Reinforcing the National Innovation System of Malaysia based on University-Industry Research Collaboration: A System Thinking Approach

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Abstract: This study attempts to reinforce the national innovation system (NIS) of Malaysia based on university-industry research collaboration (UIRC). For this purpose, the critical constraints of NIS of and their root causes have been identified first. In this regard, quality of research and human capital has been categorized as critical constraints of NIS. By using system thinking approach, it is found that lack of education and training between university-industry personals is the basic cause of low quality of research and poor human capital. Furthermore, the analysis of the research illustrates that diminutive expenditure on education and training is the root cause of low quality of research and less human capital. Secondly, this research explores the balancing and reinforcing factors that not only overcome the constraints of education and training between UIRC but also helpful to enhance the quality of research and human capital for the development of NIS of Malaysia. The developed reinforcing model highlighted the outcomes that emerge after improving the quality of research and the human capital using balancing and reinforcing factors.

Keywords: National Innovation System, University-Industry Research collaboration, System Thinking, Success factors, Outcomes of NIS.

I. INTRODUCTION

The concept of national innovation systems (NIS) has been gaining intellectual and practical coherence over a number of decades, enjoying initial strong adoption by organization of economic corporation and development (OECD) and developed countries, and more recently becoming the focus of increased attention as a means to address some of the more profound issues for developing nations (Castellacci & Natara, 2013; Lundvall, 2007). The growing number of studies of innovation systems signals that the creation of innovation-enhancing framework by evaluating the existing conditions of NIS has become a central target of policy makers around the globe (Balzat, 2003; Marx & Brunner, 2012). The reason of huge attention towards NIS is significant economic crisis that both developed and developing worlds are facing frequently (Edquist, Leif (ed.), 2008; Lundvall et al., 2006). To overcome the economic crisis and to win the future, all countries need to boost their capacity to innovate. Since, it is usually accepted that technological change and innovation has now become the mantra to ensure sustained economic growth (Crespi & Zuniga, 2012; Sharif, 2012).

An innovation is the capacity to apply new knowledge or to recombine existing knowledge and skills in order to improve productivity and to create new products and processes (Bernard, 2013; Popescu & Crenicean, 2012; Bashir, 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 & Ramlogan, 2008). A recent trend in the innovative performance is increasing R&D cooperation (Zeng, Xie, & Tam, 2010). Cooperative research and development are crucial factors in determining the innovative capacity of a nation (Lee & Park, 2006). According to the (Robertson, 2008) and (von Tunzelmann, 2009) R&D networking and collaboration play different strategic roles in the development of innovation and the system of innovation, especially in emerging and newly industrialized economies (NIEs). Networking and 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 is widely recognized as one of the key factors which contribute to the improvement and development of innovative capabilities of the country (Jin, 2011; Teirlinck & Spithoven, 2013).

Several studies were conducted to strengthen the NIS of developed countries from the perspective of university-industry research collaboration but the study about reinforcing NIS of Malaysia with the help of UIRC is totally unattended in the mainstream literature. Malaysia demonstrated a significant achievement in research and development but the extent of manpower and quality of research is still well below the minimum needed to perform R&D activities (Asgari, 2007). Education index and human resource ranking of Malaysia were relatively low in comparison with newly industrialized economies (NIEs) (Mani & Sunil, 2000). Thus NIS of Malaysia needs considerable attention towards UIRC. It is well recognized that a trained, skilled and well-educated workforce is critical in enhancing economic performance, sustaining competitiveness and the development of innovation and innovation system in a country that is possible only by the research collaboration between university and industry. University-industry research collaboration is a key factor that provide a possible pathways to improve the knowledge and skilled of the individuals. The success of socio-economic entity is assured by the success of individuals. By educating individuals their ability, talents and skills can be utilized in any organization.

