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How institutional arrangements in the National Innovation System affect industrial competitiveness: A study of Japan and the U.S. with multiagent simulation

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ABSTRACT

The institutionalized long-term business relationships among Japan's (JP's) innovating players have been indicated as a weakness of JP's National Innovation System (NIS) compared with that of the U.S.
This study examines how this institutionalized business relationship practice determines the strengths and weaknesses of the U.S. and JP's NIS using agent-based modeling and simulation. Our analysis reveals that the JP NIS is at an advantage in an industry where consumer demand changes rapidly and incremental innovation is crucial. In contrast, the U.S. NIS benefits an industry where frequent radical innovation is required. Furthermore, we show that heavy reliance on in-house R&D is advantageous over open-innovation practice in an industry where radical innovation is crucial when long-term business relationships are prominent. Based on the simulation results, we draw conclusions including strategic and policy implications for JP firms and policymakers, respectively.

1. Introduction

The concept of a National Innovation System (NIS) emphasizes the variety of and dynamic interaction among innovating actors as the primary driver of national innovation dynamics (Edquist, 2005; Chaminade and Edquist, 2010; Edquist and Johnson, 1997). How individuals establish business relationships and interact with others for innovation are governed by institutions—sets of common habits, norms, routines, established practices, rules, or laws (Lundvall, 1992)—defined within the national boundary. As such, the role of the institution has been highlighted as a crucial element of the NIS. The institution is also a key concept that bridges the two strands of economics literature, namely new institutional economics and evolutionary economics (Nelson and Nelson, 2002). New institutional economics analyzes how the institution works in determining ways in which economic players interact while accommodating transaction costs, information asymmetry, and bounded rationality of human beings (North, 1990; Williamson, 2000). Evolutionary economics considers firms as the major innovating players and emphasizes the role of technological innovation in economic growth (Nelson and Winter, 1982). The institution in evolutionary economics is expressed as the routinized operation of firms.

Accordingly, finding country-level institutional differences in NIS may help explain differential national economic development and national innovation dynamics. The widely perceived difference between the U.S. and Japan (JP) in an institutionalized business relationship practice is an example.

The JP NIS has been characterized as a long-term business relationship-oriented innovation system, whereas the U.S. NIS is a short-term business relationship-oriented innovation system. In JP, individuals collaborate with prior business partners in the presence of mutual trust strengthened by an institutionally sanctioned system (Hagen and Choe, 1998). A long historical partnership between *Toyota Motors* as a primary auto parts consumer and *Denso* as a major auto parts supplier is an example (Kani and Motohashi, 2013). A long-term relationship provides the competitive advantage in innovation for which a high degree of productivity and manufacturing flexibility is required, e.g., in automobiles and electronics. Japanese firms' high degree of reliance on internal R&D also supports the perception that the JP NIS is a "relationship-driven innovation system" in the sense that internal R&D essentially requires strong internal communication and collaboration.

Some studies have claimed that long-term business relationships are the reason why Japanese firms have been market leaders in certain industries (Clark, 1989; Fruin, 2006; Hagen and Choe, 1998; Odagiri, 1994; Abegglen and Stalk, 1985). A long-term business relationship, although potentially vulnerable to the hold-up problem because of

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opportunistic behavior by partners, can be sustained because long-term relationships between players in JP drive a repeated game, which effectively prevents opportunistic behavior by opponents (Baker et al., 2002; Holmstr and Roberts, 1998). Hofstede et al. (1991) explained that JP's long-term business relationship practice may be associated with its unique sociocultural characteristics. That is, Japanese society is more likely to rely on collectivism than the individualism pervasive in U.S. society. Also, in Japan, it is a broadly accepted norm that an individual's life is a very short moment in the long history of humankind. Accordingly, firms in JP look to serve all of society based on a long-term perspective rather than seeking short-term profits.

This institutional difference has been understood as an explanatory factor for the different styles of industrial and innovation competitiveness exhibited by the U.S. and JP at the national level. For instance, Hall and Soskice (2001) categorized Japan as a coordinated market economy (CME) that puts greater emphasis on coordination and close relationships among economic players. In contrast, they classified the U.S. as a liberal market economy (LME) that emphasizes liberal market competition among players. Their framework predicts that CME-type countries would be strong in industries where incremental innovation is critical, whereas LME-type countries have an institutional advantage in industries where radical innovation is crucial, such as information technology (IT) or biotechnology (BT), areas in which Japanese firms are traditionally less competitive (Motohashi, 2005).

Following this idea, Japanese policymakers have discussed whether JP's recent weakened innovation competitiveness in high-tech sectors relates to institutional arrangements that emphasize long-term business relationships among innovating players. This discussion does not seek to undermine the importance of the long-term business relationship among actors in innovation nor the importance of incremental innovation but to understand how such institutions interact with the innovation dynamics in the NIS and seek a more solid ground upon which to develop a better national-level strategy regarding this issue. How does this institutionalized business relationship practice shape the strengths and weaknesses of the NIS, under what dynamics, and what strategies do Japanese policymakers and firms need to take to improve the country's innovation competitiveness?

