On the Industry-University-Government Collaboration and Markets for Technology

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Executive summary

1. Purpose of this dissertation

Open innovation activities have been strategically a core part of business decision making in many industries in recent years (Hagedoorn et al. 2000; Hagedoorn, 2002). The boundaries between a firm and its surroundings have become more permeable: Innovations can easily transfer inward and outward. In a world of widely distributed knowledge, it is not desirable (or may be impossible) to develop all relevant technologies solely by a single firm, but better to buy or license processes or inventions from others in some instances. In addition, internal inventions not being utilized in a firm's business should be taken outside the firm. In the circumstances, the coordination of internal and external knowledge across a firm's boundaries is regarded as a core of R&D management (Stephan, 1996; Arora et al., 2001a; Chesbrough, 2003).

In general, government plays an essential role in open innovation activities in a number of ways (Nakamura, 2003). For example, government research agencies do their own joint research with firms and universities, and they also provide funding to research projects. How these government funds are allocated and who gets involved in these research projects may have influence on a nation's economic performance. More importantly, government arranges the legal settings and launches the policies in which firms operate: for example, government usually determines the conditions under which firms are engaged in joint R&D projects, the policies for the financing of R&D investment and networking formation among actors.

The purpose of this dissertation is to empirically examine open innovation activities such as alliances and informal networking formation with external partners through *industrial*

clusters, although we also consider the coordination of internal and external knowledge resources across a firm's boundaries through *markets for technology*. Industrial clusters have recently been recognized as important locations to promote open innovation (Porter, 1998, 2000). Thus, policymakers in various countries launched their cluster policies in the 1990s. Markets for technology through licensing are emerging as a key to organize innovative activity (Arora et al. 2001a). They are closely related with R&D management at various stages of exploration, retention, and exploitation of knowledge (Lichtenthaler and Ernst, 2006).

The three main questions we address in the dissertation are summarized as follows; 1) How does government enhance the effect of industry-university-government collaboration (hereafter IUGC) on firms' R&D productivity through a cluster policy, 2) What kind of support programs promotes IUGC and contributes to firm performance, 3) How do firms coordinate their internal and external resources through markets for technology. Discussing these topics, we derive the implications of IUGC for firm performance, the role of government as a innovation intermediary, and the organization of internal and external resources across a firm's boundaries.

2. Summary of the Chapters

Chapter 2 evaluates the Industrial Cluster Project (hereafter ICP) in terms of R&D performance and IUGC, using original survey data of 229 small and medium enterprises. We use the number of patent applications, claims, and forward citations as the measures of R&D performance of a firm participating in IUGC. Then, we examine the effect of the participation in the ICP on the patent productivity of IUGC firms, and discuss how government enhance the effect of IUGC on firms' R&D performance through a cluster policy.

Different from former policy approaches, the ICP comprises two types of support programs such as direct R&D support with heavy (hard) government intervention and indirect

networking/coordination support with light (soft) government intervention. Especially it focuses on building collaborative networks among IUG and supports the autonomous development of existing regional industries without direct intervention in the clustering process.

Industrial clusters can possibly help overcome the two kinds of market failure on R&D such as knowledge spillovers (Spence, 1984; Teece, 1986; Griliches, 1992) and technological and commercial uncertainty (Malmberg et al. 1996). Cluster policies promote the networking for IUGC and hence contribute to overcoming market failure. That is, collaborative R&D with rival firms internalizes knowledge spillovers when spillover is high (Suzumura, 1992). Further, it reduces the uncertainty through improved coordination and the pooling of risk and resources. Moreover, government-sponsored R&D consortium by the ICP is not only an important R&D support for IUGC, but also a crucial channel to promote trust among the members (Das and Teng, 1998; Zucker et al., 2001; Darby et al., 2008), which would improve R&D efficiency through better coordination and information sharing.

Unfortunately, as far as we know, few empirical studies analyze the effect of cluster policies on the R&D performance of local firms. Moreover, the conditions necessary for the effective organization of cluster policies in terms of the R&D performance of local firms still remain an open question (Yang et al. 2009). Therefore, this dissertation empirically investigates how firms improve their R&D productivity through IUGC in industrial clusters.

