THE INFLUENCE OF NATIONAL INNOVATION SYSTEM ON UNIVERSITY-
INDUSTRY RESEARCH COLLABORATION

ABEDA MUHAMMAD IQBAL

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To my family Syed Muhammad Iqbal Yousuf & Jahan Zaiba (Parents), Dr. Adnan Shahid Khan (Husband) and Ayesha binti Adnan Ali Khan (Daughter)

"Only the Almighty Allah will reward them"

ACKNOWLEDGEMENT

ABSTRACT

University-Industry Research Collaboration (UIRC) is one of the key factors for continuous innovation. Existing literature argue that UIRC can be shaped by National Innovation System (NIS). However, empirical evidence that looks into factors of national innovation system that influence UIRC is still lacking. The main goal of this research was to propose a new framework based on system thinking theory by investigating the influence of national innovation system on university-industry research collaboration. To achieve this aim, data were collected from research centers at Electrical and Chemical Engineering Departments of five research universities in Malaysia. Data were analyzed quantitatively using Statistical Package for the Social Sciences (SPSS) and Partial Least Squares Structural Equation Modeling (PLS-SEM). Whereas, some qualitative data from top management of corresponding industries of research centers were analyzed using NVivo 11. Results from the study revealed that technological infrastructure system, financing system, intellectual property right system, the culture of innovation and education and skills system have some influence on UIRC. Besides that, R&D cooperation, financial support, trustworthy culture, contractual agreement, intellectual capital, knowledge sharing and communication played significant roles as reinforcing factors in the relationship between NIS and UIRC. This study pioneered the application of system thinking theory in university-industry link research. In terms of practical contribution, findings from the study may serve as a guideline for policymakers in formulating policies and strategies to strengthen the innovative capabilities of UIRC. The limitations of this study are the non-inclusions of Ministry of Higher Education (MOHE) and the Ministry of Science, Technology and Innovation (MOSTI) as significant respondents other than research universities and their collaborated industries. It is recommended that future framework development could be expanded by exploring further factors that might have more effects on UIRC.

ABSTRAK

Kerjasama penyelidikan universiti-industri (UIRC) adalah salah satu faktor utama bagi inovasi yang berterusan. Literatur sedia ada membuktikan bahawa UIRC boleh dibentuk oleh Sistem Inovasi Kebangsaan (NIS). Walau bagaimanapun, bukti empirikal yang melihat faktor-faktor NIS mempengaruhi UIRC masih lagi kurang. Matlamat utama kajian ini ialah untuk mencadangkan kerangka baru berdasarkan kepada teori sistem pemikiran dengan mengkaji pengaruh NIS ke atas UIRC. Bagi mencapai matlamat ini, data telah dikumpul daripada pusat penyelidikan Jabatan Elektrikal dan Kejuruteraan Kimia di lima buah universiti penyelidikan di Malaysia. Data dianalisis secara kuantitatif menggunakan perisian *Statistical Package for the Social Sciences (SPSS)* dan Kuasa Dua Terkecil Separa-Model Persamaan Struktur (PLS-SEM). Beberapa data kualitatif daripada pengurusan atasan industri yang sesuai di pusat-pusat penyelidikan dianalisis menggunakan NVivo 11. Hasil kajian ini menunjukkan bahawa sistem infrastruktur teknologikal, sistem kewangan, sistem hakcipta intelektual, budaya inovasi serta sistem pendidikan dan kemahiran mempunyai pengaruh ke atas UIRC. Selain itu, kerjasama Penyelidikan dan Pembangunan (R&D), sokongan kewangan, budaya kepercayaan, penjanjian kontrak, sumber intelektual, pengkongsian pengetahuan dan komunikasi memainkan peranan yang signifikan sebagai faktor penguat dalam hubungan di antara NIS dan UIRC. Kajian ini memulakan pengaplikasian sistem teori pemikiran dalam penyelidikan hubungan universiti-industri. Sebagai sumbangan praktikal, hasil dapatan kajian ini boleh dijadikan panduan bagi pembuat polisi dalam membuat polisi dan strategi bagi memperkukuhkan keupayaan inovatif UIRC. Kekangan kajian ini adalah tiadanya penglibatan dari Kementerian Pengajian Tinggi (MOHE) dan Kementerian Sains, Teknologi dan Inovasi (MOSTI) sebagai responden yang signifikan selain daripada universiti-universiti penyelidikan dan pihak industri yang berkolaborasi. Dicadangkan bahawa pembangunan kerangka pada masa hadapan dikembangkan dengan mengkaji lebih lanjut faktor-faktor lain yang mungkin mempunyai banyak kesan ke atas UIRC.

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NIS	-	National Innovation System
UIRC	-	University Industry Research Collaboration
STP	-	Science and Technology Policy
NCSRD	-	National Council For Scientific Research And Development
GCI	-	Global Competitiveness indexing
R&D	-	Research and Development
KEI	-	Knowledge Economy Index

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CHAPTER 1

INTRODUCTION

1.1 Research Background

It is acknowledged that the continuous developments of modern innovations are the mantra to ensure sustained economic growth (Crespi and Zuniga, 2012; Sharif, 2012; Doyle and Connor, 2013). An innovation is the capacity to apply new knowledge or to recombine existing knowledge in order to improve productivity and to create new products and processes (Popescu and Crenicean, 2012; Bernard 2013). Therefore, innovations are considered as the engine of productivity and competitiveness (Abrunhosa, 2003; Autant et al. 2013). Innovation is a complex process that involves not only the innovative firm but also a system of interactions and interdependencies between firm and other organisations and institutions (Lundvall, 1992; Metcalfe and Ramlogan, 2008). A recent trend in the innovative performance is increasing a cooperative research and development (R&D) (Zeng, Xie et al., 2010). Cooperative R&D is crucial factors in determining the innovative capacity of a nation (Lee and Park, 2006). According to the Robertson (2008) and Tunzelmann (2009), R&D networking and collaboration plays different strategic roles for the development of innovation, especially in emerging and newly industrialized economies (NIEs). These collaborations are crucial for accessing resources and searching for knowledge inputs to develop specific new technologies and products. In this regard, collaboration

between universities and industries, specifically research collaboration that is normally termed as university-industry research collaboration (UIRC) is widely recognized as one of the key factors, which contributes to enhance the capabilities of research organizations in improving and developing of research and innovation, also known as innovative capabilities of that research organizations (Teirlinck and Spithoven, 2013).

