

Research Article

An Efficient Evaluation Model for the Assessment of University-industry Research Collaboration in Malaysia

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Abstract: University-Industry Research Collaboration (UIRC) is an essential, effective and dynamic factor not only for development of social community but also for the development of the nation. Despite the enormous importance of this research collaboration, there have been certain issues still remain in this domain. Several articles have been published to deal with the factors affecting this collaboration and to make the collaboration successful. However, the discussion about the concept of evaluation and its potential application to this collaboration has been excluded from the mainstream literature. In this study, we focused on the evaluation scheme to assess the strength or weaknesses of the collaboration. The contributions of this study are in threefold. First, it recognizes the highly influential constraints, evaluation parameters, success criteria and tangible outcomes of UIRC that are the core demand of the evaluation process. Second, it develops an evaluation model that illustrates the comprehensive review of Malaysian UIRC. Third, it provides a robust set of evaluation metrics that is responsible to evaluate the strength not only Malaysian UIRC but also any research collaboration between university and industry. This evaluation metrics can be utilized in term of checklist by simply following the set of generated evaluation metrics to check the strength and weaknesses of the collaboration. As far as, we aware of, this is the first time an extensive contribution is attempted in this area of research.

Keywords: Evaluation metrics, evaluation model, success criteria, tangible outcome, university-industry research collaboration

INTRODUCTION

Recently University-Industry Research Collaboration (UIRC) due to its great impact on innovation and economic growth gained the level of interest widely (Mitive, 2009; Guan and Zaho, 2013). Ample amount of knowledge have been raised about UIRC (Petruzzelli, 2011; Bruneel *et al.*, 2010). For instance, some of the researchers promote the knowledge about the importance of UIRC (Arvanitis *et al.*, 2005; Othman and Omar, 2012). Some provide the parameters to enhance the UIRC and some authors worked on the output of research collaboration (Etzkowitz and Leydesdorff, 2000; Rast *et al.*, 2012). While the research about to evaluate the strength of the collaboration is totally unattended in the main stream literature, especially in developing countries like Malaysia. Developed countries reserve a big amount of their budgets for the periodical evaluation of their UIRC (Boardman, 2009). As the UIRC have direct and significant impact on the economic growth of the nation and only the powerful collaboration between university and industry can enhance technological innovation and a precious source of progressive and prosperous society (Albuquerque *et al.*, 2008). Unfortunately research

collaboration between university and industry in developing countries are totally deprived and immature. The reason of immaturity between their collaborations is the lack of knowledge about the process of evaluation. Although some of the authors provide indicators to assess the strength of the UIRC (Esham, 2008) however, according to Philbin (2008), evaluation process is the comprehensive review of the situation that search out all the constraints that limit the collaboration, build the criteria that make the collaboration more strengthen and mention all the outcomes that one powerful UIRC should provide. This statement raises two research questions that what are the constraints that are responsible to minimize the outcomes of the collaboration? And what are the success criteria that make the collaboration stronger and maximize the outcomes of the collaboration? In well developed nations, there exists a powerful research bond within U-I to carry out innovations in smooth and healthy way. But in developing countries, certain constraints limit the efficiency of university-industry research collaboration. Moreover, lack of periodical evaluation is also a big gap between university-industry collaboration while the periodical evaluation is the best practice to measure the efficiency and deficiency of any

linkage (Barnes, 2002). Therefore, it is necessary for the developing countries to adapt important techniques to evaluate the research collaboration that can identify those elements in which they are weak. For this purpose, dynamic set of evaluation metrics has been generated in this research to evaluate the strength and weaknesses of the research collaboration and illustrated how an effective and efficient evaluation model can be developed as never been illustrated previously.

LITERATURE REVIEW

University-industry collaboration is an essential and dynamic factor in social as well as in technological development in almost all fields of life (Iqbal *et al.*, 2015a, b). Since 1980s both research efforts is considered as a major factor in the development of human societies and era (Faiz, 2013; Levy *et al.*, 2009). Progress of any nation deeply depends on the research collaboration of university and industry (Yang, 2008; Eom and Lee, 2010; Etkowitz and Leydesdorff, 2000; Odagiri and Goto, 1996; Vessuri, 1998; Casas *et al.*, 2000; Cohen *et al.*, 2002; Arocena and Sutz, 2005; Albuquerque *et al.*, 2008; Bekkers and Bodas-Freitas, 2008). Despite the enormous importance of university-industry research collaboration, Malaysian universities and industries still have certain constraints in the process of their successful collaborations. For instance, conflict of intellectual property right. Conflicts regarding possession of the Intellectual Property Rights (IPR) in Malaysia always create clashes between both parties (Ismail *et al.*, 2012; Govindaraju and Wong, 2011). It is always appears in the shape of argument between university-industry collaboration (Knight, 1992). Researchers of the university need protection of their intellectual property rights or their creativity, on the other side firms also expect ownership of Intellectual Property (IP) by virtue of their huge investment in the designing procedure of the technology. As mentioned by Hall *et al.* (2000) and Iqbal *et al.* (2013a, b) in several cases, matters of (IPR) depict unsolvable problems that limit the expected relationships between university and industry. Similarly, Universities and industries have diverging agendas and different alignments (Goomes *et al.*, 2005; Gulbrandsen *et al.*, 2011), which reflects divergent goals, time, orientations, basic assumptions and characteristics. Time constraint is also one of the major and big constraints between university-industry collaboration in Malaysia. The academic world always takes time to publish their research results without concerning towards market condition and expectation of the industry (Audretsch and Lehman, 2005). On the corresponding sides, firms cannot stay long and avail the facilities from others (Feldman and Desroches, 2004). Secondly due to time constraints university cannot communicate properly with industry and cannot provide the consultancy for the specific technology or

