

## CHAPTER V

### CONCLUSION AND RECOMMENDATION

#### **Introduction**

The U-I collaboration and technology transfer have been studied for decades, but few models or frameworks from the studies are suitable for the developing countries like Thailand. Still, areas such as U-I joint research for photovoltaic technology transfer has received little systematic exploration and study. This research ultimately aimed to understand the context related to the UIJRPTT. Thailand was a major case study selected by hoping that the research results could partly help improve the unprogressive situation of the UIJRPTT in the country. The aim of this research was to answer the research questions: why there is little number of U-I joint research for photovoltaic technology transfer, what are the factors affecting the effective UIJRPTT, what model of effective UIJRPTT should be and how to increase the effective UIJRPTT. The identification of the potential and gaps, barriers, and determinants of UIJRPTT growth and the development of the effective UIJRPTT model and analysis of the related factors could lead to the understanding of the situation and shed greater light on what could be done to improve the situation of UIJRPTT in Thailand and, perhaps, in other developing countries.

Based on the literature review and existing studies of technology transfer and U-I collaboration, the hypothesized factors affecting growth of UIJRPTT were identified and the conceptual model of effective UIJRPTT consisting of factors and variables was developed. To acquire the answer for the question of why there is little number of UIJRPTT in Thailand, the qualitative research was conducted to explore and evaluate the potentials and gap, barriers and determinants of the UIJRPTT. The quantitative and qualitative research was then conducted to explore in another part of the research aiming to identify the factors and variables affecting to the effective UIJRPTT. The CFA and SEM path analysis were undertaken to identify the model construct and validate the model and its credibility. Practical actions and issues related

to how to enhance the performance of the model factors as well as the model validation process were reported in the previous chapter.

In this chapter research objectives and their respective outcomes were discussed. Before concluding, policy recommendation, contribution to research, limitation of the study, and directions for future research were also outlined.

## **Research Objectives and Results**

As discussed, this research had two primary objectives. Those included: (1) to identify and analyze the factors that affect growth and effectiveness of the UIJRPTT; and (2) to develop a model for effective UIJRPTT in Thailand. The research results were achieved through the research process and could be summarized as followed.

### **1. Analysis of Factor Affecting Growth of the UIJRPTT: Why There Is Little Number of UIJRPTT**

Despite most of the university and industry professional viewed that UIJRPTT was necessary for them and their organizations, the research survey found that only few UIJRPTT activities were conducted. The answer for such deficiency of the UIJRPTT was the combination of various factors and variables. The research results highlighted the potential and gaps, barriers and determinants of the UIJRPTT by underlining the characteristics of university, characteristics of industry and the transfer and organization context. Gist of the research results were as followed:

#### **1.1 Potential and Gap from Reviewed Context of U-I Promoting Photovoltaic Technology and Linkages**

The background and potentials and gaps of the context related to the promotion of photovoltaic technology and U-I linkages were gathered from the data search and interviews. From the data analysis, it was found that despite there was a great potential from the government's commitment to support the renewable energy, 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 of the government organizations concerned which were the major source of project funds. In terms of university characteristics, it was found that despite the university had a goal to achieve "research based university" which was supportive

to the U-I research activities, the university still lacked of strategic plan on the development of specific technology and scattered funds and restricted rules were the concern of academics. There was no strategic plan among universities concerned in photovoltaic technology development to co-work due to different working style and organization culture. Moreover, as knowledge center, the university itself had potential in funding support from the government and university grants but faced some other obstacles in conducting photovoltaic research such as low number of key researchers conducting photovoltaic technology, deficiency in infrastructure and equipment; and the basic research related to photovoltaic cell development was in the early stage. In terms of industry characteristics, the industry had potential capabilities in adopting and adapting the technology by its own which reflected in the capabilities of the industry in producing quality products, certificates and number of engineers. However, the UIJRPTT was limited, perhaps, due to limited financial income. In terms of transfer context and organization structure, potential was found in the promotion of linkages between university and industry by the university TTO and organization concerned. Major issues such as communication channels, confidentiality and IP management rules and regulation and facilitating the process of negotiation were developed and improved.

