Asia-Pacific Journal of Business (아태비즈니스연구)
Vol. 13, No. 3, September 2022 (pp.135-155)
https://doi.org/10.32599/apjb.13.3.202209.135

APJB
ISSN 2233-5900 (Print)
ISSN 2384-3934 (Online)

Government Support Mechanisms and Open Innovation:
An Empirical Look at Korean Manufacturing Firms

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Received 30 August 2022, Revised 25 September 2022, Accepted 28 September 2022

Abstract

Purpose - The purpose of this study is to examine how a broad palette of government support measures and firms' membership in government-developed clusters are related to firms' openness in innovation processes.
Design/methodology/approach - Empirically, this study analyzes the Korea Innovation Survey 2018 data on the innovation activities of 1,450 Korean R&D-active manufacturing firms in a three-year period from 2015 through 2017.
Findings - The results suggest that firms engage in open innovation to a greater extent--as measured by the breadth of external collaborating partners and of the utilized external sources of knowledge--when they are provided with a broader palette of government support measures and are located in government-developed clusters. However, the effect of diverse government support measures is attenuated for firms located in these clusters.
Research implications or Originality - This study contributes to the innovation literature by illuminating how firms' open innovation can be understood in a national innovation system. Moreover, it provides valuable implications for firms seeking to obtain government support and collaborate with others.

Keywords: Government support, Clusters, Open innovation, National Innovation System, Collaboration
JEL Classifications: O36, O38

Ⅰ. Introduction

In his seminal work, Chesbrough (2006) defines open innovation (OI) as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (p. 1). OI is an increasingly prominent phenomenon that involves collaboration with others in developing and/or commercializing inventions, and thus sizable subsequent research has examined the antecedents and consequences of OI (Bogers, Chesbrough, Heaton, & Teece, 2019; Huizingh, 2011). The need for OI arises from benefits of diverse perspectives in solving innovation problems (Dahlin, Weingart, & Hinds, 2005; Hoffman & Maier, 1961; Hulsheger, Anderson, & Salgado, 2009), which increase information use by collaborators and in turn engender better solutions. Such collaboration takes place, premised on not only external collaborating partners' expertise but also manageable transaction costs for collaboration (Christensen, Olesen, & Kjaer, 2005; Zobel

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& Hagedoorn, 2020), as these costs are factored into any outsourcing decisions (Williamson, 1975, 1985). The significance of OI catalyzing internal innovation has been highlighted in conjunction with that of collaboration in general, which is related to higher innovation and firm performance (Du, Leten, & Vanhaverbeke, 2014; Huizingh, 2011; Jones, 2009; Singh & Fleming, 2010; Wuchty, Jones, & Uzzi, 2007).

Given that OI enhances firms' innovation performance, prior research has long suggested that government, defined as the "aggregation of public-sector agents" (Link & Scott, 2010: p.589), incorporates various measures to facilitate firms' collaboration with external partners in its implementation of science and technology policy (Cho, Kim, & Rhee, 1998; Kim, Bae, & Yang, 2014; Leckel, Veilleux, & Dana, 2020). Broadly, for the purpose of stimulating innovation at national and regional levels, government develops institutions delineating innovation regimes (such as intellectual property rights) (Hall, 2020; Hall & Helmers, 2019; Teece, 1986), develops social and physical infrastructure for interorganizational collaboration (H?yss?, Bruun, & Hukkinen, 2004; Nakamura, Nelson, & Vertinsky, 2003), and provides a wide array of support for firms, from funding and financing (Brander, Du, & Hellmann, 2015; Hall, 2002; Lerner, 1996) to technological assistance (Comin et al., 2019). These various government support measures are aimed at dealing with market frictions hindering interorganizational collaboration, such as ones arising from transaction costs in locating and selecting potential collaborating partners and monitoring them (Amit, Brander, & Zott, 1998; Brander et al. 2015; Comin et al., 2019). Related, the framework of national and regional innovation systems-NIS and RIS, respectively-underscores the importance of the interplay between government and firms, universities, and research institutes in bolstering innovation at national and regional levels and that of government support measures aimed at facilitating interorganizational collaboration (Asheim & Isaksen 1997; Cooke, 1992; Cooke, Uranga, & Etxebarria 1997; Freeman, 1988; Howells, 1999; Lundvall, 1988; Nelson, 1993).

Despite the common emphasis on interorganizational collaboration, the two strands of literature-in OI and NIS-have developed quite separately and taken distinct approaches to the understanding of interorganizational collaboration. OI researchers have focused on the phenomenon of interorganizational collaboration itself, mostly illuminating the antecedents and consequences of it at the firm level (Bogers, Chesbrough, Heaton, & Teece, 2019; Huizingh, 2011). By contrast, NIS researchers have viewed interorganizational collaboration as a means to catalyze national and regional innovation and underscored the importance of policy measures to boost economic growth (Asheim & Isaksen 1997; Cooke, 1992; Cooke, Uranga, & Etxebarria 1997; Freeman, 1988; Howells, 1999; Lundvall, 1988; Nelson, 1993). It is noteworthy that an apparent gap exists in prior work in empirically understanding what leads to a higher level of firms' OI in a NIS framework.

