European Journal of Business and Management
ISSN 2222-1905 (Paper) ISSN 2222-2839 (Online)
Vol.7, No.20, 2015

Untangling the Industry- University- Research Institute Innovation Network: Formation, Development and Performance Measurement

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Abstract
The Industry-University-Research institute (I-U-R) innovation network has attracted academic researchers' interest increasingly. However, there is little research investigate the I-U-R innovation network from the perspective of network development. To fill this gap, the present article reviews the researches on the I-U-R innovation network, mainly focusing on the three aspects: the collaboration patterns, the development and its influence factors, and performance measurement. Literature analysis shows that researches on I-U-R innovation network mostly concentrated on the joint R&D activities and joint patenting activities. The development process of I-U-R innovation network was influenced by some factors, including the regional factors, government policy and organizational attributions of cooperators and so on. On evaluating the innovation performance, most of current researches investigated the measurable performance of firm, while the personal knowledge exchange effect and innovation performance of university or research institute were less to be studied in empirical studies. Finally, the current researches have been summarized and some potential directions have been proposed for further study.
Keywords: Industry-University-Research institute collaboration, Innovation Network, Network Development

1. Introduction

Establishing and intensifying the links between science, research and industry have been the critical approach to improve the regional innovation (Buesa et al., 2010). From the view of networks, organizations like firms, universities, research institutes and others and their complex relationships form the I-U-R innovation network, which serves for supporting and facilitating the development of scientific knowledge, spread of innovation and organization learning (Bergek et al., 2008). From the viewpoint of innovation process, new knowledge is created and development by the scientific research and development activities, while the knowledge or technology transfer activities help to deliver the new knowledge to firm and then firm transforms knowledge into products (Godin, 2006). The cooperation of firms, universities, and research institutes was implemented in various forms. Accordingly, the I-U-R net-work has been established with these cooperative relationships. In recent years, the researches about I-U-R in-novation network have become a hot issue in academic literatures. Especially, researches placed their focus upon some aspects of the I-U-R innovation network, e.g. the formation, the development, the measurement of innovation performance. However, to our best knowledge, there is little researches review the I-U-R innovation network from the developing view. Related questions include: How does the I-U-R innovation network form? What are the influence factors during the developing process of I-U-R innovation network? How to measure the innovation performance in a more efficient way? With these questions, the present research aims to analyze the current related literatures, and propose some suggestions for further research.

2. The formation of I-U-R innovation network

In the first place, Etzkowitz and Leydesdorff (2000) proposed the model of "Triple Helix of university-industry-government". Since then, strengthening the relationship between firms, universities, and the research institutes has received much attention in both practices and academic researches. By using the "industry-university innovation network" as the topic words, the author did the literature retrieval in the Web of Science database. Totally, there were 88 English articles from 2003 to 2015 (4 of them were published in 2015), excluding the conference proceedings. At the meanwhile, the author employed the "industry-university-research institute" & "innovation network" to retrieve the Chinese articles in China Knowledge Resource Integrated Database (CNKI), restrict on the source journals of Chinese Social Scientific Citation Index (CSSCI). The later retrieve got 58 records from 2003 to 2015 (4 of them were published in 2015). Both the retrieve result of English and Chinese articles showed that the researches on I-U-R innovation network are in the increasing trend. The yearly distribution of these articles from 2003 to 2014 is presented as Figure 1.