However, it is also considerable lack of education and training between university-industry personals is one of the major constraints between university-industry collaboration in Malaysia (Iqbal et al., 2011), and diminutive expenditure on education and training is the root cause of inappropriate education system, low level of education and lack of individual education in a country and consequently in research and development. Singh (2005), emphasizes that effective
research and development (R&D) activities are influenced by appropriate education and the hand on skills over production systems that enhance the capability to modify and improve the technology. Furthermore, in order to transform and effectively maintained the new technology, appropriate educational systems and personnel training must be developed (Ito, 1995). In the advanced nations, corporations spend hundreds of millions of dollars to retrain and re-educate their workers (Iqbal et al., 2013). Programs like on-job training, in-house training programs, knowledge sharing programs like workshops and seminars are often carried out to keep these workers up to the standard of technological changes (Porter, 2003). Most of the researchers, especially, Baycan, (2012), gave more emphasize on the training of university researchers to furnish the basic hand on knowledge about the new innovation that’s seems healthy approach for the productive work. According to Popescu & Crenicean (2012), highly educated and trained personals in universities and industries contribute to the development of innovation and creativity. Thus, the focus of this research is to reinforce the NIS of Malaysia based on UIRC.

In addition, despite the numerous studies of NIS, one thing is profound in the previous literature is the limited use of systemic thinking. Previous studies that develop a model to measure and to strengthen the NIS are largely used analytical thinking (Fritsch, 2006; Loikkanen et al., 2009; Lin et al., 2010). Analytical thinking analyzes the efficiency of specific part or elements of the system having a linear perception. While a system of innovation is a system of different elements which maintains its existence through the mutual interaction of its parts (Bertalanffy, 1976; White, 1995). The mutual interactions of the elements of a system lead to the construction of circular causality which is unique and never occur in analytical thinking (Bellinger, 2008; Patching, 1990, Oyebisi, 2013). Systems which behave in a linear way have limited predictability of the outcomes. In this regard, only a systematic understanding allows to understand structural weaknesses in a better way and also provides opportunity to find out a sequential cause of the problems and effects and the way to cover it, which is impossible to achieve when using the analytical or linear model (Chapman, 2004; Conti, 2010). Therefore, this study proposes using the “System Thinking” to fill this existing gap. Systemic thinking is the combination of analytical and synthesitical thinking that not only focus on the parts of the system but also focus on their patterns and events and describe how they work together (Skarzˇ auskiené, 2010). 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 & Pagano, 2009; Cabrera et al., 2008). By using system thinking, this research demonstrates all the root causes of low quality of research and less number of human capital that are the hindrance in the success of NIS of Malaysia. Simultaneously, the research provides the balancing and reinforcing factors that not only remove the hindrance but also crucial to reinforce the NIS of Malaysia.

Rest of the paper organized as follows: section 2, provide modelling approach, section 3, illustrates analysis using system thinking, section 4, demonstrates a detailed model of NIS and in section 5, conclusion of the research has been presented.

II. MODELLING APPROACH

System thinking is a strong approach to deal with the system of innovation. Senge, (1990), considers systems thinking as a framework to give a full clear picture of a problem situation, and as a tool for understanding how things work. It is a framework to look beyond events and scrutinize for patterns of behavior. The NIS represents a system of innovations constituted by elements and relationships (Kharazmi, 2011). Systems which behave in linear way have limited predictability of the outcomes. Therefore, systematic understanding allows policy makers to better comprehend structural weaknesses and also provides opportunity for developing innovative networks and relationships, which is impossible to achieve when using linear model (Chapman, 2004; Behl & Ferreira, 2014). System thinking seeks to answer the question of how structures influence behaviour. This theory critically encourages a consideration of interrelationships (Senge, 1990; Fusso, 2013). System thinking viewed problem situations in terms of the big picture rather than divided into parts (Checkland, 1999).

Systems thinking help policy makers to observe unseen forces underlying events and its patterns (Kapsali, 2011). An important aspect of systems thinking is that certain patterns of structure are repeated. These patterns are very important in prompting us to learn to see structures in the system. System thinking has a major focus of examining the impact of one factor on another and it can be considered as a modeling tool to identify variables that need to be improved in order that optimum results be achieved in a specific subject with the minimization or elimination of possible barriers (Rodrigues and Bowers, 1996). Mohaparta et al., (1994), Lee and Tunzelmann, (2005) and Galanakis (2006), indicated that system thinking models are appropriate to study national systems of innovation that shows feedback mechanisms. Therefore, causal relations are developed as a series of influence and causal loop diagrams (Tejeda & Ferreira, 2014; Richmond, 1994).