innovation. Thus, gap in consultancy and weak communication always becomes hindrance between their collaboration. Simultaneously, Lack of education and training is one of the major constraints between university-industry collaboration in Malaysia. In order for the appropriate technology to be transferred and effectively maintained in the firm of developing country, appropriate educational systems and personnel training must be developed (Viotti, 2002). Fund and finance is also another issue between UIRC. At the time of the research collaboration, it is also mentioned in the agreement that industry will provide the fund and equipment for the accomplishment of the project or research. Industry provide fund to the university for the development of new research but expects commensurate return on the base of their investment (Wonglimpiyarat, 2011). This stringent perception of the industry always creates misunderstandings between their collaboration.

By following the previous theories of the research, this research provides valuable parameters that not only evaluate the strength of the collaboration but also provide the criteria that can make the collaboration successful. For instance, Cooperative and supportive R&D agreement is the parameter that can lessen the conflicts of IPR and helpful to evaluate the strength of the collaboration. According to Federal Technology Transfer Act in 1986 Cooperative Research and Development Agreements (CRADAs) has emerged as one of the popular and successful research collaboration mechanisms and gained much interest of the researchers (Tran and Kocoglu, 2009; Veugelers and Cassiman, 2005). CRADA reflects close interaction between both partners (National Science Foundation, 2000; Grimpe and Fier, 2010). While the Flexible relationship, strong agreement and strong commitment are some major success criteria to evaluate the strength of R&D agreement as well as the strength of the collaboration (Iqbal *et al.*, 2011). Similarly knowledge sharing, joint venture, frequent communication, financial support and culture development are the parameters to evaluate the strength of the collaboration as well as diminish the constraints of education and training, lack of technological competency, lack of consultancy, fund and financial matter and culture difference issues. Each evaluation parameters have their own success criteria that are illustrated in Fig. 1. As far as the concern is the outcomes of the collaboration, it is widely acknowledged that the purpose of university-industry emergence or research collaboration is to produce outcomes that can contribute in the economy of the nation. The success of university-industry collaboration can also be evaluated by their tangible and technical outcomes (Reams, 2006; Risaburo, 2005). Several studies measure the success of (U-I) partnerships widely on the basis of tangible outcomes produced as powerful collaborations (Bonaccorsi and Piccaluga, 2007; Risaburo, 2005). Thus, in this

