The interviewees were 63. Among those, the interviewees from the university and industry were 45 and 18 respectively, accounting for 71% and 29%. Majority of the respondents viewed that the UIJRPTT was necessary.

The analysis in potentials and gaps of the context in government support on the photovoltaic technology, the university and industry characteristics and the linkages between university and industry were investigated. Three hypothesized actors namely: characteristics of university (C1), characteristics of industry (C2) and transfer and organization context (C3) as factors affecting growth of the UIJRPTT in Thailand were rated in Likert scale by the questionnaire respondents and further analyzed by descriptive statistical analysis including mean, standard deviation, and t-test as barrier of the UIJRPTT. The data from the interview summary were conducted to identify determinants in photovoltaic technology development.

Four hypothesized factors and variables related to characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2), joint research mechanism (D3) and effective UIJRPTT as outcome factor (D4) derived from the conceptual framework of the model of effective UIJRPTT were analyzed and tested. Statistical methods such as mean, standard deviation, correlation, the confirmatory factor analysis and path analysis were employed to analyze and the model of effective UIJRPTT were developed. The model appeared fit to the data after various modifications. The current status of the three factors in the perspective of the respondents was also analyzed through descriptive statistics and the results showed that they were commonly rated in moderately satisfactory/adequate status. The qualitative data from the interviews were analyzed through summary and content analysis. From the results, the importance of variables in each factor was confirmed and the recommendation on how to improve the status and situation to improve the effective UIJRPTT was presented and discussed.

The final part of this chapter was the section to validate the effective UIJRPTT model path. Based on the interview results in the primary study and literature review, the variables indicators were identified, and, later, used to develop the questionnaire employed with 30 respondents from the three case study projects. The significant paths from the three factors: characteristics and perspectives of university (D1); characteristics and perspectives of industry (D2), and joint research mechanism (D3) to outcome factor were validated by the comparative analysis between actual and predicted mean value. As a result, all three factors were confirmed essential to the enhancement and evaluation of the effective UIJRPTT.