## 1.2 Barriers of UIJRPTT

After the potential and gap analysis, identification of the variables that significantly affected the formulation and growth of the UIJRPTT was conducted. Generally the study revealed that the university and industry respondents perceived that items in three factors: characteristics of university (C1), characteristics of industry (C2) and transfer and organization context (C3) were perceived as the potential barriers of the UIJRPTT. Transfer and organization context (C3) were rated highest among those factors. Overall respondents agreed that industry management barriers was the barriers impeding most to the growth of the UIJRPTT, followed by lack of communication channels, inadequate infrastructure, university difficulties with negotiation and managing collaboration, inappropriate confidentiality and intellectual management, cultural differences, potential impact on faculty and students to work with the industry, university lack of motivation, university's inadequate technical and information service, lack of trust, and industry's technical knowledge and absorptive

capacity. Three variables that the respondents viewed not the barriers of the UIJRPTT were university's reliability of knowledge and technology sources, industry lack of motivation and attitude of the industry showing that both university and industry were likely and ready to cooperate with each others in the collaboration.

### 1.3 Determinants of UIJRPTT

The qualitative data from the in-depth interview highlighted the importance of many determinants in technology development in many aspects. The government's roles and support policy affected large extent in driving the technological efforts of the university and industry. 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 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 due to lack of human resources, equipments and funds 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 determined to the growth and performance of the UIJRPTT.

The lessons learned about the root cause of the limited UIJRPTT was then discussed and summarized that it could stem from the university, the industry, the transfer and organization context and the government. The university could not provide technology and knowledge to respond to the industry need and the industry did not value the benefit and return of the UIJRPTT. University gaps such as research related to cell development was in the early stage; there was no integration of knowledge that could benefit the industry commercialization; lack of equipments, lack of specialists with experience, lack of funds to conduct big scale research were the major problems of the university capability building and bring the knowledge and capabilities to be used for the industry commercialization. The technology development was mostly in the early stage and still unproven for commercial viability. Secondly, the industry either did not value the importance of UIJRPTT due to level of

profits and income that was not high enough to invest in big scale research; perception that import technology was easier, faster and more reliable, and in-house R&D was cheaper and could keep trade secret. Thirdly, transfer context and organizational structure was confirmed as the factor affecting the growth of UIJRPTT. The mismatch of university technology and industry need reflected the deficiency of communications between the two parties. Technical and information service, trust, cultural differences and IP management were significantly rated as impacting the growth of the UIJRPTT as barriers. Lastly, it was confirmed that Thailand lacked of critical actors who involved in the system of photovoltaic technology development. The government was the key player in supporting the roles of those actors. However, main obstacle was that the photovoltaic technology was never received legitimacy from the government as key technology for the country. Therefore, the work and tasks of technology and market development from the government organizations mostly were done under the jurisdiction of the stakeholders without streamline strategic plan.

## **2. Analysis of Factor Affecting effective UIJRPTT**

The analysis of factors affecting the effective UIJRPTT was conducted through the use of quantitative and qualitative methods. The results was revealed through the identification of enabling factors and outcome factor, model development, practical action and issues related to the model factors and model validation. The gist was as followed.

### **2.1 Enabling Factors and Outcome Factor Identification**

The research results confirmed that the factors and observed variables in the hypothesized conceptual framework significantly influencing the effective UIJRPTT. Three hypothesized major factors were through statistical descriptive analysis established, namely, characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3). Joint research mechanism was rated highest mean value, followed by characteristics and perspectives of industry and characteristics and perspectives of university. The outcome factor were also measured across three different categories namely growth of joint research, economic performance and quality performance. The study was undertaken to examine the importance of the variables in the factor through factor loadings using the confirmatory factor analysis (CFA). Statistically significant factors

of the enabling and outcome factors and their variable construct were confirmed by the CFA with model goodness of fit indices (chi-square=91.39, df=88, p-value=0.380, RMSEA=0.016) detailed in Chapter IV Part Three. These empirically determined factors and variables were essential for further development of the model of effective UIJRPTT. Those factor variables included: (1) university's capability in receiving and transferring technology in terms of technique and funds, (2) adequate specialists, researchers and students, (3) adequate research tools and equipments, (4) university's willingness and motivation in working with the industry with shared value, (5) industry's capability in receiving and transferring technology in terms of technique and funds, (6) willingness and motivation in working with the university with shared value, (7) perspectives on worthiness and value of joint research in terms of economic and intelligence value, (8) understanding of cultural differences, (9) communication effectiveness, (10) management of coordination office and joint research program, (11) IP management, and (12) incentive system.