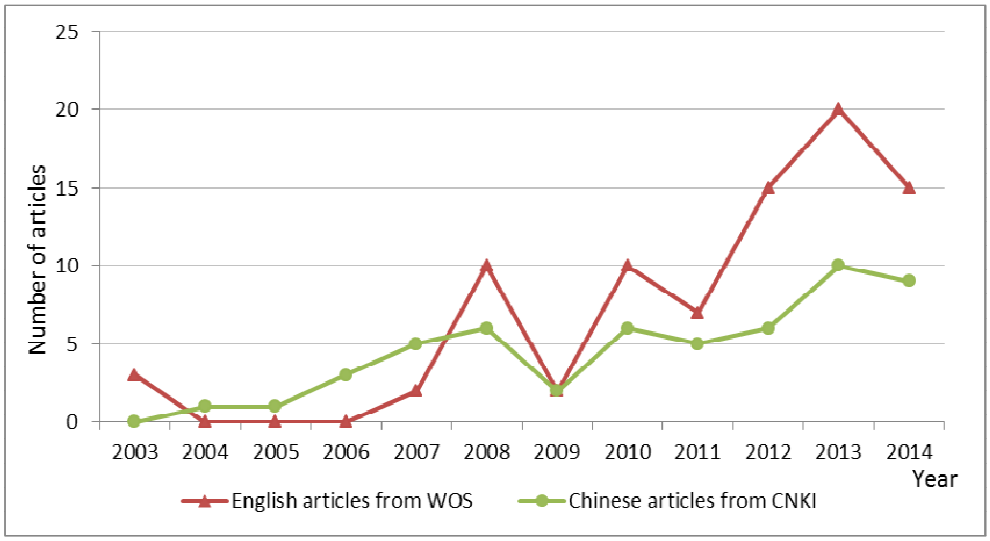

Figure 1. The yearly distribution of English and Chinese articles from 2003 to 2014

The practices of I-U-R cooperation are in various forms. Li, Liu & Liu. (2011) investigated the mode of I-U-R cooperation in Hubei province, China from the perspective of firms and universities. Their research shows that most of firms are inclined to cooperate with universities by using joint research and development while universities are more likely to joint in the public-fund research projects. Both the firms and universities responded to that they would like to maintain the cooperative relationship in various forms and carry forward the cooperation in large depth and broader breadth. The general survey of literatures showed that the research point mainly started from the R&D activities, joint patenting etc. between firms, universities, and research institutes. The development process can be understood as a linear process consisted of three stages, from the formation, development, and the innovation performance measurement.

2.1. The joint R&D activities

Wen & Kobayshia (2001) investigated the I-U-R R&D project initiated by Japanese government, and described the formation, the cooperation mode and characteristics of the I-U-R innovation network. Both Roediger-Schluga & Barber (2008) and Protogerou, Caloghirou & Siokas (2013) investigated the I-U-R innovation network under the European Union Frame Program. During the seven Frame Program implemented by European Union, both universities and research institutes showed the increasing degree of participation in the I-U-R innovation network, but the firms were in a declining trend (Protogerou et al., 2013). Chinese scholar Chi (2005) collected the data by field survey and analyzed the I-U-R innovation network in Zhejiang province, China. His research findings showed that universities, research institutes and technology agencies become more and more important to firms' innovation. Both these researches showed that universities and research institutes played a critical role in the I-U-R innovation network formed by joint R&D activities.

2.2. The joint patenting activities

Although I-U-R innovation network were formed by different activities, condition and the conclusions that draw from these network could not be generalized simply, but the data from R&D activities, strategy alliance, patent, publications and field study may reflect the information of different stages in the innovation process. The cooperation between firms, universities, and research institutes could generate the tangible outcome, e.g. patents, research papers, and inventions. Thus, the I-U-R innovation network formed by joint patenting activities had been investigated by many scholars in different aspects, e.g. the regional characteristics, the network characteristics, the development process. The network characteristics of I-U-R innovation network included the network size, the network density, and the network centrality. Ma et al. (2011) analyzed the university-firms joint patenting network, and found the network characteristics of network created by different categories were different. Lee, Seo & Choe (2012) empirically analyzed the relationship between cooperation mode and cooperation performance by using co-author data and found the cooperative relationship between research institutes and other organizations has positive effect on cooperation performance. Inouea et al. (2010) investigated the development of university- industry cooperation by analyzing the distribution of network characteristics with the joint patenting data of firms, universities, and research institutes in Japan. Tijssen (2012) found I-U-R cooperation showed the globalization trend by analyzing the co-author publication of firms and universities. Chinese scholars Chen, Zhang & Tian (2012) investigated the joint patenting network in equipment manufacture of three provinces in northeastern area of China. Their research showed that the universities and

research institutes with stronger innovation ability and occupied the central position in the network contributed to formed and lead the highly clustering ego networks. Universities have advantages in creating new knowledge and technologies, thus the universities which owned stronger innovation ability took the central position in networks.

