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Technological proximity and recombinative innovation in the alternative energy field

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ABSTRACT

Recombination of knowledge elements has been recognized as important innovation activities. This study aims to develop a new measurement of recombinative innovation and firstly explores its antecedents at the country-dyad level. We analyze 41,007 US alternative energy patents granted between 1976 and 2012. Based on multi-source data and longitudinal design, Quadratic Assignment Procedure (QAP) model results indicate that two countries' technological proximity (TP) takes an inverted U-shaped relationship with their recombinative innovation (RI), which means that TP could raise the potential of joint recombination, but should not become too high because of great knowledge homogenization. Furthermore, we test two types of distances (i.e., cultural and geographical) as moderators of the relationship between TP and RI. Cultural distance negatively moderates the relationship between TP and RI, but moderating role of geographical distance is not supported in this research. The findings of this study, besides having implications for management and policy, have implications on the research of recombinative innovation, inter-national collaboration and partner selection strategy.

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1. Introduction

From the Schumpeterian re-combinatory perspective, many scholars hold the view that most technological innovations are driven by the recombination of different knowledge elements (Carnabuci and Operti, 2013; Corredoira and Banerjee, 2015; Fleming and Sorenson, 2004; Galunic and Rodan, 1997). It is believed that needed technologies can be stimulated to be recombined because of resource scarcity and opportunity development. Gallouj and Weinstein (1997) used the term "recombinative innovation" to refer to new combinations of diverse final and technical characteristics. Previous studies have reported that recombinative innovation, showing fresh technological combinations introduced to meet customer and market needs, is often characterized by notable advances and high quality (Carnabuci and Operti, 2013; Van Den Bergh, 2008). To innovators, recombinative innovation plays a critical role in the maintenance of sustained technological advantages (Utterback and Abernathy, 1975). Recombination of technological domains, which are seldom connected, can induce more radical ideas (Fleming, 2001; Schoenmakers and Duysters, 2010). Nowadays, increasing technology complexity has been accompanied by more recombinative innovation opportunities. Not surprisingly recent developments in the field of innovation have led to a renewed interest in recombinative innovation (Barnett, 2011; Corrocher and Zirulia, 2010; Gruber et al., 2013; Schilling and Green, 2011; Yayavaram and Ahuja, 2008). However, the empirical research on measuring and understanding origins of technological recombinative innovation is still limited.

This study fills the voids by developing a new measure of recombinative innovation using patent technological classifications. Technological classifications are valid and widely used to express patents' technological components (Guan and Liu, 2016; Wang et al., 2014; Yayavaram and Ahuja, 2008). Fleming (2001) proposed that technological classifications can be used to illustrate the process of technological recombination. Closely following these approaches, we consider recombinative innovation as technologies with new combinations of certain technical classifications. To measure recombinative innovation, we compare the technological classification combinations of a focal patent with all combinatorial histories of classifications in previous inventions. Our study is set at the nation-dyad level as we focus on transnational recombinative innovation. There are two reasons for this. First, the need of transnational collaboration is great and growing in technological recombination nowadays. External transnational collaboration may provide access to valuable resources which are not generated

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internally, consequently increasing opportunities of recombination of knowledge and resources. Second, countries are distinctive in technological specialization and competence (Archibugi and Pianta, 1992; Pavitt and Patel, 1999). Today's countries have stronger motivations for recombination with a good prospect of solving technological problems efficiently.

Besides measuring recombinative innovation at the nation-dyad level, we also address the limitations of origins of recombinative innovation in previous research. Firstly, to unravel the intricate mechanisms of recombinative innovation, this study focuses on a vital aspect of the technological portfolio – technological proximity – and tests its influence on the recombinative innovation. For technological innovation, such as joint recombinative innovation, similarity in technological bases is considered as a crucial proximity (Schamp et al., 2004). As the technological portfolio differs from country to country, any efforts to understand joint innovation activities should consider technological proximity (Garcia-Vega, 2006). Technological proximity refers to the similarities in technological bases or portfolios that knowledge actors possess (Cantner and Meder, 2007; Guellec and van Pottelsberghe de la Potterie, 2001). Drawing on the recombinatory search theory and considering the contrasting impacts of technological proximity, we propose that the effect of technological proximity between two countries on recombinative innovation follows an inverted-U relationship. Secondly, to further delve into the above mechanism that establishes a model linking technological proximity and recombinative innovation, we draw a perspective view of context research and posit two underlying moderating variables to help interpret the link: cultural and geographical distance (Chua et al., 2015; Guellec and van Pottelsberghe de la Potterie, 2001). Innovation scholars have long considered the moderating roles played by both distances in resulting innovation performance (Hansen and Løvås, 2004; Hinds and Mortensen, 2005). Cultural and geographical distance could strengthen or weaken technological proximity's effects at a certain point (Cramton, 2001; Knoben and Oerlemans, 2006). We argue that the degree to which two countries are culturally or geographically distant generates difficulties in synergies and knowledge transferring, which decrease the benefits of technological proximity. We further suppose that the impact of technological proximity is moderated by conditions of cultural and geographical distance, between the dyad countries involved in the recombinative process.

