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R & D networks among suppliers and manufacturers

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ABSTRACT

Empirical evidence documents that R & D networks among vertically related firms are very common. Yet there is currently no formal modeling of such networks. In this paper, we develop a model of R & D networks among manufacturers and their suppliers in order to examine which network architectures emerge in equilibrium, and what their implications are from a welfare viewpoint. Our analysis reveals that private incentives to form R & D networks align with societal ones when vertical relations are non-exclusive, but may conflict when vertical relations are exclusive. In terms of policy, stricter antitrust regulation of exclusive vertical relations may, under certain conditions, be desirable from a social viewpoint.

1. Introduction

A growing body of empirical studies suggests that R & D networks are a prevalent phenomenon in high-tech sectors such as information technology and pharmaceuticals (Roijakkers and Hagedoorn, 2006; Hagedoorn, 2002). It has been argued, for instance, that R & D networks are easier to establish, administer and dissolve than equity forms of R & D collaborations (e.g. Research Joint Ventures), all of which are important factors that may partly explain the increasing popularity of R & D networks within the modern business world (Narula and Hagedoorn, 1999). Nonetheless, little is known about vertical R & D networks among manufacturers and their suppliers, although such networks are common empirically. The current paper aims to develop a model of vertical R & D networks in order to examine systematically which network architectures emerge in equilibrium, and what their implications are from a welfare viewpoint.

There are different types of R & D collaborations that may arise through the formation of inter-firm networks. More specifically, R & D links can be formed among firms who are located at the same market tier – that is, *horizontal* R & D networks. But R & D links can also be formed among vertically related firms, for example, among manufacturers and their suppliers; the set of such links is often referred to as *vertical* R & D networks. In other instances, firms may choose to maintain both horizontal and vertical links – that is, they may opt to engage in both *horizontal and vertical* R & D networks.

Table 1 provides information about empirical studies on R & D collaborations, focusing on the number and percentage of firms who engaged in different types of R & D collaborations. For example, using data from a survey of German firms, Inkmann (1997) shows that out of 374 manufacturing firms engaged in R & D collaborations, 289 firms (or 77.28 percent) had only vertical R & D links, 33 firms (or 8.82 percent) had only horizontal links, and 52 firms (or 13.9 percent) had both types of links.

In an empirical study using data from 14 industries in Germany during the period 1991–1993, Harabi (1998) shows that a staggering 84% of innovating firms participated in *vertical* R & D collaborations with their customers and/or suppliers. Moreover, the sharing of R & D knowledge among vertically related firms is in most cases done through non-equity forms of R & D collaboration; while equity forms have been found to account for less than 20% of the total number of R & D collaborations (Caloghirou et al., 2003).

Overall, the main findings from existing empirical studies on R & D collaboration are as follows. First, vertical R & D links (or collaborations) between firms appear to be much more common than horizontal R & D links. Second, the number of firms that maintain both vertical and horizontal R & D links is relatively smaller compared with the number of firms having vertical R & D links only. And third, vertically related firms typically prefer to share their R & D outcomes through non-equity types of R & D collaborations (such as R & D networks) rather than equity forms (such as RJVs).

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Table 1
Firms engaged in R & D collaborations.

Empirical studies	Type	N_0	Vertical		Horizontal		Both	
			N_0	%	N_0	%	N_0	%
Inkmann (1999)	German[a]	374	289	*77.28*	33	*8.82*	52	*13.9*
Kaiser and Licht (1998)	German[b]	680	484	*71.18*	66	*9.71*	130	*19.11*
Belderbos et al. (2004)	Dutch[c]	568	338	*59.51*	74	*13.03*	156	*27.46*
Badillo and Moreno (2012)	Spanish[d]	1732	1119	*64.61*	212	*12.24*	401	*23.15*

[a] The first wave of the Mannheim Innovation Panel (MIP) was collected in 1993 by the Centre for European Economic Research in Mannheim on behalf of the Federal Ministry of Education, Science, Research and Technology.
[b] The first five waves of the MIP were collected by ZEW and Infas-Sozialforschung on behalf of the Federal Ministry of Education, Science, Research and Technology.
[c] The CIS surveys in the Netherlands in 1996 and 1998.
[d] The Technological Innovation Panel (PITEC), a comprehensive database of Spanish firms collected over the period 2003–2009.

Somewhat surprisingly, there is currently no formal modeling of vertical R & D networks, as previous studies have focused exclusively on horizontal R & D networks. To advance our understanding, new research is needed. In light of the aforementioned empirical evidence, new research should consider the network formation decisions in a vertically related industry. It would also be interesting to examine R & D networks among manufacturers and their suppliers, which are empirically common as explained earlier.

The current paper aims to accomplish these objectives by being the first of its kind to develop a model of vertical R & D networks among manufacturers and their suppliers. As past empirical studies suggest that the number of firms that have both types of R & D links – horizontal and vertical – or only horizontal links is much smaller than the number of firms that have *only* vertical R & D links, we focus our attention on vertical R & D collaborations.