## 2.2 Effective UIJRPTT Model

The effective UIJRPTT model was developed by statistical techniques including the CFA, factor construct reliability and average variance extracted. The SEM or path analysis was then performed to test the model and the significant interrelationship between the factors and outcome factors. From the analysis, the significant interrelationships were discovered in the model with the goodness model of fit indices (chi-square=100.84, df=95, p-value=0.320, RMSEA=0.020). The interrelationship path consisted of the interrelationship from characteristics and perspectives of university (D1), characteristics and perspectives of industry (D2) and joint research mechanism (D3) to effective UIJRPTT (D4) as outcome factor. It was found that the three enabling factors significantly influenced to the outcome factor. The model factors and variables as well as significant paths determined from the CFA and SEM were confirmed by the interview data analysis.

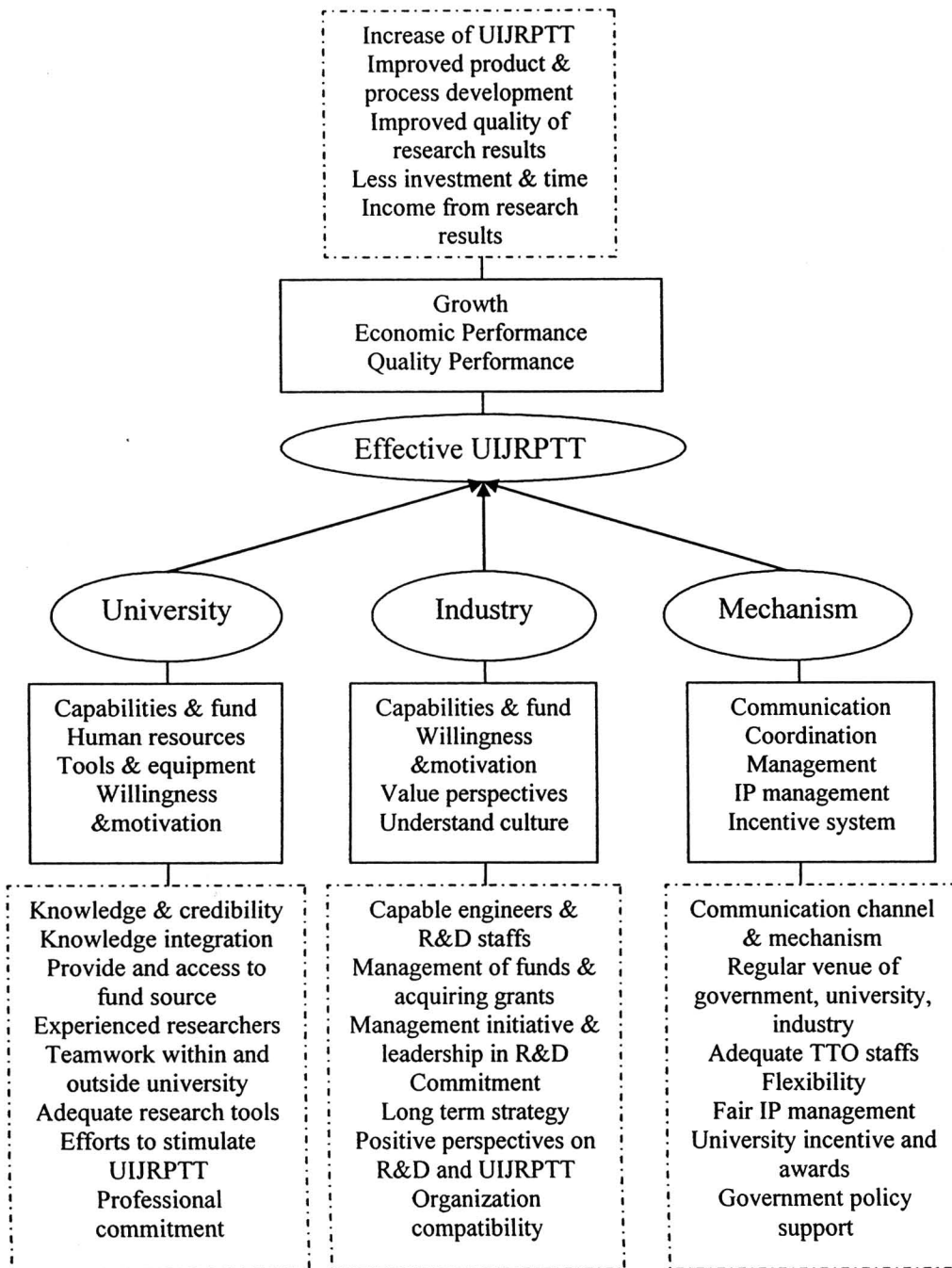
## 2.3 Practical Actions and Issues Related to the Model Factors