In Korea, national industrial complexes (NICs), government-formed clusters of co-located firms, have played an important role in stimulating innovation in the manufacturing sector (Lee & Ahn, 2011). Meanwhile, the Korean government also provided firms with a range of support measures to aid innovation. Thus, examining how a variety of government support measures aimed at spurring innovation interact with firms' residence in NICs can provide valuable implications for Korean manufacturing firms as well as research on innovation clusters. Specifically, addressing this research question can help diminish a waste of resources in facilitating vigorous interorganizational collaboration. This study focuses on Korean manufacturing firms' openness in innovation processes and shed much needed light on how government support mechanisms are linked to firms' OI.

Thus, this study examines the important question of how the breadth of government support measures is related to firms' openness in innovation processes, as widely measured by prior work with diverse external collaborating partners and external sources of knowledge. This study considers a wide array of government support measures (tax, funding, financing, technology, certification, and purchasing), whose effect may also depend on firms' residence in government-developed innovation clusters. Examining the relationship between the breadth of government support and firm-level openness is critical since it can provide opportune policy implications for encouraging OI and spurring innovation at both national and regional levels.

Furthermore, the breadth of government support is an important, yet understudied construct in both domains of OI and NIS. Much of the prior work has focused on the effect of the single government support mechanism on innovation outputs, but nevertheless overlooked the potential interdependencies among various support mechanisms the government jointly uses to boost interorganizational collaboration and, in turn, the performance of NIS. Lee and Park (2006) analyze survey responses from Korean firms in the electronic parts and mechanical industries and suggest that government financial support increases the likelihood of the success of an innovation project undertaken by a firm. Wu, Zhuo, and Wu (2017) investigate panel data on Chinese provinces and municipalities and suggest that government R&D investments increase rural labor productivity. Min, Kim, and Sawng (2020) examine panel data on Korean regions and suggest that a higher proportion of public R&D increases regional technology development efficiency. Although these studies are valuable in illuminating the individual policy's consequences for national innovation, government hardly implements one policy; rather, it implements a wide range of policies simultaneously, which necessitates studies considering their interdependencies.

Empirically, this study uses the Korea Innovation Survey (KIS) 2018 data for the manufacturing sector, provided by the Science and Technology Policy Institute (STEPI) of South Korea and contain information on 1,450 Korean R&D-active manufacturing firms and their innovation activities in a three-year period from 2015 through 2017. These cross-sectional data are comparable to the EU Community Innovation Survey (CIS) by Eurostat in the composition of the questionnaire, aimed to understand the innovation activities of firms. This study constructs two dependent variables to understand firm-level openness, the breadth of external collaborating partners and of external search for knowledge, following Laursen and Salter (2006, 2014).

The contributions of this study are threefold. This study contributes to research in OI and NIS by highlighting the interplay between them. The findings of this study suggest that while a broader set of support measures are related to both more diversified external collaborating partners and more diversified external search, such relationships-particularly, concerning the breadth of external search-weaken for firms in government-developed clusters. These novel and interesting findings highlight the substitutive interdependencies between the government support mechanisms of various support measures and cluster development in enhancing firms' OI. These findings will further help policymakers to make informed decisions in expending limited resources and providing support for firms. Moreover, this study makes empirical contributions by investigating the implications for firms' OI by using an up-to-date dataset on South Korean manufacturing firms.

II. Related Literature

2.1. Government, Innovation, and Collaboration

Prior research has long recognized the role of government in fostering innovation. Government refers to the "aggregation of public-sector agents" (Link & Scott, 2010: p.589) and supports innovation activities in the private sector. Neoclassical economists suggest that the need for government in an innovation landscape arises from coordination failures among firms. In the absence of government, a firm may underinvest in R&D when it foresees that its R&D will not lead to other firms' R&D that will in turn increase demand for its products. This phenomenon is described as so-called a "poverty trap" equilibrium (Hoff, 2000; Murphy, Shleifer, & Vishny, 1989; Rodrik, 1996). Thus, investment in R&D must be coordinated across firms, in order for it to ever happen. However, coordination failures take place, due to the lack of intermediaries bridging investors and innovating firms, as well as the difficulty of acquiring skills and knowhow that are non-tradable (Mahmood & Rufin, 2005). Government often steps in to provide the needed services to solve coordination failures and ensure innovation in an economy.

Government seeks to prevent potential coordination failures in R&D investment in a number of ways. As an actor of the national innovation system (NIS) (Freeman, 1988; Lundvall, 1988; Nelson, 1993), government 1) drafts the "rules of the game" that govern innovation activities (North, 1990); 2) supports the innovation activities of the other actors in the NIS, namely, firms, universities, and research institutes (Nelson, 1993); and further, 3) engages in innovation itself through state-owned enterprises (Bruton et al., 2015; Li, Xia, & Zajac, 2018). These support roles are detailed as follows.