3. The development of I-U-R innovation network and its influence factors

3.1 The government policy

Even though the I-U-R innovation network was formed by the cooperation between firms, universities and research institutes, the innovation policy had significant impact on it. The innovation policy in different countries has made great effort to strengthen the cooperative relationship between firms, universities and research institutes. In Korea, the science and technology policy influenced the role of universities played in different regions, and the government policy contributed to promote the linkages between universities and firms (Sohn et al., 2009). Inouea et al. (2010) compared the R&D project initiated by Japanese government and found these R&D projects helps to form various linkages between co-operators. Looy et al. (2003) thought the government policy could facilitate the I-U-R cooperation, thus promoted the innovation performance. The cooperation environment created by government was important for balancing the relationship between cooperators and pushing forward the knowledge-intensive firms develop to R&D-intensive firms.

3.2 The regional factors

The regional factors, e.g. the geographical distance between firms, universities and research institutes, have great impact on the cooperative relationship of these organizations (Inoue et al., 2010). From the perspective of geographical proximity, Laursen et al. (2011) found that firms were inclined to cooperate with outstanding universities which were closer to it. Inouea et al. (2010) proposed the growth model of I-U-R innovation network in Japan and applied joint patenting data to test it. Especially, this growth model took the geographical distance into consideration, and showed that geographical distance between cooperators had great impact on the development of I-U-R innovation network. This finding the industry clustering between firms, universities and research institutes were based on the geographical clustering.

The development path can be analyzed in time dimension and space dimension respectively. On the regional level, Protogerou et al. (2013) found the countries with stronger technology abilities were active during the implement of 25-year Framework Program of European Union, while the counties were less likely to participate in the I-U-R cooperation. These findings provided some insights for the policy makers. The regional innovation policies ought to encourage the countries with weaker technology abilities to seek cooperation partners, and balance the regional development. Lei & Chen (2011) utilized the joint patenting data of universities and firms from 1985 to 2008 in China, analyzed the development of patenting network on the regional level. The development trend showed that the center of joint patenting network had developed from Beijing to Shanghai, to Guangdong provinces developed area. Also, the unbalanced development of region in the innovation network gave the implication for policy makers to guide and support the backward region, motive the initiative to take part in the I-U-R cooperation.

3.3 The organizational attributions

The organizations involved in the I-U-R innovation network owned different attributions. For example, most of universities and research institutes gained financial support from government, while all the firms must conduct the operation in the market competition. Thus, the motives of different organizations to participate in the I-U-R cooperation were different. Yang (2011) and Li et al. (2011) did the questionnaire survey in Guangdong province and Shaanxi province in China respectively. Both of them found that the motives of cooperator were various, thus there were differences in cooperation mode of firms and universities. Laursen et al. (2011) found that firms were more likely to choose the universities with stronger research ability and higher reputation. Those universities with higher reputation had more abundant linkages with firms (Laursen et al., 2011).

From the time and space dimension, Liu et al. (2011) investigated the I-U-R innovation network of “985” project universities in China. Their empirical results showed that the development path of innovation network that consisted of universities and other organizations were different. Lei & Chen (2011) had also found that the universities with higher reputation had more advantage in patent applications. These empirically study indicated that the difference of organization lead to the various development path of I-U-R innovation network.

4. The measurement of innovation performance in I-U-R innovation network

The performance of I-U-R innovation network can be classified into intangible outcome and tangible outcome. The intangible outcome embody on knowledge exchange, which can be measured by the knowledge growth of firms and employees. The tangible outcome can be reflected by the number of patents, the prototype, the novel products, and the update speed of technology etc.