The current status of factors in the effective UIJRPTT model was evaluated. Overall respondents rated all factors in moderately satisfactory/adequate status showing that the variables can be further improved and variables in joint research mechanism were mostly rated by the university and industry lower than other

variables showing that the factor could be problematic. Interview findings clearly substantiated the importance of the given factors in the effective UIJRPTT model and to discuss practical issues and actions in each factor to develop and refine the effective UIJRPTT model. Regarding the challenges or problems facing the university and the industry in terms of organization structure and individual obstacles, the responses from the respondents showed that the need for better effective UIJRPTT was mentioned on the issues of the support from the government in the area of photovoltaic market and research development and management of funds, the improvement of capabilities, human resources management, willingness and commitment of both university and industry, equipment management as well as the improvement of joint research mechanism such as IPRs, incentives, TTOs office and communication effectiveness as shown in Table 33 in Chapter IV.

#### 2.4 Model Implementation and Validation

This part was to validate the significant path from the three factors to the effective UIJRPTT on the three project case studies. The university professionals including lecturers, researchers and TTO administrative officers and industrial professionals totaled 30 persons were purposively selected to answer the questionnaire. This comparative analysis was conducted to validate the developed model with more detailed indicators in each variable. The first stage of this part involved identifying indicators of each variable that acquired from the interview results in Part Three and literature review and developing appropriate questions for the questionnaire. It should be noted that these questions were quite similar to those used for the development of the path model with more detailed indicators and the same measurement scale was maintained. The result of the analysis indicating low percentage differences of the actual and predicted mean value of the three factors from the three cases determined that the three factors were essential for achieving the effective UIJRPTT and the empirical links between the factors to the outcome factor was reliable for further monitoring and evaluating the degree of the effective UIJRPTT.



**Figure 16 Schematic of Effective UIJRPTT Model with Factors, Variables and Indicators**

### **Policy Recommendation**

From the research results, the recommendation falls into the roles of the government, the university, and the industry on issues related to the factors and variables in the model. The first policy recommendation is related to the government role. From the previous analysis in Chapter IV, it was obvious that Thailand still never legitimated the photovoltaic technology and industry. The respondents as a result expressed their demand for the government policy support in the technology and market development. Regarding the policy support for the R&D, the government did not have clear position whether it would prefer the import of photovoltaic technology to the development of own technology. The issues that the government should consider if it prefers the industry's import technology is how to diffuse the technology and allow opportunities for the human resources in the university and industry learn and apply the knowledge and technology. On the other hand, the issue that the government should consider if it prefers that Thailand should develop its own technology is the national plan to develop the photovoltaic technology and its market both domestically and abroad. The clear vision and strong political commitment must prevail. By this point the national centralized body under the government office is crucial for the development plans by identifying the goals and targets, mobilization and development of all resources, analysis and prioritization of areas and issues, and coordination and implementation of process. The said body should involve stakeholders and experts in economics, social, environment, sciences and technology, trade, industries related, financial and monetary policies areas to gain the holistic and comprehensive views. The streamline policy, strategic support and activities will lead to the commitment of the government and the university and the industry in developing the photovoltaic technology which further affect to the effective UIJRPTT. However, this recommendation should base on the consideration of the government in the cost and benefit and "appropriateness". The cost and benefit and appropriateness may link to the evaluation of investment in R&D and market development and return from photovoltaic technology and industry, the catch-up process and speed of the research and capabilities of the domestic research institutes and industry, the future of photovoltaic technology and the other technology substitutes and the competitiveness of the Thai photovoltaic industry.

Moreover, as far as the status-quo situation still goes on, the government should not overlook to promote the intimate dialogues and meetings between the government organizations concerned in the area of science and technology policy and R&D supports and of market and industry development and the university and the industry to stimulate the participation of all stakeholders in improving the policy support and funding. For example, the government organization such as NRCT, NSTDA, and the Ministry of Energy should have regular open venues to discuss and consult to improve the cooperation and finally it could lead to the discussion in implementing long term strategy to develop the appropriate strategy for Thailand detailing which technology Thailand should go for, clustering related technology from cell development, material science, engineering and design, developing human resource plan and other infrastructure for R&D such as equipments and tools, co-labs, and appropriate and systematic funding scheme for research in long term with the same direction. The government may support the basic research work related to the selected technology to the university due to the adequate human resources in areas of science, engineering and designing. The university could also work in group or cluster in R&D. The streamline policy and working can enhance the knowledge of the government institutes and university in acquiring knowledge systematically and with long term perspective which will be able to further develop the R&D and capabilities of the university which can attract the industry to work with them in the future. The knowledge and technology can finally be transferred to the industry for example in form of technology licensing. The policies such as science and technology development, industry and investment policy and trade and market development policy and tasks of the Thai ministries concerned should compliment to each others which could finally lead to the perspectives of the industry and the industry that investing in R&D is worth and can gain rent from R&D value added. Last but not least, the R&D of photovoltaic technology should be strengthened. A national institute for photovoltaic technology R&D and market development should be founded to support the technology development and the industry. However, the government decision on this matter should be based on the feasibility on benefit and cost of technology selection which was beyond this research study.

