Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

Effects of knowledge diffusion on international joint research and science convergence: Multiple case studies in the fields of lithium-ion battery, fuel cell and wind power

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ARTICLE INFO

Article history:
Received 24 March 2015
Received in revised form 4 February 2016
Accepted 19 March 2016
Available online xxxx

Keywords:
Science convergence
Knowledge diffusion
Network density
Rao–Stirling index
VOSviewer

ABSTRACT

The goal of this study is to investigate relationships among IJR (international joint research) network, knowledge diffusion and science convergence. Based on scientometric analysis, lithium-ion battery, fuel cell and wind power were evaluated by regression analysis statistically. The following three hypotheses were established and verified: countries having higher centrality in IJR networks are more likely to be early adopters; knowledge diffusion increases as IJR network density increases; and science convergence increases as knowledge diffusion increases. For verifying hypotheses, we measured annual number of countries as knowledge diffusion, annual Rao–Stirling index as science convergence and annual network density, degree centrality of IJR network and conduct regression analysis among these. In conclusion, an important implication is that knowledge diffusion may significantly contribute to increase science convergence and international joint research network, one of the major sources of innovative technologies.

1. Introduction

In recent innovation trend, emerging sectors are characterized by rapid development of technologies based on combining various fields and increased necessity of interdisciplinary research, which is called convergence (Xing et al., 2011).

Definition's difference between convergence and fusion is defined by Curran et al. By that definition, convergence is defined as the process where the science, technology, and industry move to the different branches and are combined. And fusion is defined as the process where two technologies are combined at least in one branch.

Convergence has attracted growing interest among many researchers (Curran, 2010; Pennings and Puranam, 2001; Stieglitz, 2003). So far, the emerging discussion on convergence has tended to focus on developments within the information technology, communications and media industries (Yoffie, 1997; Lei, 2000). Most of the studies around convergence have centered on topologies, consequences and drivers.

Convergence is separated by science convergence, technological convergence, market convergence and industry convergence, it has a mutual continuity. This study was performed around the science convergence in which the convergence starts. While knowledge diffusion is one of the most important drivers of science convergence, various factors, including changing market environments and customer behavior, regulation absolutely. Also, knowledge diffusion is affected by International Joint Research (IJR) network in terms of researcher level and network level.

Despite the fact that knowledge diffusion seems to be a major driver of science convergence and it is affected by IJR network, these phenomena remain largely unexplored in the academic field. Although a number of prior studies on science convergence, knowledge diffusion and IJR network can be identified, the academic discussion on relationships among these factors so far must be considered as still emerging, meaning that the topic remains relatively uncharted empirically (Pennings and Puranam, 2001; Stieglitz, 2003; Lind, 2005).

The purpose of the proposed this study is to investigate relationships between these factors and monitor trend of science convergence, through in-depth case studies. The overall objective of this study is thus to further the knowledge of how IJR network affects knowledge diffusion and how knowledge diffusion affects science convergence.

For monitoring science convergence and investigating relationship among these factors, we establish analytical framework and conduct case studies of lithium ion battery, fuel cell and wind power using academic paper information. Lithium ion batteries, fuel cell and wind power are being widely regarded as one of the near-term solution to deal with the variations of renewable energy sources. Lithium ion batteries have gained a lot of attention since their superior energy density and cycle life compared to other battery systems. These benefits have made lithium ion batteries almost ideal for usage in eco-friendly vehicle and energy storage systems (Wagner et al., 2013). According to

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http://dx.doi.org/10.1016/j.techfore.2016.03.017

emerging energy storage and eco-friendly vehicle, lithium-ion battery, fuel cell and wind power are representative fields that have occurring convergence among electrochemical, materials, IT and energy and so on. Therefore they are suitable fields to figure out the phenomenon of convergence.

As network analysis is able to analyze the degree of IJR quantitatively, network analysis is utilized to measure a degree of IJR network such as degree of centrality and network density.

In case of knowledge diffusion, it was defined as increasing number of participating countries and measure annual participation of countries, VOSviewer program which is developed by Leiden University and Rao–Stirling index discussed in interdisciplinary research are used.

The contributions to current knowledge that proposed that this study should provide are twofold. Firstly, an analytical framework for analyzing science convergence will be developed and applied and tested on industry currently affected by science convergence. With the aim of advancing and enriching the literature on IJR network, knowledge diffusion and science convergence, this framework will investigate relationships among these factors. Secondly, both the response and the strategic options of countries affected by science convergence, with a specific focus on the capability gap are caused by science convergence. This should shed light on how to facilitate science convergence.