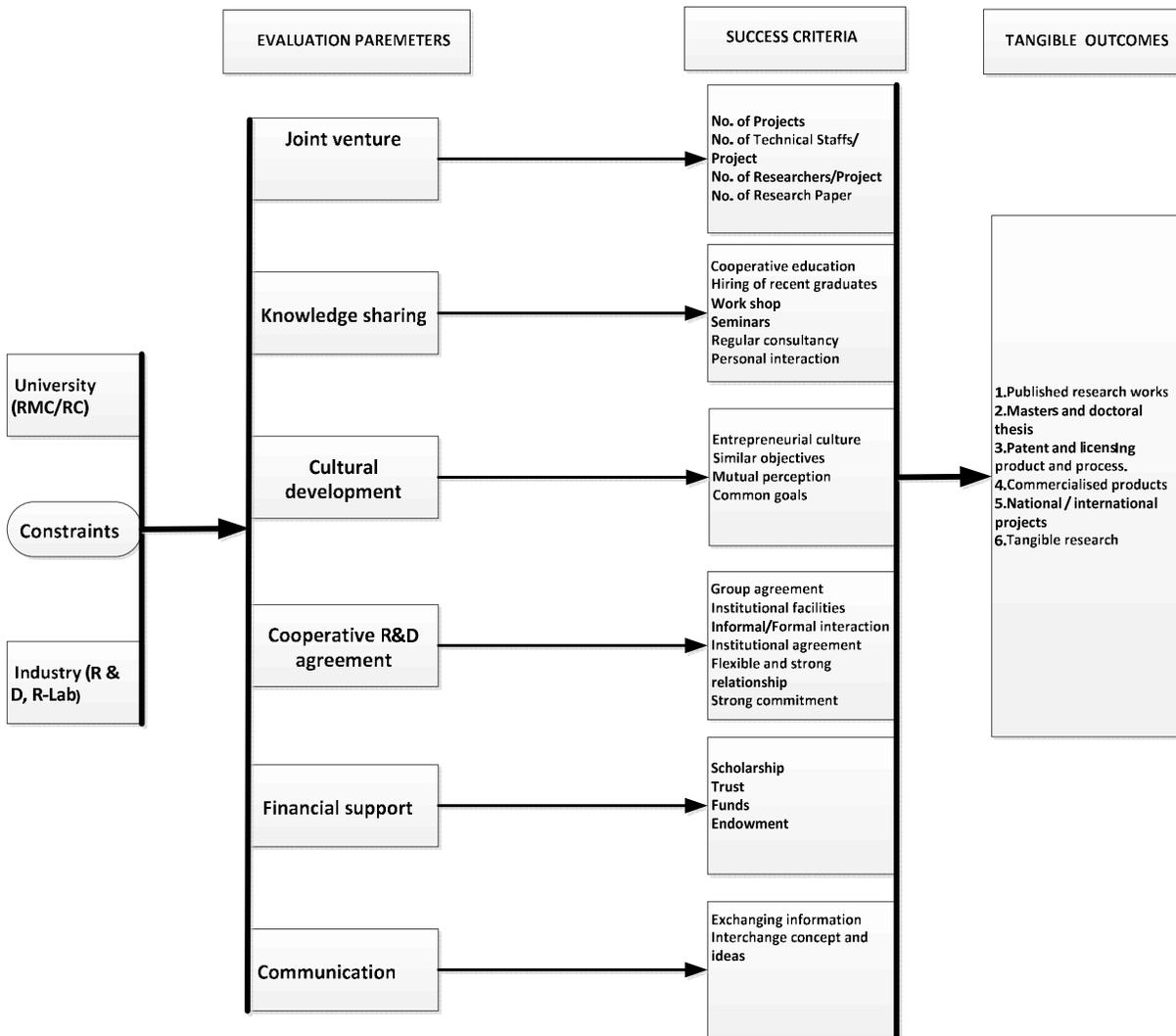


Fig. 1: Theoretical framework

research, Publication in high impact journals, Dissertations or Master and Doctorate thesis, patent and, licenses, commercialised product and national or international projects has been considered as the high impact outcomes of university-industry research collaboration.

RESEARCH METHODOLOGY

To achieve the best evaluation metrics and to develop an evaluation model both quantitative and qualitative methods have been utilized. Data has been gathered from different research centres of three research universities, Universiti Teknologi Malaysia (UTM), University Sains Malaysia (USM) and University Putra Malaysia (UPM) and their Collaborated industries. The main consideration in selecting these universities is the status of Research

University and they are highly engaged in research and development activities with different industries.

In order to ensure the research validity, sample size is carefully identified, so that it can represent the whole group from which it were taken. Our qualitative and quantitative questionnaires were designed for both university and industry. Selected PhDs graduate, currently pursuing PhDs and lecturers from these research centres were surveyed for the purpose of quantitative collections. For qualitative collections, selected directors, professors, lecturers, or administrations of research management centres from universities and the top management of the industry's director, Associate director, administrator and coordinator are interviewed. All the respondents were identified as an individual unit analysis to meet the requirements for answering the research questions. For our quantitative survey, the total population was 800

which include PhD researchers and lecturers; the confidence level is 95 with 5% margin of error. To obtain a high response rate and more accuracy results, the survey questionnaire had been delivered to 550 respondents in seven research centres. However, 362 questionnaires were considered as usable with 66% response rate. While, total 11 respondents were participated in our qualitative survey. Out of eleven six respondents are from the research centres and other five are from the corresponding R&D of industries. However, open ended questions were asked from the respondents depending on the scenarios and modes of discussion to achieve the maximum experiences of the respondents. In this research we have four different variables, constraints, evaluation parameters, success criteria and tangible outcomes. As, this research is purely on the evaluation of research collaboration between university and industry. Thus, to achieve evaluation metrics, evaluation parameters that have been mentioned in theoretical framework is dependent variable and the constraints, success criteria and tangible outcome are independent variable.

RESULT ANALYSIS

For analysing the data and for developing an evaluation metrics, a mathematical declaration is stated. A mathematical model is developed to analyse and to explain the complete scenarios of evaluation model that includes quantitative and qualitative collections. This model is comprises of five steps that are responsible for the generation of final evaluation metrics. Step 1 illustrated the all possible constraints, success criteria, evaluation parameters and tangible outcomes (quantitative data collection). In Step 2, based on mean and standard deviation, high impact constraints, evaluation parameter, success criteria and tangible outcomes were calculated. Step 3, discussed the clarification of relationship amongst the variables. Step 4, demonstrated the removal of redundancy by combining the related and non related variables. For the last step 5, concrete set of evaluation metrics were developed which includes related and non-related variables. Quantitative analysis is used to analyse step 1 and step 2 (generation of high impacts). Qualitative analysis is used to analyse step 3, 4 and 5, (relationship, redundancy and final evaluation metrics). Different symbols were selected for specific terminologies. For example, the symbol for Evaluation Metrics is (EM). Likewise in the place of Constraints, Evaluation Parameters, Success Criteria and Tangible outcomes (X, Y, Z and P) are used respectively. While HI is for the high impact:

EM = Evaluation metrics
 X = Constraints
 Y = Evaluation parameters
 Z = Success criteria