The research is based on the alternative energy field. For one thing, as a newly emerged field, alternative energy technologies usually require global collaboration and technological recombination (Guan et al., 2015). For another thing, alternative energy technologies currently play important roles in environmental protection, human life and economic development problems faced by every country (Dresselhaus and Thomas, 2001). The analysis method is the Quadratic Assignment Procedure (QAP) model where the dependent variable is recombinative innovation at the nation-dyad level, which is explained by technological proximity, geographical distance, cultural distance and control variables, such as languages and scale difference. The study is organized into five parts as follows. Section 2 shows the literature background and sets out the research framework, describing the influence of technological proximity on recombinative innovation, and the moderating roles of geographical and cultural distances. Section 3 outlines the data sources and describes variables and models. Section 4 illustrates the QAP and robust test results, and Section 5 presents our conclusions and discussion.

2. Theoretical background and hypotheses

This section consists of four main parts. The first part reviews the theoretical background of recombinative innovation (RI), technological proximity (TP) and two types of distance. The second part proposes the nonlinear relationship between technological proximity and recombinative innovation. The last two parts motivate our hypotheses on the moderating roles of cultural and geographical distances on the TP-RI relation.

2.1. Theoretical background

Recombinative innovation exploits the innovation possibilities by recombining existing technical characteristics or recombining existing with novel characteristics (Keupp and Gassmann, 2013). There are two important perspectives on recombinative innovation. The first involves departing in a significant and creative way from past component combinations (Sundbo and Gallouj, 2000). Based on this perspective, recombinative innovation can be considered as the recombination of knowledge, which is a source of innovation. The second involves architecture change of a product or technology (Henderson and Clark, 1990), which destroys architectural knowledge and preserves the usefulness of component knowledge. Recombinative innovation can change existing components' linking way, while leaving the basic and core design untouched (Galunic and Eisenhardt, 2001).

Some scholars have studied recombinative innovation, especially using survey items and in service industries (Corrocher and Zirulia, 2010). For example, using survey data, Corrocher and Zirulia (2010) examined the relationship between users' features and recombinative innovation, measured by tariff plan characteristics. Gallouj and Weinstein (1997) identified recombinative innovation using service characteristics. Gremyr et al. (2010) used a multiple case study to identify examples of recombinative innovation in manufacturing and service firms. Using evolutionary analogies, some scholars proposed that the recombination of existing technologies can generate technological novelty (Fleming and Sorenson, 2001). However, there is a shortage of empirical literature studying recombinative innovation in the technological context. In this study, we draw on previous work to develop a measurement and theory of recombinative innovation in the technological context. We argue that an understanding of recombinant innovation requires the considerations of technological proximity, and how it interacts with geographical and cultural distances in this process.

Technological proximity is a significant determinant in cooperation, absorptive ability and innovation activities (Benner and Waldfogel, 2008; Cantner and Meder, 2007; Knoben and Oerlemans, 2006). To utilize mutual technological know-how, the owners of such know-how should possess certain technological proximity (Cantner and Meder, 2007). The similar technological backgrounds facilitate the acquisition of heterogeneous resources, technological learning and development. However, as technological proximity increases to a certain extent, inventors from two countries cannot efficiently acquire recombination opportunity due to their homogeneity and cognitive overload (Kirsh, 2000). Moreover, large quantities of homogeneous information not only taper off the cooperative partners' ability to cope with information but also hamper their recombinant search. Previous research comes short in terms of synthesizing theories and elucidating mechanisms of how technological proximity affects recombinative innovation. The purpose of this article is to build upon technological proximity research and fill the voids in literature.

Culture has various and inclusive definitions (Smircich, 1983). In this study, we adopt Hofstede's definition which considers national culture as the collective mental programming of members and part of the condition sharing with other members. We can share these thoughts and emotions with others in our specific region, group or country but not with members from other regions, groups or countries (Hofstede, 1983). In the present era of globalization,

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