4.1 The measurement of knowledge exchange

The I-U-R innovation network provides the opportunity for firms, universities, research institutes to transfer knowledge, thus the performance of knowledge exchange can be viewed as the performance of I-U-R cooperation. Based on the Small-world network structure, Ge et al. (2009) analyzed the knowledge transfer activities in the cooperation, and proposed a new framework to measure the performance of I-U-R cooperation. Yang and Wu (2012) empirically studied the influences in the knowledge transfer, testing the role of various influences by using structural equation model. In their research, the depth of knowledge transfer and degree of satisfaction of cooperators were used to reflect the performance of I-U-R cooperation.

As mentioned in previous sections, outcome of the joint patenting or co-author can be viewed as the outcome performance of I-U-R innovation network. Ma et al. (2011) investigated the relationship between the network structure and the outcome of patent in the I-U-R innovation network by using the linear regression method. But this method has some limitation since the patent data was used to construct the innovation network as well as the innovation performance. Based on the data of joint patenting, Pond et al. (2010) analyzed the effect of knowledge diffusion in the I-U-R cooperation by using the data of joint patenting. Lee et al.(2012) used the number of Science Citation Index(SCI) papers, the number of patents and the income of technology licensing to represent the performance of I-U-R cooperation, and investigated the relationship between input and output by applying the data envelopment analysis.

4.2 The measurement of firm's innovation performance

There is much attention paid on firm's innovation performance in I-U-R cooperation. To investigate the relationship between I-U-R cooperation and firm's innovation ability, Liu (2009) used the sales revenue of new products to total revenue to measure firm's innovation abilities. Their research used the degree of connection in the I-U-R cooperation, instead of the network characteristics. From the perspective of innovation process in the firm's level, firm's technology innovation is a complex process. Firms acquire the knowledge and technology from its partners in the I-U-R cooperation, and assimilate the knowledge into its knowledge base, then utilize the knowledge to generate new technology and product. Knowledge and technology acquire from external sources were the direct outcome result from the I-U-R, and the new technology and product were the result of applying the knowledge and technology. Hui & Zou (2010) divided this process into three parts, the I-U-R innovation network, the knowledge integration, and the performance of technology innovation. Moreover, the performance of technology innovation in their research was differentiated as product innovation and technology innovation.

4.3 The systematic measurement of innovation performance in the cooperation process

The performance of the I-U-R cooperation can be measured by different indictors during the process of cooperation. From the view of the organization relationship, Xu et al. (2011) investigated the effect of network capacity on knowledge transfer. The innovation performance was measured by the amount of knowledge acquired, the quality of knowledge, and the application of knowledge. Their research inspired that the performance of I-U-R cooperation not only reflect on firms' knowledge acquisition, but also the knowledge exchange of different participators. In the literatures, most of researches mainly focused on firm's innovation performance, but the performance of universities and research institutes were less paid attention.

On the performance in the I-U-R innovation network, Perkmann et al. (2011) analyzed the firm's performance in different stages that it engage in the I-U-R alliance, and proposed the measurement indicators correspondingly. There are four stages in their frame work, namely the input, the process, the outcome and the influence. The outcome of I-U-R cooperation can be presented as the new technologies, new scientific knowledge, and the result of employee training, which can be measured by the patents or other intelligent property, scientific publications and the measurement of employee training respectively. Besides, Perkmann et al. (2011) distinguished the outcome and the influence of I-U-R cooperation. The influence of I-U-R can be reflected by the number of new R&D projects, the number of new solutions, the number of novel product and the human capital. Based on the contribution of Perkmann's work, Seppo and Lilles (2012) asserted that the performance of I-U-R cooperation should be measured from the input, activities, the outcome, and the influence. Moreover, Seppo & Lilles (2012) summarized the measuring indictors of input, the indictors of outcome and the indictors of influence. With the research of I-U-R innovation network went further, more and more scholars devoted in to investigate the different stages in the innovation process, and used the quantitative indicators to measure the outcome of each stage.