P = Tangible outcomes
 HI = High impact

For the,

Step 1: All possible constraints, evaluation parameters, success criteria and tangible outcomes is listed down. Where X_i , Y_i , Z_i and P_i are all possible constraints, evaluation parameters, success criteria and tangible outcomes respectively:

$$\text{Step 1: } X_1, X_2, X_3 \dots \dots X_n = \sum_{n=1}^N X_n$$

$$Y_1, Y_2, Y_3 \dots \dots \dots Y_n = \sum_{n=1}^N Y_n$$

$$Z_1, Z_2, Z_3 \dots \dots \dots Z_n = \sum_{n=1}^N Z_n$$

$$P_1, P_2, P_3 \dots \dots \dots P_n = \sum_{n=1}^N P_n$$

Step 2: Elaborates the high impact constraints, evaluation parameters, success criteria and tangible outcomes. To develop the statistical method “mean and standard deviation” are utilized. To finalize the high impact values, average of all the means values is taken. If the mean of any attributes related to their respective variables is higher than the total average value, these attributes of variables are considered as high impact attributes:

$$\text{Step 2: } H_i / \sum_{n=1}^N X_n = C$$

$$H_i / \sum_{n=1}^N Y_n = Y$$

$$H_i / \sum_{n=1}^N Z_n = Z$$

$$H_i / \sum_{n=1}^N P_n = T$$

Qualitative analysis is used to evaluate the relationship of evaluation parameters with other variables. Evaluation of this relationship is highly mandatory for the removal of redundant attributes of respective variables. In Step 3, ‘r’ stands for relationship and in step-4, ‘R’ stands for related and ‘N-R’ stands for non-related parameters and ‘U’ stands for Union of both related and non-related parameters. In step 5, evaluation metrics is comprises of union of related and non-related parameters. Step-3 shows the relationship of evaluation parameter with constraints, success criteria and tangible outcomes. Once the relationship identified using qualitative approach, all the redundant parameters were removed and remaining parameters merged together to generate the final evaluation metrics. In the final step-5, complete evaluation metrics is listed down to evaluate research collaboration within university and industry. However complete sets of steps are considered as evaluation model (Fig. 2).

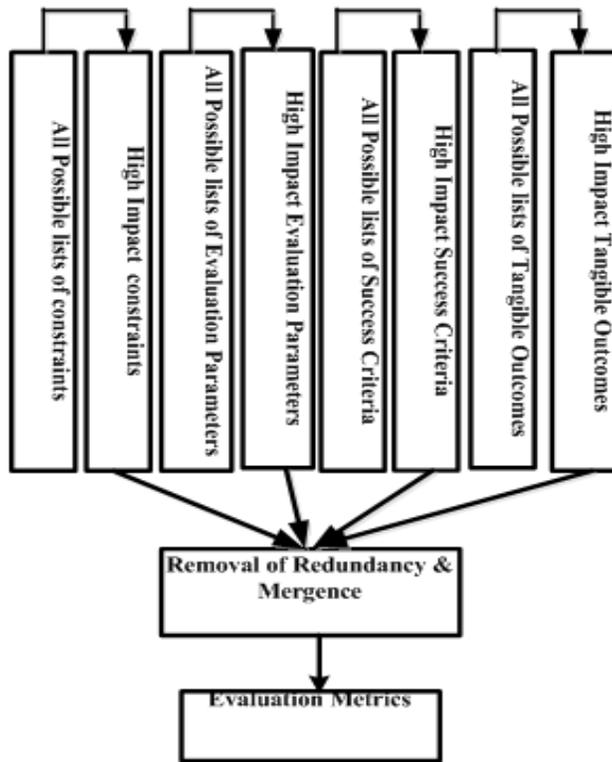
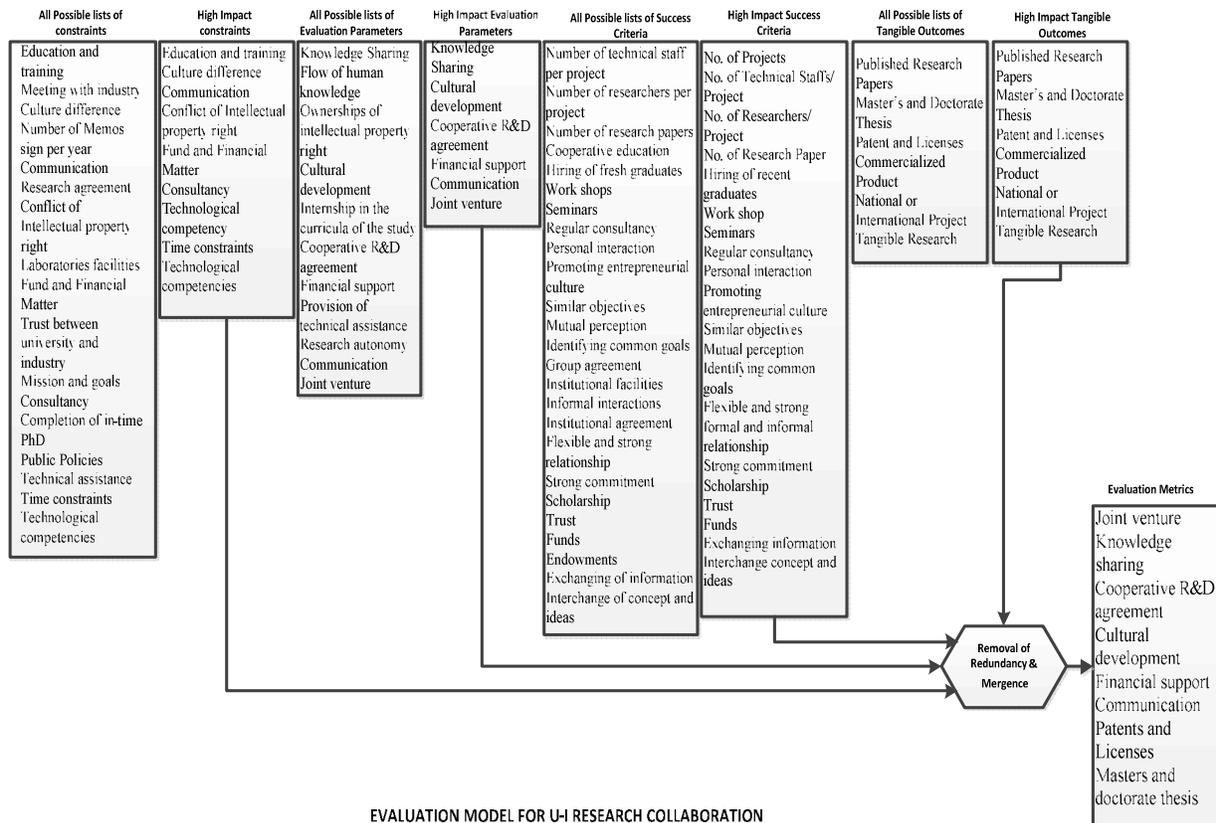