Our estimation results in Chapter 2 suggest that the participation in the cluster project alone has no significant effect on the R&D productivity of firms, even after taking endogeneity into consideration. Importantly, the results show that the collaboration with partners in a distant area increased patent productivity. This implies that the firms should look for optimal partners according to specific research topics even when they are located in distant areas. However, the cluster participants that collaborate with national universities in the same cluster region

significantly improve the R&D productivity, without reducing the quality of applied patents.

Chapter 2 analyzes the overall relationship between the participation in the ICP and R&D productivity in terms of IUGC. However, it does not suggest which kind of support programs contribute more to firm performance. Therefore, we try to fill the gap by empirically evaluating and comparing the effects of direct and indirect support programs of the ICP, and discuss the role of government as a innovation intermediary.

In Chapter 3, we examine two research questions concerning the cluster policies: if the project participants who exploit various support programs are more successful in the formation of IUGC within the cluster than others, and which kind of support program contributes to improving firm performance. We use 511 original survey data and control for firm characteristics, considering the endogeneity problem. Then, we address the conditions necessary for the effective organization of cluster policies to improve firm performance.

Direct R&D support is an important channel to overcome market failures on R&D (David et al., 2000). However, such support fails to solve market failures if it generates the crowding-out effect (e.g. *pick-the-winner strategy*). In addition, several scholars have recently disagreed with the targeting and subsidization of particular regions, industries, and technological fields through R&D supports (Wolf, 1993; Cowling et al., 1999; Hospers et al., 2009). They insist that there is no reason to believe that policymakers have better information than managers of local firms about the economic potential of the targets.

Several studies discuss the effectiveness of indirect networking/coordination supports. Incremental and trial-and-error problem-solving enhances the need for continuous interaction, both formal and informal, with other external organizations due to fundamental uncertainty in the innovation process (Malmberg et al., 1996). Face-to-face contact accelerates the accumulation and exchange of knowledge and thus smoothes continuous interaction. Therefore,

indirect supports are essential for cluster policies, and face-to-face communication increases localized knowledge spillovers (Fujita, 2007).

As a recent trend, cluster policies often consist of direct and indirect support programs not only in the ICP but also in other countries' cluster policies. Particularly, the successful cluster policies in Europe often have the characteristics of concentrating efforts on indirect supports (Hospers et al., 2009). However, few empirical studies explicitly discuss the relative efficiency of contrasting policy approaches. Thus, we will examine which policy approach contributes more to firm performance.

Our estimation results in Chapter 3 clearly suggest the importance of indirect supports on the formation of IUGC and firm performance. Indirect support programs have an extensive and strong impact on discrete outcomes, whereas direct R&D support has a rather weak effect in terms of marginal effect. That is, we find that participation in meetings and events and using coordination and advisory services enhance firm performance such as IUGC formation, financial and sales transactions, and innovation activity, while R&D subsidy leads to increase of sales transactions and innovation activity.

Finally, to analyze the coordination of R&D portfolio of a firm through markets for technology, Chapter 4 examines how R&D portfolios of pharmaceutical firms affect licensing decisions, controlling for firm size, therapeutic diversity, and the degree of competition. Pharmaceutical industry is the leading industry in which markets for technology have rapidly grown and actively utilized (Arora and Gambardella, 2010). The R&D portfolio of a pharmaceutical firm is mainly reflected in *drug pipelines* which consist of drug candidates under clinical testing as well as approved drugs being marketed. Drug pipelines can be observed quite accurately owing to rigorous regulatory process of clinical testing. Accordingly, pharmaceutical industry is a most suitable candidate in examining the coordination of R&D

portfolios through licensing.

In this study, we define the portfolio effect as that the change of drug pipelines would dictate a licensing decision as a result of portfolio adjustment process. For example, if the number of drug candidates at a stage is diminishing compared to other stages, inward licensing at that stage would be accelerated to level off the drug pipelines across stages. We use data on licensing closed by 54 Japanese pharmaceutical companies. We classify licensing contracts into the early stage and the late stage and pay special attention to the stage-specific licensing.