5. Some suggestions for further research

5.1 The variety of I-U-R cooperation patterns

The practices of I-U-R cooperation were in various forms, such as R&D activities, the joint patenting, the person mobility etc. Most of scholars used data of joint R&D activities, joint patenting to construct the network of co-operators for subsequent analysis. Theses researches have showed that the important role played by universities

and research institutes, but less attention paid to the role of firms in the I-U-R innovation network. The activities of firms should have impact on the cooperators. For example, the leading firms might act as the "backbone" in the network, thus supporting the innovative resources exchange in the network. The future research should widen the view of research data sources, comparing the impact of different cooperation forms on the development and the innovation performance of innovation network.

5.2 The Influencing Factors during the development of Innovation Network

5.2.1 The government policy

Most of scholars thought that the government policy had great impact on the development path of I-U-R innovation network, since the government policy would influence the cooperation mode among cooperators. Most importantly, different policy tools of government had different objectives, thus affect the orientation of I-U-R cooperation among cooperators. For example, the I-U-R cooperation in China was promoted by the government policy greatly. The existing academic researchers deployed their researches with joint R&D activities or joint-patent, less focus on the I-U-R innovation under different policies. Thus, the influence of government policy on the I-U-R innovation network in deeper insight, and the comparison between different policies and regions might be put on agenda for future research.

5.2.2 The regional factors of cooperators

Taking the researches of joint-patenting as example, the cooperators distribute in different geographic regions. More preciously, the cooperators who came from the developed regions were more active than those that located at the poor developing regions. In other words, the unbalanced development situations may have impact on the formation and the development of I-U-R innovation network. As the cooperators were located at different regions or areas, the geography distance can affect the relationship building among cooperators. Besides, the geography distance might have great impact on the knowledge learning and the exchange process among cooperators. The current researches about the regional I-U-R innovation network should pay attention to the geography distance among cooperators empirically. Therefore, using the geography distance and the difference regional characteristics to investigate the relationship between the network structure development and innovation performance may be a meaningful direction for research.

5.2.3 The organizational attributions of cooperators

The basic assumption for the I-U-R cooperation was the heterogeneous knowledge laid in different organizations. However, different organizations hold variant background and goal. Universities and research institutes had more advantages in the scientific research fields, and the firms skilled at transforming the knowledge and technology into the products. Thus, the advantages on knowledge or technology of different organizations might affect the cooperation forms. The research trend on I-U-R innovation network has developed from the network-level to the ego network level. This helps us to understand the driving power of network development and the mechanism of network development at a deeper level.

5.3 The measurement of innovation performance

Apart from the tangible output such as the patents, and new products, the innovation performance of I-U-R innovation network should take the intangible performance into account, e.g. the effectiveness of employee training and the personal knowledge exchange. From the viewpoint of innovation process, the performance in different stages has different indicators. And from the perspective of cooperators, universities and research institutes that participated in the innovation network could benefit from the network differently. In previous studies, firm's performance has earned much attention, but the performance of universities and research institutes were less being concerned. This limitation restricted the full understanding the effect of knowledge exchange in the innovation network. To measure the performance of universities and research institutes, some additional indicators might be taken into account. For example, the learning performance of scientists in the I-U-R cooperation, and the performance of technology transfer e.g. the number of technology transfer contracts. Most importantly, the knowledge flow in the I-U-R innovation network is changing by time, as well as the supplier or receivers of knowledge should not be fixed for one specific organization. Further research ought to pay attention to this important issue.

6. Conclusions

From the perspective of development process of I-U-R innovation network, the formation form of I-U-R innovation network, the influence factors during the development process and the measurement of performance have been reviewed based on the current literatures. Moreover, some potential directions for the further research have been identified. Further researches should investigate more factors that might influence the network development, and the effect of these factors as well as the combining effect of them on I-U-R innovation network performance. Most importantly, more empirical studies are extremely necessary to explicitly explain the transmission mechanism from the network formation to the innovation output of the I-U-R innovation network.

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