We envisage an industry with two upstream and two downstream firms. These vertically related firms maintain either exclusive or non-exclusive relations with one another. Within this setting, we examine the endogenous formation of vertical R & D networks, that is, networks among manufacturers and their suppliers. Through the formation of such networks, manufacturers and suppliers can share know-how emanating from cost-reducing R & D investments. Our analysis reveals that, when vertical relations are non-exclusive, the complete network (in which all firms are connected) is uniquely stable and maximizes social welfare. By contrast, when vertical relations are exclusive, different network architectures emerge in equilibrium as the spillover differential between manufacturers and their suppliers varies. Yet only one network architecture maximizes welfare. Thus private incentives to form R & D networks align with societal ones in some cases but conflict in others, potentially providing new insights into the formation of R & D networks in vertically related industries.

2. Background literature and contribution

The current paper contributes to the literature on R & D cooperation among vertically related firms in oligopoly (see e.g. Banerjee and Lin, 2001; Atallah, 2002; Ishii, 2004). The approach adopted in this paper, nonetheless, differs from earlier studies on R & D cartels and Research Joint Ventures (RJVs) in two important ways.[1] First, in an RJV or an R & D cartel firms join R & D efforts to maximize their joint profits. By contrast, in the context of R & D networks, firms choose their R & D efforts non-cooperatively (to maximize their individual profits), and subsequently communicate their R & D outcomes through spillovers. Furthermore, unlike an RJV, in an R & D network a firm can form a new R & D collaboration without the need of consent from its existing partners. Most importantly, in real world industries, R & D networks are much more common than RJVs and have been found to account for more than 80% of the total number of R & D collaborations (Caloghirou et al., 2003).

Besides the general literature on R & D cooperation, the current paper also contributes to the growing literature on R & D networks. Previous studies have mainly focused on R & D networks in one-tier industries, aiming to provide a thorough understanding of which network architectures emerge in equilibrium, and what their implications are from a welfare viewpoint (e.g. Goyal and Moraga-González, 2001; Deroian and Gannon, 2006; Zikos, 2010; Zu et al., 2011; Zirulia, 2012; Marinucci, 2014; Vonortas and Zirulia, 2015).

Goyal and Moraga-González (2001) were the first to study the endogenous formation of R & D networks among firms investing in cost-reducing R & D. Within a three-firm industry, they showed that the complete network always emerges in equilibrium, while the partial network that includes two firms but excludes the third emerges if spillovers are sufficiently low. Moreover, the number of welfare-maximizing links tends to decrease with the level of spillovers: the partial network, followed by the empty network, maximizes welfare. It appears then that private and social incentives to form R & D networks align if spillovers are sufficiently low and conflict otherwise.[2]

While these findings have contributed considerably to our understanding of R & D networks in one-tier industries, relatively little is known about R & D networks in two-tier industries. In this paper we extend the analysis *vertically* in order to consider the role of upstream suppliers to the downstream firms. Firms do not generally produce their own inputs but they source them from other firms. Modeling the role of input suppliers thus seems important in that respect. Moreover, like Goyal and Moraga-González (2001), we study firms' incentives to form R & D networks but shift the focus from horizontal to vertical R & D collaborations. Goyal and Moraga-González (2001) examine the formation of R & D networks among firms located at the same market tier, but they did not consider vertical links as we do in this paper. Although both types of links – horizontal and vertical – are common in real-world industries, and in some cases firms may want to establish both types of links, the formation of vertical links itself appears to be a much more prevalent phenomenon. Inkmann (1997), Kaiser and Licht (1998), Belderbos et al. (2004) and Badillo and Moreno (2012) all conclude that vertical R & D links accounted for more than 50% of the total number of links among German, Dutch and Spanish firms. What this implies is that extending the standard one-tier setting by considering the role of input suppliers and their incentives to establish R & D collaborations with final good manufacturers is important both from a theoretical and practical point of view.

Only a handful of studies in economics have examined R & D networks within the context of a vertically related industry. Kesavayuth and Zikos (2012) investigated how horizontal R & D networks emerge at the upstream and downstream market tier, but they did not consider R & D links between the two market tiers. Likewise, Kesavayuth et al. (2016) studied the formation of R & D networks among upstream firms only. Given that previous studies have focused exclusively on horizontal R & D networks, relatively little is known

[1] For earlier studies on Research Joint Ventures (RJVs) and R & D cartels between firms located at the same market tier, see, for example, d'Aspremont and Jacquemin (1988), Kamien et al. (1992), Poyago-Theotoky (1995, 1999), Atallah (2005), Falvey et al. (2013), Manasakis et al. (2014), Ouchida and Goto (2016). Caloghirou et al. (2003) and Marinucci (2012) provide extensive reviews of the literature on R & D cooperation.

[2] Goyal and Moraga-González (2001) also showed that when firms compete in a homogeneous-product oligopoly, the complete network in which all firms are connected emerges in equilibrium, although it is not efficient. When firms operate in independent markets, however, the complete network is uniquely stable and efficient. These results hold under the assumption of symmetric networks in which every firm has the same number of links.