The second recommendation relates to the university roles. Several following points should be addressed. First, the results proved that the integration of knowledge and technology of the university was crucial for the university's capabilities and effective UIJRPTT. One of the obstacles to the growth of the UIJRPTT is that the Thai university laboratory and research units related to photovoltaic technology accumulated their specific knowledge in the specific area that they are interested in or capable with and, due to the different culture and system, those specific knowledge can not fully support the research and need of the industry which aimed for commercialization. The industry expressed its demand in complete products and technology development which required integrated knowledge and sciences. In this regard, the university may consider establish the special research groups to work together in the area that the university staffs from different universities are interested after consulting with the industry and the government funding agencies. The research should be long term project and the research results should be solving the problems of the industry. Second, due to the fact that the government budget is scattered allocated to the university laboratory, this has lead to the deficiency of the facilities, research tools and equipments. The respondents indicated that pooled facilities might be the solutions. However, the problem is whether pooled facilities and research tools worked when obstacles such as location proximity, bureaucratic system, different organization cultural and mismatching of equipment and needs exist. The university may consider working together in discussing about how to share equipments and conduct research and what to apply for equipments and facilities on yearly budgeting. If the equipments and tools are not often used, the university may consider consult with the NSTDA to purchase or cooperate with foreign laboratories and outsource the research part. Third, the human resource management that is crucial for the university should include the capabilities building, incentives and adequacy of specialists, and researchers. Individually, the university faculty members and researchers should adjust themselves in being well rounded in technology they are working and should be able to inform the industry which technology and knowledge can be applied to the work of the industry currently and in the future as well as the global trends of photovoltaic development. The willingness and motivation of the university should also be further promoted. In order to develop technology and conduct research for technology

adaptation and adaptation, the university human resources should have adequate knowledge and technology and experience for a period of time. Therefore the university should do their best in providing training, stimulating and encouraging the university professionals to conduct continuous research, co-lab collaboration with other universities, governmental research institutes and industry to learn the technology altogether and develop technology in long term by giving incentives for conducting research and allow career path to the researchers to avoid brain drain. However, those recommendations will work out when the university has clear vision and goal for developing the photovoltaic technology. The university should also consider the number of the faculty members and researchers as well. It should be considered that in order to achieve the successful research, number of quality faculty member and researchers in the laboratory is important. To produce the technology breakthrough, the country may need a lot of technology developers and scientists who had learning experience from successive research conducting. Looking into each university laboratories/research groups in Thailand, the number of the faculty members and researchers mostly were in the range of 5-15 persons. This is not surprised that in working with the industry the faculty members will face the problem of time constraints. Moreover, the university and faculty member should pay attention to more communication channels with the industry to discuss about the technology and knowledge that they can support each other. This can lead to more possibilities that the two sides will be able to pursue joint research together that they are mutually interested.

The third recommendation is that the industry should be encouraged to realize the importance and the necessity of R&D for competitive growth. The government should promote the industry to work and invest more in conducting R&D. The data from the research indicated that the industry was willingness to work and conduct with the university and would conduct R&D if the government supported the fund. Moreover, with the R&D only, it is not a factor for success for commercialization of the products; the industry also needs the support from the government in the market development, export promotion and industrial infrastructure development. This will help the industry to survive and compete in the global market which would at the end of the day link to the perspectives of the industry that the growing market and trade

facilities were worth for them to invest for improved photovoltaic products and process and could cover the cost for R&D investment. In this case the industry could play a crucial role in lobbying the government organizations concerned in supporting the legitimacy of photovoltaic technology, implementation of policy and support for technology and market development, organizing the regular venues for discussion on concrete plan for photovoltaic and technology development, human resources and research plans and funding scheme among all stakeholders.