Many studies have provided pieces of evidence for the strategic importance of the UIRC (Motohashi, 2008; Fiedler and Welpe, 2010; Robin and Schubert, 2013). The phenomena of research collaboration between university and industry are almost double within ten years and increasing exponentially (Teirlinck and Spithoven, 2013). For the last decades, more or less 20,000 corporate collaborations are established globally and number of collaborations in developed nations raised up to twenty percent annually since 1987 (Motohashi, 2012). University-industry research collaboration (UIRC) is a key factor that provides possible pathways to accelerate the process of technological catch-up as well as sustain productivity growth and competitiveness thus, greatly contribute to the development and enhancement of the economies of the nation (Bayarçelik and Taşel, 2012).

UIRC is not an isolated factor, it is the primary actor of national innovation system (NIS) and affected by many internal and external systemic factors within the system of innovation that influence their collaboration and their collaborative innovation performance. Systemic factors are the factors that influence the behaviour of interaction of universities and industries in-terms of research and innovations collectively called national innovation system (NIS) (Cacere and Pagano, 2009). According to Lakitan (2013), factors of NIS should also be considered comprehensively if the intentions have to strengthen the research collaboration between universities and industries. In addition, according to Guan and Chen (2012), factors of NIS are the key innovation environment where innovative actors in which universities and industries are also included enhance their collaborative innovative performance. So far, an ample amount of researches have been conducted to strengthen the UIRC but the empirical researches on the analysis of the influence of NIS on UIRC

are scarce. This gap is particularly outstanding in developing countries, specifically in Malaysia (Hall, 2003; Fontana et al., 2006; Ankrah et al., 2013; Chaminade et al., 2012). So, the limited knowledge about the influence of NIS on UIRC has attracted researcher to study this area.

There is a consensus among the researchers that the demand of research collaboration between university-industry is very high (Othman and Omar, 2012; Fiaz, 2013). Most authors claim that if this research collaboration is supported by strong channel of an innovation system, it can exponentially improve the competencies of the nation (Etzkowitz, 1998; Bjerregaard, 2010; Kato and Odagiri, 2012). As the main agenda of this collaboration is to obtain innovation, access to business market, minimize financial and political factors and target competitive advantage (Wheelen, 2000; Wu and Mathews, 2012; Bodas et al., 2013). However, despite the extensive evidence on the importance of research collaboration between university and industry in developed and developing countries, knowledge to strengthen the research collaboration between university-industry and their collaborative innovation performance is still limited, especially, when it comes at the issue of systematic analysis. Since the key focus of this research is to study the influence of NIS on UIRC especially in Malaysia. Thus, it is mandatory to discuss the detailed revolutions phases of innovations in Malaysia. Next section will present an extensive overview of science, technology and innovation in Malaysia.

1.2 Overview of the Revolution of Science, Technology and Innovation in Malaysia

The Malaysian government formulated the first National Science and Technology Policy (STP1) in 1986 with the purpose of outlining a framework for science and technology development in Malaysia. This policy aims to ensure the achievement of continuous scientific and technological development for accelerating economic growth, industrial development and creating a high-tech (advanced) society (NPSTI, 2013). The national science and technology policy were then incorporated

into the fifth Malaysia plan (1986–1990) and the national action plan for industrial technology development was launched in 1990. The main objectives of the plan were to strengthen the role of national science and technology organizations in enhancing the scientific and technological capabilities of the Malaysian society at a huge level. This plan outlined the strategies for strengthening science and technological capabilities to overcome the structural weakness that have been associated with the national industrial development. Among the strategies includes the efforts of strengthening technological capabilities of local industries, mainly in adopting process technologies and enhancing market driven R&D (Fifth Malaysia Plan, 1986).

The second National Science and Technology Policy (STP2) launched in 2002 addresses the following issues: (1) promotion of commercialization of research outputs; (2) developing technological capacity and capability; (3) building competence for specialization in key emerging technologies; and (4) promoting techno-entrepreneurship and a culture for science and innovation. The STP2 emphasizes on linkages between the public and private sectors, developing indigenous technology and product development capabilities among local firms (MOSTE, 1991). Additionally, within the five years of each Malaysia plan, the issues of scientific and technological capabilities were further addressed. During the Sixth Malaysia Plan (1991–1995), the goals set for science and technology were to obtain a continuous scientific and technological development in Malaysia by providing incentives and supporting services for science and technology (Sixth Malaysia Plan, 1991). Emphasis was made to ensure that public R&D programs became more markets oriented by exploiting the commercialization of research and technology. In addition, the private sector was expected to complement the government in expanding the R&D and science and technology by using appropriate technology assimilation, diffusion and application. During the Seventh Malaysia Plan (1995–2000), the focus was on economic growth and competitiveness by increasing scientific productivity.

It was recognized that Malaysia needed to expand and develop its technological capacities for technology adoption and assimilation. Consequently, the Seventh, Eighth and Ninth Malaysia Plans focused on creating indigenous technology

capabilities (Seventh, 1996; eighth, 2001 and ninth Malaysia Plan, 2006). The 10th Malaysia plan (2011-2015) emphasizes more on the importance of improving innovation capability and institutional efficiency. Table 1.1 summarized the revolution of science, technology and innovation policies in Malaysia.