There are four major elements of system thinking: the open or closed boundary: feedback Loops: stocks or flows and observed conditions within the system (Forrester, 1976; Sterman, 2002). The essential idea behind the influence diagrams is an information–action–consequences paradigm. In this paradigm the consequences are always in the sense that something flows in the system. The action that is based on the information is attempted creates consequences that may appear after some time. These consequences generate further information and actions which may, in turn, continue the process. System thinking have two fundamental loops that shows the flows in the system which in combination create the influence diagrams of any system (Senge, 1990): These fundamental loop are: a) Reinforcing loop, b) Balancing loop as shown in figure 1& 2.
Reinforcing loop (Fig 1a) is an open loop which output will increase or decrease with respect to the increase and decrease in its input without any limit. While the Balancing loop (Fig 1b) brings one additional factor to create a target the final condition of the system can take. This target is compared to the actual state of the system to deliver information about the next action (Fusso, 2013). Based on theory of system thinking, following section will present the effect of constraints, balancing and reinforcing factors of UIRC on NIS.

III. HYPOTHESIS DEVELOPMENT AND ANALYSIS

A) Effect of lack of Education and Training between UIRC on Quality of Research and on Human Capital

Figure 2 and 3 illustrates the negative effect of lack of education and training between university-industry research collaboration (UIRC) on quality of research and on human capital. As the figures demonstrate that less number of employment and brain drain is the cause of less number of human capital, secondly, less number of research centers and research parks and less number of research universities is the cause of low quality of research. While the basic cause of these issues is lack of education and training between UIRC and the diminutive expenditure on education and training is the root cause of lack of education and training between UIRC. Secondly, lack of personnel training, lack of hand on skills, less efforts to retain existing workforce and incapability to modify and improve the technology are some other root causes that affect the research collaboration between UIRC as well as NIS.

Education and training between UIRC have a great impact on national quality of research and on human capital. Becker (1993), views human capital as organizational assets whose economic value is derived from the knowledge, skills, competencies and experience. Similarly, (Ahmed, 2012), provide positive relationship between education and training and research productivity. The result of the research reveals that proper channels of education and training between public and private organizations increase the quality of research and number of human capital. Eid (2012), examines the impact of R&D and its impact on productivity growth in 17 high-income OECD countries using country level data over the period 1981-2006 and the results suggest that R&D performed by highly educated and trained personals is positively influence on productivity growth in all production areas. The high rate of productivity growth to R&D performed by the highly educated skilled personals is found as outstanding.
But the limited expenditure on education and training and lack of education and training between UIRC resulting in low quality of research and poor human capital consequently affect NIS. (Pavitt and Pattel, 1999). Thus the research hypothesizes that:

**H1:** The constraints of university-industry research collaboration have negative effect on national innovation system.

**B) Effect of Knowledge Sharing between UIRC on Education and Training, Human Capital and on Quality of Research.**

Figure 4 and 5 shows the positive effect of knowledge sharing on education and training, human capital and on quality of research. These figures indicate that knowledge
sharing as a balancing factor is helpful to remove the constraints of education and training between UIRC. Knowledge sharing between UIRC is an important factor in order to manage the heterogeneity of education and training of both partners.

Fig 4: Knowledge sharing (UIRC) VS Human capital (NIS)

provide environment to share their knowledge and issues and produce progress during innovation process by developing human capital and quality of research (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Edmondson & Nembhard, 2009; Ratcheva, 2009). Thus, it can be concluded that knowledge sharing is not only the balancing factor of education and training but also the balancing factor of human capital and quality of research. So the next hypothesis of this research is:

**H2:** The balancing factors of university-industry research collaboration have positive effect on national innovation system.