Fig. 2: A conceptual model



EVALUATION MODEL FOR U-I RESEARCH COLLABORATION

Fig. 3: Evaluation model for the assessment of university-industry research collaboration

Table 1: Descriptive statistics of high impact constraints

Constraints	Mean	S.D.
Education and training	4.58	0.495
Meeting with industry	4.32	0.468
Culture difference	4.59	0.492
Number of memos sign per year	4.40	0.492
Communication	4.36	0.481
Research agreement	4.35	0.479
Conflict of intellectual property right	4.56	0.497
Laboratories facilities	4.35	0.479
Fund and financial matter	4.58	0.494
Trust between university and industry	4.45	0.499
Mission and goals	4.36	0.483
Consultancy	4.59	0.492
Completion of in-time PhD	4.39	0.490
Public policies	4.58	0.495
Technical assistance	4.43	0.497
Time constraints	4.56	0.498
Technological competencies	4.57	0.496

S.D.: Standard deviation

Step 3: (Y r C), (Y r S), (Y r T)

Step 4: (R, N-R)_(Y/C) (R, N-R)_(Y/S) (R, N-R)_(Y/T) ((R_{Y/C}) U (R_{Y/S}) U (R_{Y/T})) U ((N-R_{Y/C}) U (N-R_{Y/S}) U (N-R_{Y/T})) (R) U (N-R)

Step 5: EM = ((R) U (N-R))

Generation of high impacts: In this section, descriptive statistics of all possible Constraints, Evaluation parameters, Success criteria and Tangible outcomes have been evaluated using mean and standard deviation. This technique helps to find out high and low impact variables within their all possible lists. However, all the high impacts are selected based on the average value of their means. All the HI variables have been mentioned clearly in the concrete model of evaluation in Fig. 3.

Relationship of high impacts by qualitative approach: A Non-mathematical procedure is implemented to produce the findings from interviews, along with some observations and documents concerning to the evaluation of research collaboration between university and industry. The relationship of evaluation parameters with different variables have been presented in the following table that have been collected from our qualitative respondents (Table 1 to 4).

From the Table 5 it can be concluded that almost all the evaluation parameters is linked directly or indirectly with constraints and success criteria. However, if evaluation parameter is compared with tangible outcomes, it can be analysed that all the parameters of evaluation is related to tangible outcomes except (patent and licenses) and (masters and doctorate thesis). According to the fifth step of evaluation model, after the successful removal of redundancy in the parameters of variables non related parameters has been merged with related parameters to generate the evaluation metrics. Thus below Table 6 shows the final list of evaluation metrics.

Model for the evaluation of research collaboration: Figure 2 show the conceptual evaluation model where

Table 2: Descriptive statistics of high impact evaluation parameters

Evaluation metrics	Mean	S.D.
Knowledge sharing	4.60	0.491
Flow of human knowledge	4.36	0.481
Ownerships of intellectual property right	4.46	0.500
Cultural development	4.62	0.487
Internship in the curricula of the study	4.42	0.495
Cooperative R and D agreement	4.61	0.488
Financial support	4.56	0.498
Provision of technical assistance	4.44	0.498
Research autonomy	4.43	0.497
Communication	4.55	0.498
Joint venture	4.57	0.496

S.D.: Standard deviation

Table 3: Descriptive statistics of high impact success criteria

Success criteria	Mean	S.D.
Number of projects	4.57	0.496
Number of technical staff per project	4.57	0.496
Number of researchers per project	4.58	0.494
Number of research papers	4.58	0.495
Cooperative education	4.49	0.501
Hiring of fresh graduates	4.58	0.495
Work shops	4.58	0.495
Seminars	4.55	0.498
Regular consultancy	4.56	0.497
Personal interaction	4.56	0.497
Promoting entrepreneurial culture	4.57	0.496
Similar objectives	4.56	0.497
Mutual perception	4.56	0.497
Identifying common goals	4.58	0.494
Group agreement	4.53	0.500
Institutional facilities	4.63	0.483
Informal interactions	4.34	0.477
Institutional agreement	4.42	0.496
Flexible and strong relationship	4.58	0.495
Strong commitment	4.58	0.495
Scholarship	4.58	0.495
Trust	4.58	0.495
Funds	4.62	0.487
Endowments	4.46	0.500
Exchanging of information	4.58	0.495
Interchange of concept and ideas	4.62	0.487