Table 1.1: Science, Technology and Innovation Policies of Malaysia

Year	STI Policies
1960s	Limited focus
1970s	Dedicated Ministry for Science established as well as the national council for scientific research and development (NCSRD).
1980s	1st National science and technology Policy; First chapter on science technology and innovation (STI) in Malaysia plans; Intensification of research in priority areas (IRPA) grants; Established double deduction incentives for R&D.
1990s	Multimedia super corridor established; National IT council; Mega projects era; Returning scientist program.
2000s	2nd national S&T policy; National innovational council; Biotech strategy announced; Inventors relations professional association Singapore (IRPAS) streamlined; Brain gain program launched.
2010s	Year of innovation; Talent corporation established; established Unique Performance management and delivery unit (UNIK PEMANDU) in regards of research and innovations.

Compiled by the author

Till 2000, Malaysia already chips itself into several competitive indexing bodies, especially Global Competitiveness indexing (GCI). The GCI includes several factors in which research and development intensity, research collaboration between university and industry and the rate of research and innovations are also included to evaluate the ranking of the worldwide countries. In this regard, according to GCI Thailand, Malaysia, and Singapore are the top ranked countries among the Southeast Asian countries (Indonesia, Thailand, Philippines, Malaysia, Singapore, Vietnam,

Myanmar, Cambodia, Loas, Brunei, Timor Leste). Figure 1.1 shows the GCI ranking from 2002-2016 of above mentioned three countries and the world's top rank country i.e. Switzerland. Figure shows that from 2002 to till 2007, Singapore fluctuates between 5-7 ranks, but from 2008 stabilized its self to 2 till date. Similarly, Switzerland, the top ranked country is retaining its 1st position from 2010 to till now. However, from the figure it is clearly analyzed that till date Malaysia has not significantly improved within the last decades. It fluctuates between 25 to 30 that demonstrate a considerable distance from Singapore and Switzerland.
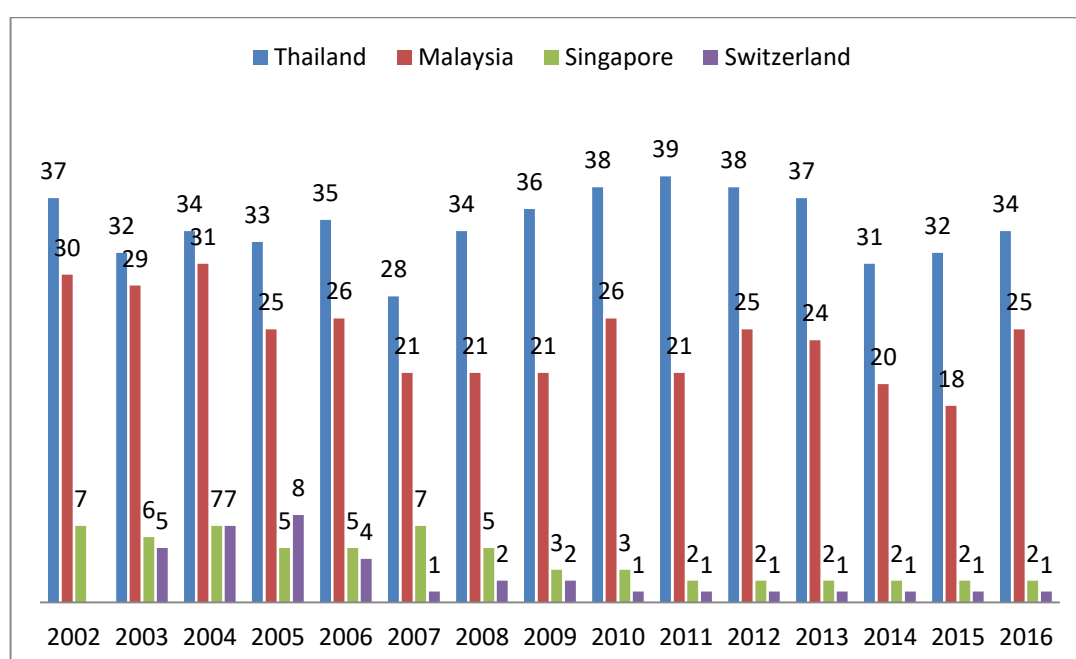
Figure 1.1: Comparison Based on GCI Report

Source GCI report: Compiled by author

Similarly, according to Hamri et al., (2013) and Gua-zhen et al., (2006), scientific and technological results are also the criteria to rate the efficiency of research and innovation of the country. Under the framework of the National Innovation System, "innovation" signifies the creation of knowledge or technology (Metcalfe and Ramlogan, 2005). Prior studies have suggested that papers (Rosenberg and Nelson, 1994; Nelson and Rosenberg, 1998) are direct indicators for evaluating knowledge accumulation. For example, Rosenberg and Nelson (1994, 1998) have suggested that

papers are critical for industrial technology development. Scientific papers are the only medium of reporting scientific achievements (Wouters, 1998), and citation patterns can also be used for examining knowledge exchange among scientists and interdependencies among disciplines (Small and Garfield, 1985).