In order to work with the university under the effective UIJRPTT, the industry should continue enhance the capabilities of their staffs through participating in co-learning, special courses, and research activities. The industry should encourage the university and the government organization concerned to work altogether and co learning with the industry in photovoltaic technology development. It is important for the two sides to keep up with new technologies and changing nature and scope of issues related to photovoltaic development. To work smoothly, the industry should also discuss with the university to find compatible solutions to diminish the gaps emerged from their cultural differences. Both sides should understand the other constraints and adjust the working style by indicating clear objectives and the roles and responsibilities of each side. Last but not least, the industry should communicate with the university and the governmental organizations concerned more on the short, medium and long term needs of the industry and consult in the future plan that the industry, the university and the government organization should head to particularly in the area of research development. For the time being, it was observed that the industry acquired the knowledge and technology from the UIJRPTT only for short term basis such as testing, and development of photovoltaic system. However, from the technology push and changing technology in the world market, it might be unavoidable that the industry should consider the medium and long term cooperation with the university and government research institutes in photovoltaic technology development. Due to the fact that the R&D took some time, all the stakeholders should consider planning altogether on what they could do and how long. The cooperation should be based on the mutual and country benefits.

The final recommendation is that the university and the industry should work together in emphasizing the importance and improving of the regulatory and promotional laws and regulations related to IPRs, communication effectiveness and TTO management. The fairness of the contract and bylaw provision for sharing, confidentiality, IPRs and conflicts resolution was the step to boost trust from each others. Without communication effectiveness, each side will continue separately working, and will lead to deficiency of interactions and participation. Communication channels and strong linkages between the university and industry should also be fostered. It can be done in two levels. First, the university as “research based university” should encourage the interactions with the industry through organizing venues to talk and discuss on the improvement and future of research plan for photovoltaic development. The position from this venue can lead to further discussion with the government agencies. The venue should be persistent and sincere. This recommendation will work when the university and the industry agreed upon the necessity of photovoltaic technology development. Another level is communication in practice which involves three steps. First, the step of building relationship and engagement between the university and industry for joint research and technology transfer activities. It can include the communication that brings the two sides to familiarize and know each others such as site visit and recreation activities which will pave the way to build trust and understanding for future collaboration. It should also include the exchange of information such as the updated information of the university and industry through an on-line linkages detailing regular updated of the Thai researcher lists, activities, research results and progress of the R&D in global community. This website should interface the connection and communication network between the university and industry. Once the UIJRPTT is conducted, the step to maintain the relationship should be considered such as establish venues to discuss the problems and obstacles and evaluation of the joint research works as well as finding the ways to improve the joint research for technology transfer. The last step is keeping contacts to each others in the post joint research projects. The TTO management is also important as the TTO can play a crucial role in facilitating the process of communications and arrangement of IPRs, funding and conflicts and problems solving. But the obstacle is that the staffs of the TTO in the Thai university who are

handling over the issues of linkages with the industry directly are scarcely. The university and the TTO should consider and consult with the university and industry more to be efficiently working and facilitating them in promoting and conducting the UIJRPTT. Moreover, when the collaboration between the universities and the industry work out in the way of integrated team work, the TTO will play more roles in dealing and arranging the issues related to contract, benefit allocation and others facilitation works such as funding and reimbursement. The university and the TTO may consider set up the system arrangement in the future.

## **Contribution of Research**

### **1. Contribution to Implication to Photovoltaic Technology Development**

The first contribution of the research was that this research provided the analysis that led to the understanding of the context related to the photovoltaic technology development through the UIJRPTT and identification and analysis of barriers and determinants of growth of the UIJRPTT. Such understanding allowed opportunities for all stakeholders to realize the strength, weakness, opportunities and threat of the context and factors related to the effective UIJRPTT. The weakness of the university was obviously including the factors related to individual academicians and university system. The weakness in individual aspect included limited faculty time, limited capabilities and skills, ability to work with the industry and the capabilities in integrating scientists and researcher in working together. In terms of systematic approach, lack of continuation of policy support, incentive system and plan for human resources development in the photovoltaic technology and direction of photovoltaic research development was also considered as weakness. For the industry, lack of capital for research investment, negative attitude of research work and lack of value related to the concept of 'research for owning technology' that was connected to the firm's competitiveness and catching up technology by purchasing technology abroad could be considered the weakness of the industry affecting UIJRPTT. The strength of the university included the wide ranges of researchers working in the engineering, design, and material development which related to the photovoltaic technology development by which their capabilities could be enhanced with continuous support. The strength of the industry included the capable and skilled

