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The strength of long ties and the weakness of strong ties: Knowledge diffusion through supply chain networks☆

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ABSTRACT

Using a large firm-level panel dataset for Japan, this paper examines the effects of the structure of supply chain networks on productivity and innovation capability through knowledge diffusion. We find that ties with distant suppliers improve productivity (as measured by sales per worker) more than ties with neighboring suppliers, which is likely because distant firms' intermediates embody more diversified knowledge than those from neighboring firms. Ties with neighboring clients improve productivity more than ties with distant clients, which is likely because neighboring clients more effectively diffuse disembodied knowledge than distant clients. By contrast, ties with distant suppliers and clients improve innovative capability (as measured by the number of registered patents), whereas ties with neighboring suppliers or clients do not affect innovative capability. In addition, the density of a firm's ego network (as measured by how densely its supply chain partners transact with one another) has a negative effect on productivity and innovative capability, implying knowledge redundancy in dense networks. These results suggest that access to diversified ties is important for improving productivity and innovation capability through knowledge diffusion.

1. Introduction

Growth in the productivity and innovation capability of firms is substantially affected by the diffusion of knowledge, technology, and information from other firms (Bloom et al., 2013; Romer, 1990). An evident channel of such knowledge diffusion is research collaboration (Ahuja, 2000). Another less evident channel is buyer-supplier relations between firms because buyers often provide new knowledge to their suppliers when seeking to procure high-quality products (Dyer and Nobeoka, 2000). In addition, buyers can benefit from their suppliers because the productivity of assemblers is higher when they employ a larger variety of intermediates from different suppliers and utilize the knowledge embodied in their products (Dixit and Stiglitz, 1977). Supply chain ties are often associated with research collaboration for the development of new intermediates (Uesugi, 2015), which promotes knowledge diffusion between suppliers and buyers.

Knowledge diffusion through buyer-supplier relations has been tested extensively in the empirical literature, in which an improvement in the measures of productivity and innovation capability associated with such relations is typically considered to reflect knowledge diffusion. For example, when firms improve their productivity through exporting, it is assumed that exporting has led to new knowledge gains. Knowledge diffusion through international trade has been found by Amiti and Konings (2007), Crespi et al. (2008a), Lööf and Andersson (2010), and Piermartini and Rubínová (2014), among many others. Javorcik (2004) provides evidence of

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knowledge spillovers from foreign-owned firms to their upstream suppliers.

Other studies pay more explicit attention to supply chain networks as a channel of knowledge diffusion. For example, Crespi et al. (2008b) use firm-level data for the United Kingdom to show that both the number of registered patents and growth in total factor productivity (TFP) are higher when firms report that they gain knowledge from their suppliers. Isaksson et al. (2016) analyze patent data for US firms in the high-tech sectors and find evidence that buyers' innovation has a positive effect on their suppliers' innovation. In the supply chain management literature, Flynn et al. (2010) use firms' subjective measurements and determine that the strength of relations with customers has a positive effect on firm performance but that the strength of relations with suppliers has an insignificant effect. Bozarth et al. (2009) find that the number of suppliers or clients does not affect subjectively measured firm performance. Using a firm-level dataset for Japan similar to that used in this study, Bernard et al. (2014) and Belderbos et al. (2015) examine how firms' productivity is affected by their buyers and suppliers.

However, there are two remaining issues in the literature. First, the existing studies have not focused on how a firm's direct suppliers and clients are connected with other firms. Knowledge diffusion to a particular firm from its supply chain partners may be influenced by whether those partners are connected with one another and/or with whom they are connected. For example, the amount of knowledge that diffuses to a firm from its suppliers may vary depending on whether the suppliers are in the same closed firm group or are connected with different types of firms. However, the previous literature ignores such detailed characteristics of whole supply chain networks in the economy and instead identifies supply chain relations only through firms' engagement in trade (Kimura and Kiyota, 2006; Lööf and Andersson, 2010; Van Biesebroeck, 2005), firms' subjective perceptions (Crespi et al., 2008a; Flynn et al., 2010), input-output tables at the industry level (Javorcik, 2004; Piermartini and Rubínová, 2014), or – at best – firms' direct supply chain partners (Belderbos et al., 2015; Bernard et al., 2014; Isaksson et al., 2016).