Secondly, International scientific papers in each nation are the proxy for innovative scientific outputs (Furman et al., 2002). The number of publications can be understood a measure of scientific research output, because researchers usually codify new and sufficiently important scientific knowledge in terms of publications. (Torban et. al, 2011). Since the scientific publications is the base line approach to evaluate the current strength of the research and innovation activities of any nation (Wong, et al., 2010). In this regard, figure 1.2 shows the record of scientific publications of five research universities of Malaysia, National University of Singapore (NUS) and Massachusetts Institute of Technology (MIT) USA. From the figure, it can be seen that almost all Malaysian universities shows less number of publications as compared to NUS and MIT. In this regard, the World Bank's Knowledge Economy Index which captures the ability to generate and diffuse knowledge, ranked Malaysia 48th out of 145 countries (KEI, 2012).
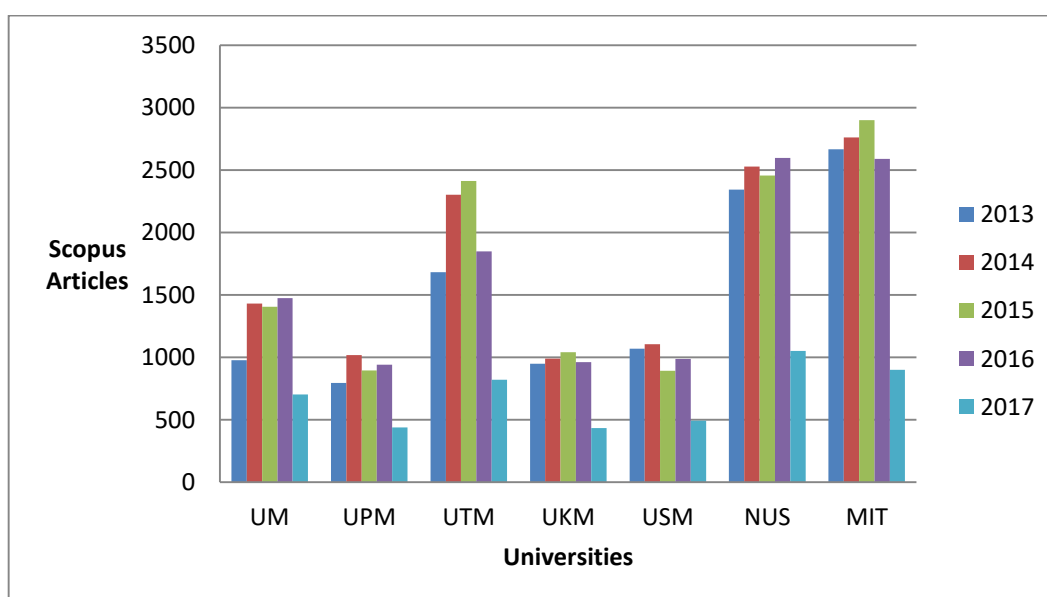
Figure 1.2: Scientific publications in Scopus (Engineering Faculties),

Source: Scopus.com. Compiled by author

Furthermore, the innovation efficiency rank of Malaysia fell from 33rd in 2014 to 72nd in 2016 (WIPO, 2016). In this regard, figure 1.3 shows the overall innovation efficiency of Malaysia. From the figure it is clearly analyzed that the rate of innovation in Malaysia is not satisfactory as compare to other leading countries, especially Singapore and Switzerland.
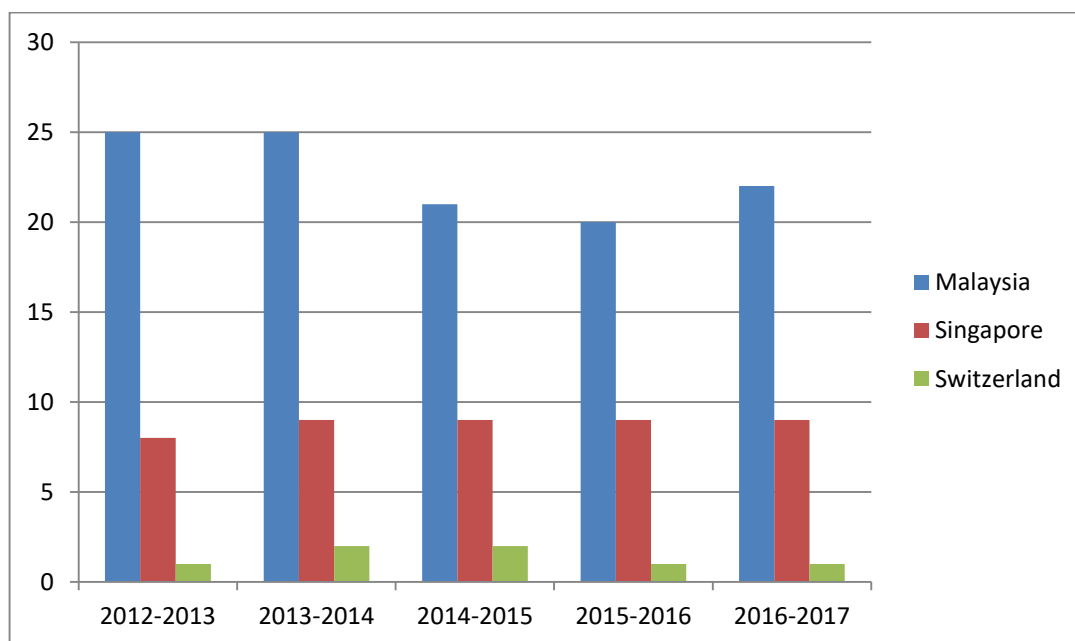
Figure 1.3: GCI Report Based on innovation

Source GCI report: Compiled by author

Furthermore, the figure 1.4 clearly illustrate the number of patents granted for the last fifteen years (WIPO -2017). It can be visualized that Switzerland, the top tier nation got the highest patents followed by Singapore and then Malaysia. The figure shows an ample room of improvement in patenting activity in Malaysia.
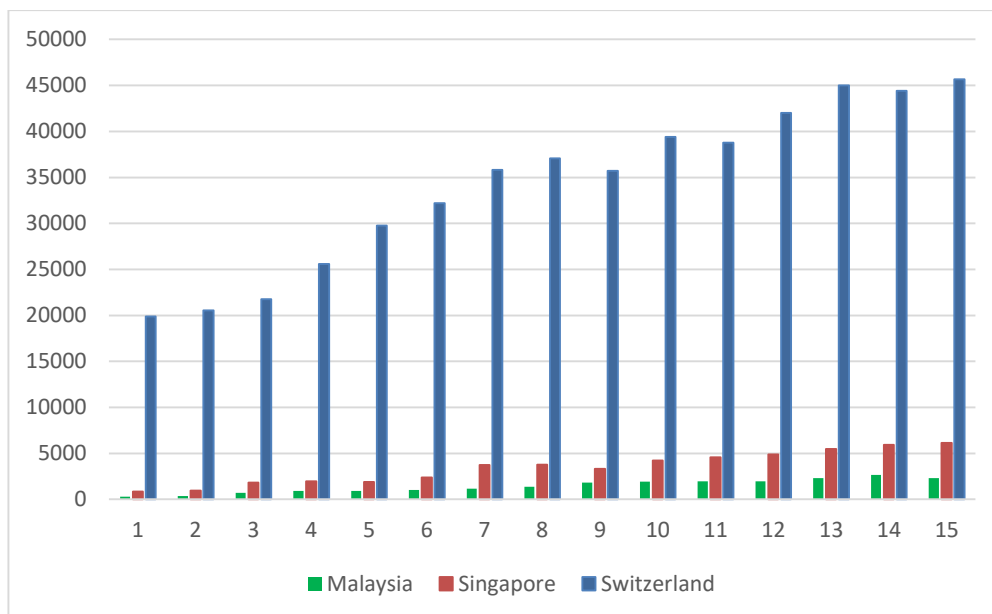
Figure 1.4: Patents Granted Report