human resources in engineers and willingness to work with the university if the research work was supported by the government and if the industry viewed the possibility of research results for commercialization. The opportunities included the university support scheme, the government funds and the 'research university' aim, which provide more rooms and opportunities for further support if all stakeholders emphasize the necessity of photovoltaic technology development. The threats that could be seen from this research involved obstacles to increase the capabilities of the university human resources due to lack of budget in conducting large scale research, and lack of legitimization of the government on the photovoltaic industry and technology which affected to the domestic market development, export promotion and policy in industry and science and technology. It could be said that if the threat still exist, the cooperation and collaboration between university and industry under the UIJRPTT could not be improved. Therefore, the university, the industry and the government could bring this research results particularly the factors and variables to be considered in improving the weakness, developing the strength, increasing the opportunities, and reducing the obstacles and threats. The result of the improvement from understanding the factors as the U-I joint research is considered the vehicle for true research and development process of technology. Increase in effective U-I joint research means the development of human resources and technology in the field of photovoltaic. The industry will also become less dependent on foreign technology, be more competitive and enhance the renewable energy industry and applications in Thailand.

The model developed in this research reflected that the UIJRPTT required the factors: characteristics and perspectives of university, characteristics and perspectives of industry and joint research mechanism which were compliments with the study of barriers and determinants of the UIJRPTT. All stakeholders may be interested in the pathways from those factors in achieving the effective UIJRPTT. The factor variables that should be discussed were the extensive knowledge base and fund, adequate specialists, adequate tools and equipments which were the basis factor that the university should be equipped. The variables related to the characteristics and perspectives of industry such as the perspectives on management teams on worthiness and value reflected that the decision of the industry to participate in the UIJRPTT

depending mainly on the benefit and cost and value of research results. The joint research mechanism which was rated in the least satisfied status had high impact in building up the linkages and the readiness of both university and industry to work together and the allocation of benefits from the UIJRPTT. The understanding of those factors and issues would support the work of the university and the TTO to improve, and develop the working system to be more effective. In terms of the recommendation from the respondent's interview, some of them could be done without delay such as to increase the communication channel such as development of website, support of training, special vocational course for industry staffs and site visit of the university to industry. This could improve the U-I linkage. However, the suggestions related to the government policy and strategic plan on market development, research budgeting, and university human resource management to the photovoltaic technology and industry was the suggestions that all stakeholders should consider the possibility to improve the situation.

## **2. Contribution to Literature**

This research contributed to two main areas of studies, namely the U-I collaboration and technology transfer by providing empirical evidence from the context of the developing country like Thailand and of the emerging industry like photovoltaic industry.

The contribution to technology transfer literature entailed the confirmation on the roles of the government in developing countries like Thailand in playing crucial roles in supporting the technology and market development and university-industry joint research. With regard to the fact that the photovoltaic technology and market development required market push from the government, without the legitimization from the government, it could affect to the discrete of vision and long term strategy for photovoltaic technology and market development to the industry and innovation system of the country. Moreover, due to the fact that technology transfer literature related to developing countries largely involved with technology transfer modes and effect of technology transfer but overlooked the interactive long term relationship between the university and industry, this study integrated those two-studies concept and provided empirical evidence on the barriers and obstacles as well as source of the problems of photovoltaic technology transfer under the university and industry joint

research. The results confirmed that developing countries like Thailand still faced the problems and obstacles in promoting the collaboration and in developing photovoltaic technology, innovation and technology transfer. The university still lacked of capabilities in terms of technical and funds, specialists and equipments that could support the large scale research, research for photovoltaic innovation and research for photovoltaic commercialization. From the results, despite viewing that the UIJRPTT was essential, the industry did not considerably invest in the UIJRPTT due to perspectives on cost and benefit, and profit and loss basis which related to the photovoltaic market growth and limited competitiveness of the industry.

The studies on U-I collaboration had continued to mature throughout the last decades, with large number of and varieties of studies examining the relationship from education, knowledge management, organization and innovation perspectives. This study results on effective UIJRPTT contributed to a better understanding of the relationship between U-I collaboration organization mechanism, technology transferor and transferees characteristics as well as individual and government roles in promoting U-I joint research in developing countries in different dimensions. The results also reflected the perspectives of both university and industry. Moreover, the application of the extensive knowledge gained from qualitative and quantitative data analysis and model development allowed the development of a holistic understanding of relationships. In the developed model of effective UIJRPTT, all factors and variables related characteristics and perspectives of university, characteristics of industry and joint research mechanism were equally important. By this, it can assist the university and industry as well as governmental organizations in Thailand and in developing countries to better evaluate the U-I joint research for technology transfer and to accelerate the rates of U-I joint research and technology transfer.