This study addresses these questions using an agent-based model (ABM). ABMs are a suitable way to virtualize and navigate the dynamics (Macal and North, 2011) that emerge from complex interactions of various individual factors in a social system. The NIS can be described by the existence of complex and dynamic interactions among innovating actors that will result in an evolutionary change of the NIS (Nelson and Nelson, 2002; Etzkowitz and Leydesdorff, 2000). Hence, we believe that the ABM is a proper research tool for this study.

This paper is structured as follows. Section 2 reviews studies on institutional differences between the JP NIS and U.S. NIS. We also review studies that use an ABM to examine innovation dynamics. Section 3 describes our model according to a standard ABM documentation protocol suggested by Grimm et al. (2006). Section 4 establishes the simulation plan and illustrates results. Section 5 provides a detailed analysis of the results. We discuss the results in Section 6 and draw conclusions in Section 7. Section 8 discusses the limitations of this study.

2. Literature review

2.1. Varieties of capitalism and country-specific industrial sector specialization

Some theoretical studies have examined the role of economic institutions in shaping innovation patterns and dynamics at the national level. Hall and Soskice's (2001) varieties of capitalism (VoC) theory is an example. The VoC theory divides the world's affluent economies into two types: LMEs and CMEs. The U.S. and U.K. are categorized as LMEs; Germany and Japan are grouped into CMEs. The theory predicts that LMEs are strong in industries that require radical innovation, such as BT or microprocessor technology. In contrast, CMEs enjoy advantages in medium-high-tech industries.

Empirical studies have tested the VoC propositions. Akkermans et al. (2009) used patent analysis to examine whether LMEs specialize in industries where radical innovation is important and whether CMEs are strong in incremental innovation. The results show more complex dynamics than that predicted by the VoC. LMEs specialize in radical innovation in the chemicals and electronics sectors, whereas CMEs are strong in radical innovation in the machinery and transport equipment industries. Schneider and Paunescu (2012) argued that economic systems cannot be simply divided into LMEs and CMEs. Indeed, they found that the institutional configuration of national economic systems can be dynamically transformed and that there are other groups that do not fit into either CMEs or LMEs.

Other scholars have attempted to understand how countries followed different routes to become competitive in particular industrial sectors (industrial sector specialization) and how such behavior can be explained by the institutional characteristics of the national economic system. Kitschelt (1991) argued that players in JP are willing to maintain a cooperative relationship with other players. This practice helps to improve production system flexibility and is beneficial in both the incremental process and product innovation, although it places too little importance on high-risk technology that may bring radical innovation. Lehrer et al. (1999) argued that country-specific industrial sector specialization is associated with national corporate governance structure. The national-level financial system can be divided into the "insider-dominated system (I-system)" and the "outsider-dominated system (O-system)." The U.S. and U.K. fall into the O-system, whereas most East Asian and European countries have the I-system. They claim that the I-system is a conventional system where technological progress involves a great deal of cumulative learning and cooperation among employees as part of the innovation process. In contrast, the O-system is advantageous in an industry that requires rapidly changing and high-novelty technology since it encourages investment in the whole industrial system rather than focusing on a particular industry. Haake (2002) espoused a similar idea. He classified national business systems into two types: (1) an individualistic system with loose interfaces and (2) a communitarian system with tighter interfaces among actors. Communitarian business systems may be advantageous in industries where players are likely to rely on an accumulated knowledge pool of organization-specific knowledge. Such a system requires a closer and long-term relationship among actors, an approach that enables companies to retain and accumulate specific knowledge. In contrast, individualistic business systems are of benefit in industries where diffusion or reallocation of organization-unspecific knowledge occurs because fluid and short-term relations between players are predominant. He claimed that the individualistic business system is advantageous in industries where organization-specificity of knowledge is low, whereas the communitarian system confers institutional benefits in industries that require a high degree of organization-specificity of knowledge.

2.2. Studies on dynamics in innovation using ABM and simulation

Although it seems evident that economic institutions play a significant role in configuring innovation dynamics, understanding the nature of the underlying mechanisms and how they shape the strengths and weaknesses of the NIS, as well as deriving policy implications for improving the NIS, are not trivial. This is because national innovation dynamics are not solely determined by particular features of the economic institution, but they reflect a variety of interactions among institutions, individual actors, and other socio-economic factors (Edquist, 1997; Edquist, 2005). These various interactions increase the complexity of dynamics in the NIS, which makes conducting a systematic study difficult. ABMs lend themselves to the study of complex NIS dynamics because they allow researchers to mimic complex social system and human interactions systematically (Gilbert and Troitzsch, 2005; Gilbert, 2008; Wooldridge, 2009). Indeed, ABMs are increasingly