Source: WIPO Statistics Database Last Updated 5, 2017

However, as an emerging tiger of Asian economy, Malaysia has the potential to go ahead and to compete the global competitiveness index but demand serious efforts to enhance the technological innovation and development (Wonglimpiyarat, 2011), and effective technology development within a country depends on the strong linkages between public and private institutions that shape technological capabilities (Beaudry & Allaoui, 2012; Boardman, 2009; Chen & Guan, 2010; Fiaz, 2013). In this manner, university-industry research collaboration with the factors of institutions is one of the most prominent organizational interfaces to make their role more beneficial to support the growth of high-technology activities at the country and to national economic development (Bodas, et al., 2013; Moeliodihardjo et al., 2012; Wong et al., 2007).

In this regard, a substantial amount of research has been devoted to the investigation of university-industry collaboration in Malaysia, but less attention has so far been given to the analysis of the factors of the national innovation system on university-industry collaboration. Thus, this study attempts to fill this gap by examine the influence of the national innovation system on university-industry research

collaboration in Malaysia. The detailed discussion about national innovation system and Malaysian national innovation system is elaborated in section 2.3 in chapter 2.

1.3   Problem Statement

A substantial amount of research has been devoted to the analysis of the university-industry research collaboration (UIRC), (Siyanbola et al, 2012; Lee and Park , 2006; Robin and Schubert, 2013; Tsai, 2009; Motohashi, 2008; Aissaoui, 2011; Etkowitz et al., 1997; Freel and Harrison, 2006; Frenz and Gillies, 2009; Kaufmen and Toddling, 2001; Loof and Bostorm, 2001). UIRC is crucial for accessing resources and searching knowledge input to develop new innovation (Jin, 2011; Teirlinck & Spithoven, 2013). Thus, the analysis of the previous studies show that UIRC is a major source for research and innovations and economic growth (Chaminade et al, 2012; Edquist, 2008; Lundvall et al, 2006; Muchie, 2007; Mytelka, 2003).

However, the existing literatures suggested that the rate of innovation and contribution from the UIRC is not satisfactory in several developing countries (Khayyat and Lee, 2015; Almeida and Fernandes, 2008; Archibugi and Coco, 2004; Fagerberg and Verspagen, 2007) including Malaysia. For instance, Wong and Goh (2010), highlighted that the accumulation of Malaysian science is not sufficient to develop virtuous cycle among knowledge stock, new scientific ideas and benefits of knowledge. Similarly, Wong, et al., (2010), claimed that the scientific production of Malaysia is low compared to Taiwan and Japan. For instance, the growth behavior of publications and patents that is being produced by Malaysia is not much appreciated. Ramli (2013), highlighted that Malaysian industries should seek their local expertise within local universities in developing their technologies instead of looking at the foreign expertise overseas. Khayyat and Lee (2015), reported that Malaysia had amounted to notable comprehensive efforts to promote the collaboration between universities and industries, but challenges remained affecting successful innovation

strategy. Similarly, Vu, (2012), come up with the understanding of patents record in developed countries (US, Canada, Switzerland) and suggest that their economies have evolved toward more openness. One aspects of this openness has been to gradually adapt the system of innovation as world status. The above studies indicate that the collaborative internal factors within the universities and industries are not solely responsible for generating high-impact innovative performance, there are some external factors influence this relation. For instance, a system of innovation that consists of several key factors includes: resource allocation (Cowan, 2013), knowledge management (Edquist, 2008) decisions making (Motohashi, 2005) and laws and regulations (Hsieh, 2009), which is used to create an environment where universities and industries strengthen their research collaboration and enhance their collaborative innovation performance vigorously. However, the Malaysian NIS still lacks in placing the proper mechanisms, especially, with regards to the fundamental factors of NIS to accelerate the process of research and development and innovation in the country (Khayyat and Lee 2015). Thus, policy makers in developing countries, particularly, in Malaysia need a comprehensive understanding of those factors that affect the UIRC and their collaborative innovation performance.

Numerous studies were conducted to investigate the factors that affect the university-industry collaboration, but most of them focused more on the university-industry orientation related factors. These factors are usually related to the university-industry culture, their priorities and their vision and mission (Tina et al, 2002; Kafouros et al, 2015; Bruneel et al, 2010; Freitas et al, 2013; Fuentes and Dutrenit, 2012; Rasiah and Govindaraju, 2009; Salleh and Omar, 2013; Ramli, 2013), very few researches were conducted to investigate the factors related to the national system of innovation and their influence on UIRC. For instance, Guan et al., (2015), provided knowledge about the networking between the actors of national innovation system and their effects on university-industry collaboration. Similarly, according to Efrat (2014), culture within an innovation system has a great effect on university-industry linkages. However, to the author's knowledge, studies for the comprehensive knowledge about the factors related to the national system of innovation and their influence on university-industry research collaboration has gained scant attention of the previous researchers. Thus to fill this gap, this study aims to investigate the effect of NIS on

UIRC and to provide a framework that may help policy makers to develop the strategy to strengthen the collaborative innovation performance of the university and industry based on an effective system of innovation.