In terms of the U-I collaboration management, joint research mechanism was considered important to the effective UIJRPTT. Communication channel, IP and confidentiality management were discussed among the university and industry respondents as crucial basis for the UIJRPTT formulation. Various recommendations came out from the respondents by suggesting the increase in informal communication and acquaintances such as recreation activities, classroom linkages and special vocational courses for the industry staffs and university' site visits to the industry. IP

and confidentiality were discussed more among the industry respondent that the factor was affecting high in the decision in making to participate in the UIJRPTT and in in-house R&D investment. The two issues were rarely found discussed in the literature related to Thai context. The empirical evidence could contribute to the communication and IP management literature.

### **Limitation of Research Study**

Some limitations from the research study were discovered and presented as followed:

1. In quantitative analysis, the sample size for this thesis was rather small compared to number of factors and variables in the model. However, due to the fact that there was limited number of faculty members and TTO administrative officers who directly handle with the UIJRPTT and limited number of engineers that could be accessed to, the sample size in the study was limited.

2. The measurement analysis depended on the perceptions and experience of the respondents. Most of the university respondents were researchers, professional academicians, and administrative staffs and most industry respondents were engineers. If the author changed the respondents, the answer could be changed and affected the model. Therefore, data analysis from the interviews was conducted to confirm the quantitative analysis and acquire more detail on the factors and variables.

3. The questionnaire for part B asking the respondents to indicate the effect of the item to growth of UIJRPTT in column B may raise the misunderstanding to some part of the respondents. Therefore, their values rated were excluded as missing value from the data analysis. The results and analysis of the data in that part was not from overall respondents.

### **Areas for Further Research**

With the limitation of the research study, the future research should bring the research results to further study and reexamine in the following area:

1. It should bring the report instruments and measurement methods from this research work to test with the photovoltaic industry and university in other developing countries and the other renewable energy sectors in Thailand to compare the results.

2. It should be considered to conduct further feasibility study on the recommendations from the respondents and the author. The results could provide valuable advice to the government, university and industry in adjusting and implementing policy and supports of photovoltaic technology and industry development and other renewable energy in Thailand as well as to develop the scientific development system in the university and in the country as a whole.

3. Roles of public policy in supporting photovoltaic technology and UIJR, roles of university and industry should be further investigated in the context of Thailand and in comparison with other countries both developed countries such as Japan, the United States and Australia, etc. and developing countries such as China and South Korea, etc. to identify the key common and special factors those countries acquire that can lead them to be the photovoltaic technology developer and global suppliers.

## **Conclusion**

The incorporation of the existing research in the area of U-I collaboration and technology transfer had created unique opportunities for this research. The mix qualitative and quantitative analyses related to the factors affecting growth and the effective UIJRPTT outlined in this thesis could provide a framework for clearly understanding of the nature, source of problems, and obstacles derived from the university and industry as well as the joint research mechanism that affected the formulation, the relationship and the effectiveness of the UIJRPTT. Through the foundation of the existing U-I collaboration and technology transfer literatures, this research could provide a basis and empirical evidence for future study on U-I collaboration, joint research and technology transfer development as well as practical issues for the university, the industry and the government organizations to overcome barriers and improve the UIJRPTT situation in Thailand.

The formulation barriers and determinants of the UIJRPTT growth in Thailand clearly required a thorough investigation of the underlying combination of factors and issues individually and systematically. To achieve the favorable situation of the UIJRPTT growth for the case of Thailand, it is not only to overcome the barriers but also to understand the context, the situation, and the root cause and to evaluate the

possible ways to resolve problems and improve the strength of variables related to the studied factors.

The effective UIJRPTT perceived as highly satisfied by the university and industry depended on the ability of the university and industry in building up their capabilities in terms of human resources, technology, equipments and positive attitudes on the UIJRPTT and the ability of both university and industry to understand the similarity and differences in dealing with the relationship. More importantly, the effective UIJRPTT also required the commitment from the university and the industry staffs and CEOs, the willingness and motivation of academicians and industry staffs, the legitimacy to the photovoltaic technology and market development derived from government policy and supports, as well as the improvement of joint research mechanism that created favorable relationship environment, communication, linkages and trust in completing the initiated cooperative working.