C) Outcomes of Quality of research and Human Capital

Figure 6 and 7 illustrate the positive effect of reinforcing factors on education and training. As the figure indicates that cooperative education, workshops and seminars, combined research projects, hiring of fresh graduates and personal interactions are the reinforcing factors that have a positive influence on the each root causes of lack of education and training. As mention above the education and training between UIRC have strong relations with the quality of research and human capital. So these factors receive positive influence from the reinforcing factors of education and training and consequently developed and promote economic growth, quality of life, prosperous and progressive society and global competitiveness that are the crucial outcomes of successful NIS. Thus the third hypothesis of this research is:

**H3:** The reinforcing factors of university-industry research collaboration have positive effect on national innovation system.
Lack of Education and Training

- Diminutive expenditure on education and training
- In appropriate education system
- Low level of education
- Lack of individual education

Lack of hand on skills
- Lack of personal training
- Incapability to modify and improve the technology

Knowledge Sharing

Fig. 5: Knowledge sharing (UIRC) VS Quality of research (NIS)

Low Quality of Research

- Less number of research universities
- Less number of research centers and research parks
- Weak national economy
- Less number of commercialized products
- Less number of innovations

Fig. 6: Outcomes from Quality of research
IV. MODEL FOR REINFORCING THE NIS OF MALAYSIA

Figure 8 illustrates the detailed conceptual model that has been developed to reinforce the NIS of Malaysia. In this model constraint of UIRC and NIS their balancing and reinforcing factors and outcomes of NIS were demonstrated. The model shows that lack of education and training between UIRC is the basic cause of low quality of research and less number of human capital that negatively affect the NIS. To increase the number of human capital and quality of research, education and training between university-industry personals must be developed in a prior consideration.

For this purpose, knowledge sharing as a balancing factor has been proposed that provide possible pathways to accelerate the knowledge and skill within UIRC and consequently positively affect the quality of research and human capital as well. Furthermore, there are five variables (combined research projects, workshops and seminars, personal interaction, cooperative education and hiring of fresh graduates) were identified as a reinforcing factor that minimize the root causes of lack of education and training between UIRC. Once the education and training improved between UIRC, the quality of research and human capital will be reinforce automatically that produce economic growth, quality of life, prosperity of the society and global competitiveness as the outcome of NIS. Table 1 shows the overall proposed factors that help in reinforcing the national innovation system in Malaysia.
Figure 8: A detailed model to strengthen the NIS

Table 1: Proposed Reinforcing Model

<table>
<thead>
<tr>
<th>Actors</th>
<th>Constraints</th>
<th>Balancing factors</th>
<th>Reinforcing Factors</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| NIS    | 1. Human capital  
         2. Low quality of research | Knowledge sharing | Combined research projects | 1. Economic growth  
2. Quality of life  
3. Global competitiveness  
4. Progressive and prosperity of the society |
| UIRC   | Lack of education and training | Knowledge sharing | 1. Workshops  
2. Seminars  
3. Combined research projects  
4. Personal interaction  
5. Cooperative education  
6. Hiring of fresh graduates | |

V. CONCLUSION

In this research one step ahead has been taken to reinforce the national innovation system (NIS) of Malaysia that is valuable for the Malaysian policy makers. By using system thinking approach this paper analyzed the effect of university-industry research collaboration (UIRC) on NIS that is totally unattended from the mainstream of the literature. In this regard, low quality of research and less number of human capitals have been identified as critical constraints of NIS of...
Malaysia. Simultaneously, from the extensive research of (Iqbal et al., 2011), it has been analyses that the UIRC in Malaysia is also weak and lack of education and training between university-industry personals is a major constraint between their collaboration. Thus, in this research the system thinking approach illustrated that lack of education and training between UIRC is the basic cause of low quality of research and less number of human capital, consequently the cause of weak innovation system of Malaysia. The research shows that diminutive expenditure on education and training is the root cause of lack of education and training between university-industry personals thus low quality of research and less number of human capitals. So the research reveals that knowledge sharing is a balancing factor for both UIRC and NIS. It provides possible pathways to accelerate the knowledge and skills of university-industry individuals, for instance workshops and seminars, personal interaction, cooperative education, hiring of fresh graduates and combined research projects are the channels of knowledge sharing and as reinforcing factors not only strengthen the level of education and skills of individuals but also increase the quality of research and human capital that consequently enhance the country’s innovation system, economic growth, quality of life and in prosperity of society. Consequently the country become in the rank of global competitiveness. In conclusion, the overall analysis of this research shows that UIRC have a great influence on NIS of Malaysia.

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