In addition, national innovation system is a system of different elements which maintains its existence through the mutual interaction of its parts (Bertalanffy, 1976). The mutual interactions of the elements of a system lead to the construction of circular causality and required systemic approach for its evaluation (Patching, 1990; Bellinger, 2008). Previous studies that develop a model to measure the strength of UIRC are largely used analytical thinking as analytical thinking is the most appropriate model if the idea is to evaluate orientation related problems. For instance, knowledge base model (Soh and Sabramanan, 2014), Stakeholder Model (Abidin et al, 2014), Two-sided matching Model (Estanol et al, 2013), Resource-based model (Eom and Lee, 2010), Mode 1 Model (Kim, 1993; Cowan and Zinovyera, 2013) and Triple Helix Model (Schiller and Diez, 2007; Cai and Lui, 2013; Hayashi, 2003; Klomklieng et al., 2012; Martin et al., 2012).

A main limitation of above models is focusing only on the analytical model or analytical thinking. Analytical thinking analyzes the efficiency of specific part or elements within the system that have a linear perception. For example, Soh and Sabramanan (2014), used knowledge base model and studied the learning capabilities of universities and industries. Similarly, Estanol et al., (2013) used two-sided matching model and analyze the ability of producing scientific outcome of universities and industries, Abidin et al., (2014) used stakeholder model and analysed the resources to enhance the research collaboration of university and industry, Furthermore, Schiler and Diez, (2007); Cai and Lui, (2013); Hayashi, (2003); Klomklieng et al., (2012) Martin et al., (2012), utilized Triple Helix model and analyse the role of the government on UIRC. (The detail of the above mentioned studies can be seen in Sec 2.8).

Some of the study used systemic approach model (Guan et al., 2015; Efrat, 2014), but these studies also have evaluated the UIRC in a linear perspective that is the characteristics of analytical thinking. Systems which behave in a linear way have limited predictability of the outcomes. In this regard, only a systematic understanding allows understanding structural weaknesses in a better way and also provides an opportunity to find out a sequential cause of the problem and the way to cover it, which is impossible to achieve when using the analytical or linear model (Chapman, 2004). Therefore, this study proposes using the "system thinking" to fill this existing gap. System thinking not only focuses on the parts of the system but also focuses on their patterns and events and describes how they work together. By demonstrating the relationship of each part with their patterns and events, its describe the main cause of all the systemic problems and provide the solution to resolve it (Cacere and Pagano, 2009).

This study using theory of system thinking will visualize the effects of NIS on UIRC in Malaysia. For this purpose, it is necessary to identify the critical factors of NIS that affect the UIRC, simultaneously; it is also necessary to identify the critical constraints of UIRC, so that the effects of the critical factors of NIS on the constraints of UIRC can be visualized and analyzed precisely. Furthermore, the balancing and reinforcing factors that overcome the constraints and reinforce the strength of UIRC and their collaborative innovation performance will also be identified respectively. To the author's knowledge, until now, there is no investigation focused on such factors and the effects of NIS on UIRC in Malaysia. Generally, the previous literatures reflected the little efforts to answer the question like "is there any direct relationship between university-industry collaboration and their collaborative innovation performance or some external factors exist between these relations? What is the effect of the national innovation system on university-industry research collaboration? How university-industry research collaboration can be strengthened based on the national innovation system. Thus to bridge this gap in the literature, this study offers to establish an empirical framework to investigate the effects of NIS on UIRC and will provide a possible pathway to enhance the collaborative innovation performance of university and industry in Malaysia.

1.4   Research Aim

This study adds to the literature by proposing a framework using system thinking approach and by investigating the influence of national innovation system on university-industry research collaboration. Furthermore, the research hypothesizes that national innovation system has a great influence on university-industry research collaboration. Thus, the aim of this study is to analyze a framework of the influence of the national innovation system (NIS) on university-industry research collaboration (UIRC).

1.5   Research Objective

The main goal of the research is to propose a new framework based on system thinking theory by investigating the influence of the national innovation system on university-industry research collaboration, specifically the objectives of the proposed research are:

1. To analyze:

   a. The factors of national innovation system that influence university-industry research collaboration.

   b. The factors that are the constraints of university-industry research collaboration?

2. To examine the influence of the factors of national innovation system on the factors that are the constraints in university-industry research collaboration.

3. To investigate the reinforcing factors of NIS that can reinforce the innovative capabilities of university-industry research collaboration.

4. To propose a framework to investigate the influence of national innovation system on university industry research collaboration.

1.6   Research Question

1. What are the factors of national innovation system that influence the university-industry research collaboration?

2. What are the limiting factors of university-industry research collaboration?

3. What is the influence of the factors of national innovation system on the limiting factors of university-industry research collaboration?

4. What are the factors that can reinforce the innovative capabilities of university-industry research collaboration?

5. What would be the framework that can investigate the influence of national innovation system on university industry research collaboration?

1.7   Scope of the Study

Since the studies related to the relationship between national innovation system and university-industry research collaboration is scarce, especially the developing countries have received scant attention by the researchers. Thus, this study tries to fill this gap and improve the literature about the influence of national innovation system on university-industry research collaboration by investigating Malaysia as a scope of the study. Therefore, participants are from the universities and industries of Malaysia. Particularly, all five research universities (USM, UKM, UM, UPM and UTM) are the

focused universities in this research. The targeted respondents are from the departments of chemical and electrical engineering research centers, and their collaborated industries. The specific two departments have been selected based on the high number of their research group as shown in (See 3.5) that are much active in research activities as compare to other departments. Secondly, this research focused on research centers of universities and industries, thus, the idea is, any department, excellent in publication and have high research groups will consider as a best candidate to be respondents.