The literature on social networks has emphasized the importance of considering the overall structure of networks (Granovetter, 2005). For example, Burt (1992) finds that actors who create bridging links between otherwise disconnected groups of actors – or across structural holes – have superior access to diverse information. This finding is related to the argument of Granovetter (1973) that weak ties to relatively less frequently met partners are instrumental for accessing new information because such links frequently extend beyond the immediate circle of densely interconnected strong ties among similar partners with similar shared information. In other words, network density may prevent active knowledge diffusion due to knowledge overlaps and redundancy among partners.

However, structural holes and weak ties may not always be the key to knowledge diffusion. Other studies have found that dense networks within an organization in which actors are closely connected with one another but are not closely connected with outsiders can promote knowledge diffusion. The positive effect of dense networks most likely emerges in these studies because actors in these networks know one another well and thus trust new knowledge from each other (Ahuja, 2000; Phelps, 2010).

This study adopts methods from social network analysis to examine how the structure of the entire supply chain network affects the knowledge diffusion manifested in innovations and productivity increases using a large firm-level panel dataset for the Japanese manufacturing sector that covers most firms within the country and major buyer-supplier relations. Following the literature, we test for knowledge diffusion by estimating whether the structure of supply chain networks positively affects productivity and innovation capability, as measured by sales per worker and the number of registered patents respectively.

More specifically, we investigate how the density of a firm's ego network – or how frequently its supply chain partners transact with one another – affects its performance, which is the first time this subject has been addressed in the literature on knowledge diffusion through supply chain networks. The effects of ego network density have been studied by Ahuja (2000) and Phelps (2010) in research collaboration networks but not in supply chain networks. Ego network density may have both positive and negative effects on knowledge diffusion, as we argued above. Therefore, the net effect of the network density should be empirically examined.

The second remaining issue in the literature is the role of geographic distance in knowledge diffusion. In their seminal papers, Jaffe and Trajtenberg (1999) and Jaffe et al. (1993) found that geographic distance has negative effects on the degree of knowledge and information diffusion. Knowledge diffusion from neighboring partners may be easier than knowledge diffusion from distant partners because of lower transportation costs (Marshall, 1890). It has been shown that supply chain ties and research collaboration ties are more likely to be created between neighboring firms (Crescenzi et al., 2016; Nakajima et al., 2012). However, geographic proximity may have a negative impact on innovation because neighboring partners are more likely to be similar to the firm and to one another and thus to be characterized by similar knowledge, as argued by Boschma (2005). In other words, more knowledge and intermediate products that are new to the firm are available from the firm's distant partners than from its neighbors. Therefore, the net effect of distance from network partners on firm performance is not particularly clear.

This study incorporates the two issues and examines whether and how knowledge diffuses through supply chain networks using a large firm-level dataset that contains detailed information on the major transaction partners of 800,000 firms in Japan. Our empirical estimation employs a dynamic panel model, assuming that supply chain ties and firm performance interact with one another over time. In this framework, we can incorporate causality between firm performance and characteristics of supply chain networks in both directions and hence can alleviate possible biases in estimations of the effect of networks on performance that are due to reverse causality.

Our findings suggest that the geographic proximity of supply chain partners and the density of supply chain networks tend to reduce the benefits of knowledge diffusion, which is most likely due to knowledge redundancy in such networks. Therefore, this study emphasizes the importance of diverse network partners in knowledge diffusion.

2. Conceptual framework

2.1. Channels of knowledge diffusion through supply chain networks

Supply chain ties can improve firm performance through the diffusion of knowledge in the following three ways. First, clients frequently provide new knowledge and technology for production and market information to their suppliers to improve the quality and reduce the price of the goods they purchase. For example, Dyer and Nobeoka (2000) show that Toyota frequently organizes associations of its suppliers in which it provides valuable technical and managerial assistance to suppliers. Egan and Mody (1992) show that a US shoe importer sent Italian skilled artisans to Taiwanese shoe manufacturers to provide them technical assistance. Through such technical assistance, buyers' knowledge diffuses to