S.D.: Standard deviation

Table 4: Descriptive statistics of high impact tangible outcome

Tangible outcome	Mean	S.D.
Published research papers	4.62	0.485
Master's and doctorate thesis	4.62	0.485
Patent and licenses	4.60	0.490
Commercialized product	4.58	0.495
National or international project	4.52	0.501
Tangible research	4.56	0.497

S.D.: Standard deviation

initially all the possible constraints, evaluation parameters, success criteria and tangible outcomes is listed down. From quantitative data analysis, high impacts variables were identified. Relationships amongst the attributes of these variables are finalized by using qualitative approach. After sorting out the related attributes, redundant variables were removed and only the HI attributes have been selected as a candidate for evaluation metrics. The selection of this attributes is based on qualitative analysis. At this stage, all the related and non-related parameters are enlisted. Finally, evaluation metrics that is responsible for evaluating the research collaboration listed down by the merge of related and non-related parameters. The final version of evaluation model has been shown in Fig. 3, where evaluation metrics is comprised of joint

Table 5: Relationship of high impact evaluation parameters with other high impact variables

S. No.	Respondents	Evaluation parameters	Constraints	Success criteria	Tangible outcomes
1	ACK	1-1 Financial support 1-2 Knowledge sharing	1-1-1 Financial matter 1-2-1 Education and training	1-1-1 Fund 1-2-1 Workshops 1-2-2 Seminars	1-1-1 Commercialized product 1-2-1 Published research paper 1-2-2 Commercialized product
2	GU	2-1 Joint venture	2-1-1 Time constraints	2-1-1 No of researchers 2-1-2 No of research paper	2-1-1 Published research paper 2-1-2 Tangible research
3	NH	3-1 Joint venture	3-1-1 Conflict of IPR	3-1-1 No of researchers 3-1-1 No of technical staff	3-1-1 Commercialized product 3-1-1 Tangible or intangible research
4	AS	3-2 Cooperative R and D agreement 4-1 Culture development	3-2-1 Conflict of IPR 4-1-1 Culture difference	3-2-1 Strong commitment 4-1-1 Mutual perception	3-2-1 Tangible research 4-1-1 Tangible research 4-1-1 Commercialized product
5	NR	5-1 Communication	5-1-1 Consultancy	5-1-1 Interchange of concept and ideas	5-1-1 Published research paper 5-1-2 National or international projects
6	ZL	5-2 Culture development 6-1 Financial support	5-2-1 Culture difference 6-1-1 Financial matter	5-2-1 Similar objective 6-1-1 Scholarship 6-1-2 Fund	5-2-1 Tangible research 6-1-1 Commercialized product
7	TA	6-2 Communication	6-2-1 Consultancy	6-2-1 Exchanging of information	6-2-1 Tangible or intangible research
8	RA	7-1-1 Cooperative R and D agreement	7-1-1 Conflict of IPR	7-1-1 Strong agreement 7-1-1 Formal or informal relationship	7-1-1 Tangible research
9	kz	7-2-2 Joint venture	7-2-2 Time constraints	7-2-2 No of projects 7-2-2 No of researchers	7-2-2 Tangible research
8	RA	8-1 Knowledge sharing	8-1-1 Education and training	8-1-1 Personal interaction	8-1-1 Published research paper
9	kz	9-1 Cooperative R and D agreement	9-1-1 Conflict of IPR	9-1-1 Strong agreement 9-1-2 Strong commitment	9-1-1 Commercialized product

Table 6: Evaluation metrics

S. No.	Evaluation metrics
1	Joint venture
2	Knowledge sharing
3	Cooperative R and D agreement
4	Cultural development
5	Financial support
6	Communication
7	Patents and licenses
8	Master and doctorate thesis

venture, knowledge sharing, cooperative R&D agreement, cultural development, financial support, communication, patents and licenses, master's and doctorate thesis.

CONCLUSION AND RECOMMENDATIONS

This study aimed to:

- Recognizes the highly influential constraints, evaluation parameters, success criteria and tangible outcomes of university-industry collaboration that are the core demand of the evaluation process.
- It develops an evaluation model that illustrate the comprehensive review of the collaboration.
- It provides a robust set of evaluation metrics that have a capability to evaluate the strength of the research collaboration of university and industry. To meet these objectives we have used mixed method approach (quantitative and qualitative) and collected data from the Malaysian university's research centers and their collaborated industries.

Specifically three universities were focused in this research that is included in University Sains Malaysia (USM), University Putra Malaysia (UPM) and University Teknologi Malaysia (UTM).

To develop an evaluation model, first of all we identified all the constrains that exist in Malaysian U-I research collaboration. In the second phase we identified all the parameters that can evaluate the

research collaboration. By considering the evaluation parameters, respective success criteria were also developed. In fact the developed success criteria are solely responsible to generate the tangible outcomes of the research collaboration. By using mathematical model and from the quantitative approach we identified highly influential constraints, evaluation parameters, success criteria and tangible outcomes. Form the qualitative approach we identified the relationships of evaluation parameters with other three variables (constraints, success criteria and tangible outcome). At the end, from the combination of all related and non-related variables a robust set of evaluation metrics were developed for the evaluation of university-industry research collaboration.