As far as the data collection is concern, academicians and the top management of the industries are the respondents of this research. In this regard, the focus of survey approach is on mix method (qualitative and quantitative), where, Survey questionnaire is the research instrument for data collection from the large number of participants. By considering the close framework of the industries, it has been analyzed that the qualitative survey is suitable for them. On the contrary, universities always have open framework and the number of academicians is very high in the departments, so, the conducting of quantitative (PhD Staff) and qualitative (Directors of Research Centers) survey is appropriate for them.

1.8   Contribution of the Study

The purpose of this study is to contribute a significant amount of knowledge to the policy makers to visualize the influence of NIS on UIRC extensively. The significant contributions of this study are based on three perspectives 1) knowledge, 2) Policy and from the 3) Practical perspective.

Knowledge Perspective:

This study argues that theory of system thinking is an appropriate underlying theory to investigate the influence of national system of innovation (NIS) on university-industry research collaboration (UIRC). System thinking is a strong approach to give a clear picture of a problem situation and as a tool for understanding that how things work (Patching 1990). It is a framework to look beyond events and scrutinize for patterns of behavior (Bartlett, 2001). Systematic understanding allows policy makers to better comprehend structural weaknesses and also provide an opportunity for developing innovative networks and interrelationships, which is impossible to achieve when using the traditional analytical or linear model (Chapman, 2004). To the author's knowledge, knowledge to use the system thinking theory to strengthen the university- industry research collaboration is very scarce.

Policy Perspective:

Secondly, previous studies provide the knowledge to strengthen the UIRC by investigating the internal characteristics of universities and industries. Such as by enhancing the capacities and capabilities of universities and industries (Solleiro and Castañón, 2005), by changing university, industry perspective and preferences (Loikkanen, Ahlqvist et al., 2009), by utilizing and enhancing their own resources (Lin, Shen et al., 2010), by investigating the nature of universities and industries (Kim, 1993; Cowan and Zinovyeva, 2013), and by providing the role of the governments (Samara, Georgiadis et al. 2012). Therefore, the emerged framework provides significant insights into the influence of national system of innovation on university-industry research collaboration. This study investigates this valuable relationship in one of the potential developing country in Malaysia. As Malaysia is still in the ranking of developing countries, this research can contribute to the knowledge of policy makers and help them to enhance the intensity of university-industry research collaboration, and their collaborative innovative performance by recognizing the critical constraints of university-industry research collaboration, by identifying the

factors of national innovation system that have capability to minimize the constraints of UIRC and by analysing the factors that have capability to reinforce the innovative capability of UIRC.

Practical Perspective:

By recognizing the critical constraints of UIRC and by considering the factors of NIS and the reinforcing factors, valuable outcomes can be received from the country's universities and industries and finally, the developed framework not only valuable to enhance the innovative capability of UIRC of Malaysia but the implementation of this framework is general for any country.

1.9   Definition of Key Terms

A number of terms that have high frequency in the current study are briefly defined as below. These terms will be explained more in the chapter two.

Contractual Agreement: Formalization of contractual agreement between the sectors of institutions is the elements that should be considered as one of the key factors for the success of the innovational organizations (Dooley & Kirk, 2007; Thune, 2011). In this study, contractual agreement has been referred as "the criteria of the commitment among the actors of innovation that helps in publicizing the new research and innovations (Carayol, 2003)."

Communication: Communication is the process of R&D collaboration (Chin et al., 2011). In this study, communication has been referred as "the channel where the

information, concepts, ideas and skills are exchanged between the actors of innovations (Mora-Valentine et al., 2004)".

Constraints of University-Industry Research Collaboration: The term "constraints" have been used for the factors that inhibit the collaborative innovation performance of university and industry. Thus, in this study, "collaborative innovation performance of university and industry is the alternate use of the constraints of university- industry research collaboration." In this study, constraints of university-industry research collaboration or collaborative innovation performance of university and industry is measured by six variables: 1) education and training, 2) technological competency, 3) lack of exchanging information, 4) fund and finance, 5) culture difference and 6) conflict of IPR.

Intellectual Property Rights: In this study, intellectual property rights reflects the issue of the "ownership of the new knowledge between university-industry personals (Hall et al., 2000)."

Culture of Innovation: Culture of innovation is the cognitive framework that affects how members within an organization perceive issues, as well as how they view their firm's competitive landscape (Johnson, 1999). In this study, Culture of innovation has been referred as "the environment of the beliefs that could facilitate the development of researches and innovations (Johnson and Scholes, 1999)".

Culture Difference: In this study, culture difference reflects the issue of diverging aim of universities and industries within their research collaboration (Guimon, 2013)."

Collaboration between the Actors of NIS: Collaboration between the actors of NIS fuel researches and innovations (Smith, 1991). In this study, Collaboration

between the actors of NIS has been referred as "the cooperative behavior among institutions and organizations that enables research organizations to access complementary resources and knowledge that lead to the development of research and innovations (Hagedoorn, 1994; Powell, 1996)".

Education and Skills System: Education and skills system is the central part to economic development and social welfare (Becker, 1993). In this study, education and skills system has been referred as the "key driver for the development of researches and innovations (Schultz 1961; Denison, 1962; Becker, 1993)."

Fund and Finance: In this study, fund and finance reflect the issues of "financial support to the development of research and innovations between university-industry personals (Popescu and Crenicean, 2012)".

Financial System: Financing system is the system of R&D investment (Hall, 1999). In this study, financing system has been referred to the system "that can help in the expenditures of research and development in any shape (Hall, 1992)".

Financial Support: financial support for R&D activity leads to the establishment of collaborations between firms and universities as well as the development of the new innovations (Hanel & St-Pierre, 2006). In this study, financial support is referred as "the ways where maximum efforts are applied to minimize the financial issues for the development of researches and innovations (Okamuro, 2007)".

Human Capital: Human Capital is the embodiment of productive people (Santos-rodrigues, 2010; Storper, 2009). In this study, human Capital has been referred as "the larger stock of the labor forces that can help in faster production (Romer & Paul, 1990)".