Most previous studies focus on complementary asset as a licensing decisions (Teece, 1986; Arora et al. 2001a, 2001b; Shane, 2001; Kollmer and Dowling, 2004; Arora and Ceccagnoli, 2006). A firm with complementary assets would absorb knowledge more effectively, thereby exploit her own inventions internally rather than acquire royalties by licensing them out. In addition, two conflicting effects (revenue and rent dissipation effect) are regarded as significant determinants of license-outs (Arora and Fosfuri, 2003; Fosfuri, 2006).

However, in a recent theoretical study, Chan et al. (2007) provide a model of project selection that explicitly incorporates R&D pipelines, transaction costs, and downstream complementary assets. They indicate that the state of R&D pipelines and downstream complementary assets affect the optimal R&D portfolio as well as the incentive to use the technology market at different R&D stages. Unfortunately, few empirical studies explore the impact of R&D portfolio on inward or outward licensing, except for the technology transaction through mergers and acquisitions (M&A) (Higgins and Rodriguez, 2006; Danzon et al., 2007). Therefore, we examine the relationship between R&D portfolios and stage-specific licensing.

Estimation results in Chapter 4 reveal that the change of drug pipelines significantly affects stage-specific licensing. In particular, the Japanese pharmaceutical companies level off drug pipelines by either license-outs at the early stage or license-ins at the late stage. Our results

also indicate that license-outs at the late stage may be influenced by rent dissipation effect and license-ins at the late stage would be affected by complementary assets.

3. Implications

There are several implications that can be obtained from this dissertation. In Chapter 2, first of all, our empirical results indeed imply the effectiveness of direct and indirect support systems that lead to better matching among cluster participants and enhancement of efficiency in IUGC. Both programs are expected to help overcome market failures on R&D and knowledge-specific failures. Second, SMEs have limited business resources and difficulties in finding appropriate research partners; thus, the ICP is expected to support local SMEs in selecting optimal partners within the cluster. However, our results generally suggest that local firms collaborating with partners outside the cluster show higher R&D productivity both in terms of quantity and quality. In order to improve the R&D efficiency of local firms, it is generally important to construct a wide-range collaborative network within and beyond the clusters for optimal partners, although most clusters focus on the network at the narrowly defined local level. Finally, policymakers should concentrate on networking or R&D supports to build and develop collaborative network between cluster participants and core national universities if the former are willing to cooperate with research partners in the same clusters.

In Chapter 3, the effectiveness of indirect support programs on network formation and firm performance is an important result from the viewpoint of cost-benefit performance, because direct R&D support costs much more than indirect support programs. Thus, this means the effectiveness of such “soft” policy intervention and the role of government as an innovation intermediary to promote open innovation activities. Moreover, we find that not every support program contributes to this aim; firms should therefore select the program that is most aligned

with their aims. It is noteworthy that according to our survey, only 63% of the cluster participants have utilized any support programs, because participation in the ICP means no more than registration. Therefore, it may be necessary to encourage the exploitation of various support programs. In recent years, the focus of public support for local firms has clearly shifted toward networking and coordination for those who help themselves. Thus, cluster participants should be actively engaged in the ICP support programs to improve their performance. This is also important for the development of industrial clusters because active communication among cluster participants leads to higher productivity of innovation activity in the region.

Chapter 4 also provides important implications on R&D management through markets for technology. We find that the change of drug pipelines significantly affects stage-specific licensing. That is, the number of drug candidates at the early stage is positively associated with license-outs (or license-ins) at the early stage (or at the late stage, respectively). On the other hand, the number of drug candidates at the late stage is negatively correlated with license-outs (or license-ins) at the early stage (or at the late stage, respectively). The combined result of the opposite impacts of drug pipelines on licensing indicates that licensing plays a significant role in the coordination of the state of drug pipelines across stages. It is crucial for a pharmaceutical firm to keep a well-balanced portfolio, since releasing a new drug continuously would secure stable cash flow and facilitate efficient use of complementary assets. Most empirical studies do not examine stage-specific licensing. However, our results imply that the degree of rent dissipation effect (R&D competition) also would have an effect on timing of license-outs. Inefficient late signing in license-outs may induce significantly higher costs of R&D and affect innovation rates and growth in pharmaceutical industry. Thus, understanding the factors that influence this timing is essential both for industry participants and government authorities.