2. Literature review and research model

The existing literature on relationship among IJR network, knowledge diffusion and science convergence can roughly be divided into: 1) studying relationship between IJR network and knowledge diffusion; and 2) studying knowledge diffusion as driving factor of science convergence.

2.1. International Joint Research network and knowledge diffusion

International Joint Research network has always been implied, often without elaboration, in the knowledge diffusion literature: knowledge diffusion through a social system has usually been studied as a process of communication between connected researchers (Rogers, 2003; Iacobucci, 1996). Knowledge diffusion researchers employing the IJR network perspective have sought to explicate the actual structure of relationships that shape and constrain the communication, thus throwing further light on the knowledge diffusion process. The core idea in IJR network tradition is that social structure influences the spread of new ideas and practices by shaping patterns of interaction within IJR network (Burt, 1987). The fundamental intuition of IJR network theory of knowledge diffusion is that structural patterns determine whom given researchers will choose as a "model". While IJR networks are composed of relationships between a set of researchers, there are two broad approaches to the study of how relationships influence knowledge diffusion: relational and structural models of knowledge diffusion (Valente, 1995). Relational models consider the focal researcher's adoption or non-adoption in light of the behavior of those to whom the former is directly connected. Thus, for a given researcher, direct contact with an influential "opinion leader" might be seen as impelling adoption. Structural models, in contrast, consider all relationships in IJR network, rather than only the direct ties that a given researcher may have. Founded on the key assumptions of IJR network analysis (Wellman, 1988), structural IJR network models acknowledge that the overall structure of the IJR network, as well as a given researcher's position in it, influence that researcher's behavior and subsequent performance. In modeling the effect of the overall IJR network structure on knowledge diffusion, we adhere to the structural model. The history of IJR network model of knowledge diffusion may be traced (Valente, 1995) from opinion leadership formulations (Coleman et al., 1966), to the strength of weak ties formulation (Granovetter, 1973), to the communication IJR network formulation (Rogers and Kincaid, 1981) and finally to the structural equivalence formulation. IJR network analysts refer to the specific process of knowledge diffusion; thus, the chief concern of IJR network model of knowledge diffusion is the variety of network mechanisms through which knowledge diffusion operates (Burt, 1987). In this study, we draw upon and expand the core ideas in this literature. The following key conclusions of the existing IJR network research on

Academic paper	Information of organization	Information of Nationality
Paper 1	Organization 1; Organization 2	Country 1; Country 2
Paper 2	Organization 1; Organization 3	Country 2; Country 3
Paper 3	Organization 2; Organization 4	Country 1; Country 4
Paper 4	Organization 2; Organization 3	Country 1; Country 3
...	...	...

Making Co-occurence

	Country 1	Country 2	Country 3	Country 4
Country 1	3	1	1	1
Country 2	1	2	1	0
Country 3	1	1	2	0
Country 4	1	0	0	1

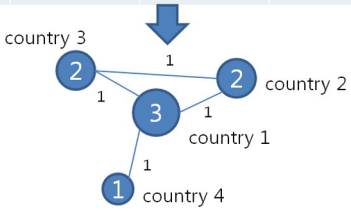

Fig. 2. An example of method of creating an IJR network diagram (example).

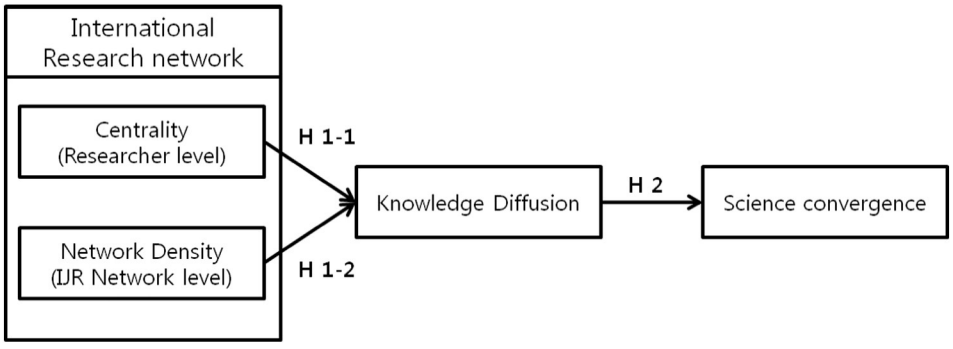

Fig. 1. Analytical framework.

Please cite this article as: Jeong, D., et al., Effects of knowledge diffusion on international joint research and science convergence: Multiple case studies in the fields of lit..., Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.03.017