Intellectual Property Right System: Intellectual property right system is a bundle of legally recognized rights when ideas and innovations are protected (Yaakub, 2011). In this study, Intellectual property right system has been referred to the system "that enforced the laws, rules and regulations to protect and to promote the innovation growth (Samaniego, 2013)".

Intellectual Capital: Intellectual capital refers to the behavior of using brain (Galbraith, 1969). In this study, intellectual capital has been referred as "the extant of intellectual personals among the sectors of innovations can speed up the transfer of information and the development of new knowledge (McElroy, 2002)".

Innovative Capability: in this study, innovative capability is referred as the abilities of research organizations that are considered as the prerequisites for the development of any research and innovation (Xu, 2013).

Knowledge Sharing: Knowledge sharing refers to ''the provision of task information and know-how to help others and to collaborate with others to solve problems, develop new ideas, or implement policies and procedures'' (Wang and Noe, 2010). In this study, knowledge sharing has been referred as "the resource that provides the basis for the development of the research and innovations (Wang and Noe, 2010)".

Education and Training: In this study education and training reflects two issues: "1) low level of education in the country and 2) the unbalance level of education and skills between university-industry personals (Mathews et al., 2008; Guimon, 2013)".

Technological Competency: In this study technological competency refers to "the ability of relying on firm's internal technical capabilities that are necessary for the development of the innovation (Xu, 2013)".

Exchanging of Information: In this study, lack of exchanging information reflects the issue of giving and receiving the knowledge, expertise and advices during research and innovation processes between university-industry personals (Cohen et al., 2002).

National Innovation System (NIS): National innovation system is a set of interacting institutions and organizations that provide a national innovation production framework (Guan and Chen, 2012), thus have influence on the interactions of universities and industries. The term "institution" is the alternate of national innovation system, and the "institutional factors" are the alternate of the factors of national innovation system has been used within this thesis. In this study, national innovation system is measured by seven variables: 1) technological infrastructure system (Eastanol, 2013), 2) financial system (Guan and Yam, 2015), 3) human capital (Storper, 2009), 4) collaboration between the actors of NIS (Teece, 1992; Baum, 2000), 5) culture of innovation (Johnson and Scholes,1999), 6) intellectual property right system (Samaniego, 2013) and 7) education and skills system (Becker, 1993).

Reinforcing Factors: The term reinforcing factors has the same meanings as "moderating factors." In this study, purpose of using the reinforcing factors is to "reinforce" the collaborative innovation performance of university and industry by using seven variables: 1) R&D cooperation (Veugelers and Cassiman, 2005), 2) financial Support (Okamuro, 2007), 3) contractual agreement (Carayol, 2003), 4) intellectual capital (McElroy, 2002), 5) knowledge sharing (Wang and Noe, 2010), 6) communication (Mora-Valentine et al., 2004) and 7) trustworthy culture (Doney et al., 1998).

R&D Cooperation: R&D cooperation is the coordination of resources and expertise among the innovators (Cassiman and Veugelers, 2002). In this study, R&D cooperation is referred to the "cooperative behavior between the institution and organization of research and innovations to share the resources and capabilities with each other (Veugelers and Cassiman, 2005)".

System Thinking: System thinking highlights the importance of the systematic analysis by identifying cause and effects and mapping the relations among them. In this study, theory of system thinking has been used "to investigate the effect of national innovation system on university-industry research collabortion".

Trustworthy Culture: Trustworthy culture refers to cooperation between the actors of innovations that allows the collaborating partners to cooperate in research confidently in a manner that their research partners will treat them fairly and help them to solve any problem that may occur during the collaboration (Bruneel et al. 2010). In this study, trustworthy culture has been referred as "the culture where innovative actors' beliefs in the integrity, honesty and reliability (Doney et al., 1998)".

Technological Infrastructure System: Technological infrastructure system is a set of collectively supplied innovation-relevant capabilities into two or more research organizations (Justman and Teubal 1995). In this study, Technological infrastructure system has been referred to the system that helps "in the production of scientific knowledge and its transformations (Eastanol, 2013; Wong and Goh, 2010)".

University-industry research collaboration (UIRC): In this study university-industry research collaboration refers to the collaboration that relates directly to research activities between universities and industries (Schartinger, 2002).

Influence: In this thesis, the word effect, influence and relationship are the alternate of each other.

1.10   Outline of the Thesis

Key concepts from the research were introduced in this chapter. It outlines the background of the research, overview of the revolution of science, technology and innovation in Malaysia, statements of problem, research objectives, research questions, scope of the research and contributions of the study.

The following chapter two reviewed the related literature to this study. The literature review starts by discussing the importance of innovation, national innovation system, and the critical factors of national innovation system of Malaysia. After this, university-industry research collaboration and the factors that are the impediments between their collaboration and their collaborative innovation performance have been reviewed critically. Simultaneously, the literature provides the previous theories and models that have been used to evaluate the UIRC and continued with the discussion related to system thinking as the main theory in this study. Furthermore, review of the literature provides critical analysis of related theoretical and an empirical literature on the influence of NIS on UIRC. Finally, the theoretical framework and research hypotheses have been explained for the study.

Chapter three presents the research methodology and items measurement for testing the proposed framework of the study. Chapter three includes the research design, method of study, research instrument, sample frame, data collection and analysis method and ethical consideration. The research instrument includes in the quantitative and qualitative questionnaires that are structured in five-point Likert scale and interview questions. The data collection includes the content validity, and construct's validity and reliability of the instrument. Finally, the data analysis includes pre-analysis, assessment of measurement model, descriptive statistics of variables, assessment of structural model and qualitative analysis.

Chapter four presented an analysis of collected data and evidences of the research framework. Chapter four includes data screening, pre-analysis, assessment of measurement model, assessment of structural model, assessment of the Matrix approach, hypothesis results and the empirical framework of the study.

Finally, chapter five consists of discussion of research questions and hypotheses, theoretical contribution and practical implications of the research, recommendation for future research and the conclusion of research findings.

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