In this research we also enrich existing theory by drawing attention towards the evaluation process that has been totally excluded from the mainstream of the literature. As according to Kharazmi (2011) to enhance the national system of innovation, it is mandatory to evaluate the research collaboration of university and industry periodically. Previous researches have been drawn attention towards the impending factors and success factors of the research collaboration. In this research, we contribute to the literature beyond the impending and success factors of the collaboration and developed an efficient evaluation model that not only remove the constraints and improve the success rate of UIRC but also it can evaluate the strength and weakness of the collaboration. Secondly, although this model has been developed for the evaluation of Malaysian UIRC but can be used generally for the evaluation of any research collaboration in any country by simply following the procedure of the model. Simultaneously, the generated evaluation metrics have a capability to work as the checklist to investigate the strength of the collaboration.

As with all research, this study also suffers some limitations that must be taken into account when considering its result and implications. In particular,

Future study should focus more on respondent's types. Specially from industry area, researchers working in R&D field, administrative staff specially related to academic culture i.e., visiting professors or lecturers in any university, as these people know the exact working environment of industry. From the university perspective, masters and PhD researchers and non-academic staff that includes project manager and research officers, should also include in qualitative and quantitative collections to develop the expected result more interesting and useful. Secondly, as university belongs to public sectors and university is directly or indirectly affected by a lot of public policies and also from Ministry of higher education. Thus to get the better understanding, MOHE (Ministry of Higher Education) or other related government sectors should be included in the survey. Thirdly, future research can involve the variables like intangible outcomes to measure the behaviours and environmental effects on university-industry collaboration.

To date few authors provide theory of evaluation for university-industry collaboration. We provide one step in this direction and hope further research continues along this path. For instance, researchers should extend this study in other countries in which collaboration between researches universities and industries are well developed. Finally, our findings have not just theoretical implications, but practical implications as well. For example, university and industry can evaluate their strength of the collaboration by considering the generated set of metrics or they can generate their own evaluation model by simply following the procedure of this developed model.

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REFERENCES

Albuquerque, E., W. Suzigan, S. Cário, A. Fernandes, W. Shima and J. Britt, 2008. An investigation on the contribution of universities and research institutes for maturing the Brazilian innovation system: Preliminary results. Proceeding of the Globelics Conference, Mexico City.

Arocena, R. and J. Sutz, 2005. Latin American universities: From an original revolution to an uncertain transition. *Higher Educ.*, 50: 573-592.

Arvanitis, S., U. Kubli, N. Sydow and M. Wörter, 2005. University-industry Knowledge and Technology Transfer in Switzerland: The University View. KOF-Arbeitspapiere/Working Papers No. 119, December, Zurich.

Audretsch, D. and E. Lehman, 2005. Do university policies make a difference? *Res. Policy*, 34: 343-347.

Barnes, 2002. Catalysts and Barriers: Factors that Affect the Performance of University-industry Collaborations. Eindhoven Center for Innovation Studies (ECIS).

Bekkers, R. and I. Bodas-Freitas, 2008. Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Res. Policy*, 37: 1837-1853.

Boardman, P.C., 2009. Government centrality to university-industry interactions: University research centers and the industry involvement of academic researchers. *Res. Policy*, 38(10): 1505-1516.

Bonaccorsi, A. and A. Piccaluga, 2007. A theoretical framework for the evaluation of university-industry relationships. *R&D Manage.*, 24(3): 229-247.

Bruneel, J., P. D'Este and A. Salter, 2010. Investigating the factors that diminish the barriers to university-industry collaboration. *Res. Policy*, 39(7): 858-868.

Casas, R., R. de Gortari and M. Luna, 2000. University, Knowledge Production and Collaborative Patterns with Industry. In: Cimoli, M. (Ed.), *Developing Innovation Systems: Mexico in a Global Context*. Continuum, London.

Cohen, W., R. Nelson and J. Walsh, 2002. Links and impacts: the influence of public research on industrial R&D. *Manage. Sci.*, 48(1): 1-23.

Eom, B.Y. and K. Lee, 2010. Determinants of industry-academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. *Res. Policy*, 39(5): 625-639.

Esham, M., 2008. Strategies to Develop University-industry Linkages in Sri Lanka. Research Studies on Tertiary Education Sector Study Series 4 (2007/2008), National Education Commission, Colombo.

Etzkowitz, H. and L. Leydesdorff, 2000. The dynamics of innovation: from national systems and "Mode 2" to a triple helix of university-industry-government relations. *Res. Policy*, 29(2): 109-123.

Faiz, M., 2013. An empirical study of university-industry R&D collaboration in China: Implications for technology in society. *Technol. Soc.*, 35(3): 1-12.

Feldman, M. and P. Desroches, 2004. Truth for its own sake: Academic culture and technology transfer at Johns Hopkins University. *Minerva*, 42: 105-126.

Goomes, J.F.S., P. Hurmelinna, V. Amaral and K. Blomqvist, 2005. Managing relationships of the republic of science and the kingdom of industry. *J. Workplace Learn.*, 17(1/2): 88-98.

Govindaraju, V.G.R.C. and C.Y. Wong, 2011. Patenting activities by developing countries: The case of Malaysia. *World Patent Inform.*, 33(1): 51-57.

Grimpe, C. and H. Fier, 2010. Informal university technology transfer: A comparison between the United States and Germany. *J. Technol. Transfer*, 35: 637-650.

- Guan, J. and Q. Zaho, 2013. The impact of university-industry collaboration networks on innovation in nanobiopharmaceuticals. *Technol. Forecast. Soc.*, 80(7): 1271-1286.
- Gulbrandsen, M., D. Mowery and M. Feldman, 2011. Introduction to the special section: Heterogeneity and university-industry relations. *Res. Policy*, 40: 1-178.
- Hall, B., A. Link and J. Scott, 2000. Universities as Research Partners. Working Paper 7643, National Bureau of Economic Research, Cambridge MA.
- Iqbal, A.M., A.S. Khan, S. Iqbal and A.A. Senin, 2011. Designing of success criteria-based evaluation model for assessing the research collaboration between university and industry. *Int. J. Bus. Res. Manage.*, 2(2).
- Iqbal, A.M., A.S. Khan, S. Iqbal and A.A. Senin 2013a. A novel cost efficient evaluation model for assessing research-based technology transfer between university and industry. *J. Teknol.*, 64(2).
- Iqbal, S., A.M. Iqbal, A.S. Khan and A.A. Senin, 2013b. A modern strategy for the development of academic staff based on university-industry knowledge transfer effectiveness & collaborative research. *J. Teknol.*, 64(3).
- Iqbal, A.M., A.S. Khan and A.A. Senin, 2015a. Reinforcing the national innovation system of Malaysia based on university-industry research collaboration: A system thinking approach. *Int. J. Manage. Sci. Bus. Res.*, 4(1): 6-15.
- Iqbal, A.M., A.S. Khan, S. Parveen and A.A. Senin, 2015b. Evaluating national innovation system of Malaysia based on university-industry research collaboration: A system thinking approach. *Asia. Soc. Sci.*, 11(12), In Press.
- Ismail, K., T.N. Tengku Azhara, C.Y. Yongb, A.S. Aslana, W.Z. Omar, I. Majidd and A.M. Ajagbe, 2012. Problems on commercialization of genetically modified crops in Malaysia. *Asia Pac. Bus. Innovat. Technol. Manage.*, 40: 353-357.
- Kharazmi, O.A., 2011. Modelling the role of university-industry collaboration in the Iranian national system of innovation: Generating transition policy scenarios. Ph.D. Thesis, Stirling Management School, University of Stirling.
- Knight, J., 1992. *Institutions and Social Conflict*. Cambridge University Press, Cambridge.
- Levy, R., P. Roux and S. Wolff, 2009. A study of science-industry collaborative patterns in a large European university. *J. Technol. Transfer*, 34: 1-23.
- Mitive, 2009. Evaluation of an academic-industry research collaboration. Social Science Research Network.
- National Science Foundation, 2000. University-industry research relationships: Myths, realities and potentials. 14th Annual Report, US Government Printing Office, Washington, DC.
- Odagiri, H. and A. Goto, 1996. *Technology and Industrial Development in Japan*. Oxford University Press, Oxford.
- Othman, R. and A.F. Omar, 2012. University and industry collaboration: Towards a successful and sustainable partnership. *Proc-Soc. Behav. Sci.*, 31: 575-579.
- Petruzzelli, A.M., 2011. The impact of technological relatedness, prior ties and geographical distance on university-industry collaborations: A joint-patent analysis. *Technovation*, 31(7): 309-319.
- Philbin, S., 2008. Process model for university-industry research collaboration. *Eur. J. Innov. Manage.*, 11(4).
- Rast, S., N. Khabiri and A.A. Senin, 2012. Evaluation framework for assessing university-industry collaborative research and technological initiative. *Proc. Soc. Behav. Sci.*, 40: 410-416.
- Reams, B., 2006. *University-industry Research Partnerships*. Quorum Books, Westport, CT.
- Risaburo, N., 2005. *Technology Transfer, Intellectual Property Right and University-industry Partnerships: The Experience of China, India, Japan, Philippines, the Republic of Korea, Singapore and Thailand*. WIPO, Geneva.
- Tran, T.A. and D.F. Kocaoglu, 2009. Literature review on technology transfer from government laboratories to industry. *Proceeding of Portland International Conference on Management of Engineering and Technology (PICMET, 2009)*, pp: 2771-2782.
- Vessuri, H., 1998. *La Investigación y Desarrollo en las Universidades de América Latina*. Fondo Editorial FINTEC, Caracas.
- Veugelers, R. and B. Cassiman, 2005. R&D cooperation between firms and universities: Some empirical evidence from Belgian manufacturing. *Int. J. Ind. Organ.*, 23: 355-379.
- Viotti, E.B., 2002. National Learning Systems: A new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea. *Technol. Forecast. Soc.*, 69(7): 653-680.
- Wonglimpiyarat, J., 2011. Government programmes in financing innovations: Comparative innovation system cases of Malaysia and Thailand. *Technol. Soc.*, 33(1-2): 156-164.
- Yang, Y., 2008. *Group Sequential Analysis Using the New SEQDESIGN and SEQTEST Procedures*. SAS Institute Inc., Rockville, MD.