First, government delineates taxes and subsidies to influence market prices, in order to ensure that firms invest in R&D, and provides intellectual property right (IPR) systems, such as patents and trademarks, in order to protect innovators' proprietary technologies. Second, government bolsters innovators by offering social and physical infrastructure (H?yss?, Bruun, & Hukkinen, 2004; Nakamura, Nelson, & Vertinsky, 2003) as an innovation platform, and a wide range of support, from funding to human capital, often bundled under overarching national science and technology policy. Third, government establishes state-owned enterprises, in order to develop firm competencies (Musacchio, Lazzarini, & Aguilera, 2015), especially in emerging economies where weak institutions limit resource access (Li et al., 2018). In providing the needed support to innovators, government also assumes entrepreneurial risk and can be viewed as entrepreneur (Link & Scott, 2010).

Furthermore, prior research has recognized that government helps to solve innovation problems, which is a relatively understudied role in supporting innovators. This role is critical, in the presence of market frictions that hinder innovation (Arrow, 1962; Crafts & O'Mahony, 2001). Comin et al. (2019) suggest that technological problems can be firm-specific and that solutions to these problems are not readily available in the market. While the market mostly supplies solutions to generic technological problems, as opposed to firm-specific ones, solving these specific problems also entails search frictions and contractual frictions. Search frictions arise when it is difficult to find experts suited for solving the specific problems, and contractual frictions arise when contracts are imperfect in detailing solutions to them. Thus, government may establish public non-profit research organizations, such as the Fraunhofer Gesellschaft

in Germany, in the attempt to offer solutions to innovation problems, which the market fails to provide.

Government also serves as an intermediary bridging investors and innovating firms. For example, a growing body of research has examined government-sponsored venture capitalists (GVCs) (Brander et al., 2015; Grilli & Murtinu, 2014), which deal with market frictions in capital markets (Amit et al., 1998; Lerner, 1999). Informational asymmetries lead to moral hazard and adverse selection, which in turn lead valuable projects to be unfunded or underfunded. Venture capital investors seek to fill the financing gap (and profit from the resultant innovations), using their expertise in selecting and monitoring opportunistically behaving entrepreneurial firms (Amit et al., 1998; Hall, 2002). GVCs have stronger motives to fill the financing gap because R&D investment creates knowledge spillovers and thus has social value (Lerner, 1996). These spillovers also tend to benefit local firms (Anselin et al., 1997; Breschi and Lissoni, 2001) and further motivate government to fund venture capital (Bertoni & Tykvov?, 2015).

The preceding discussion of the role of government in innovation can be understood in the framework of national innovation system (NIS), or alternatively, national systems of innovation (NSI) (Freeman, 1988; Lundvall, 1988; Nelson, 1993). What is at the heart of the NIS is collaborative relationships/networks among the NIS actors of firms, universities, research institutes, and government. In the NIS, government seeks to devise institutions aimed at facilitating collaborative relationships, which lead to knowledge spillovers among the NIS actors and, in turn, to increased firm- and network-level innovation. Thus, the NIS framework postulates that open innovation is valuable for building innovation capabilities. In open innovation, innovations are created using external knowledge residing outside the boundary of the single firm (inbound open innovation) (Laursen & Salter, 2006; Leiponen & Helfat, 2010, 2011), and/or they are commercialized through the complementary assets of external entities (outbound open innovation) (Lichtenthaler, 2005, 2008).

Indeed, government seeks to enhance open innovation by firms, as shown by a wide range of support measures it deploys. For example, government sponsors industry-wide R&D consortia, which offer access to R&D expertise and external knowledge and foster collaboration among the participants (Cho, Kim, & Rhee, 1998; Kim, Bae, & Yang, 2014), and remedies coordination failures in R&D investment. R&D consortia can be especially important in latecomer countries since they reduce search frictions in locating and accessing critical resources (such as R&D expertise, as well as government-granted access to funding, land, and technical infrastructure), and consolidate fragmented R&D efforts, whereby inefficient, duplicate R&D investment by individual firms diminishes (Cho et al., 1998). Choi (2015) has suggested that Korean firms' interorganizational R&D collaboration increased with government measures supporting technology and human resource aspects.

Taken together, various forms of government support provide a critical impetus for firms' OI in various ways, given the pervasive imperfections in the markets for technology. Thus, broader government support can potentially enhance firm-level openness, providing valuable multi-faceted solutions for firms that might otherwise be discouraged from collaborating with others in the development and commercialization of technologies and/or from acquiring knowledge from others.

Hypothesis 1. Firms that take advantage of a wider range of government support measures will be positively related to firm-level openness in innovation.

2.2. National Industrial Complexes (NICs)

Aside from implementing the aforementioned support measures, government may also build NICs, in order to aid the nation's innovation actors. NICs can be understood as government-formed clusters of co-located firms, research institutes, and/or universities, which are related in terms of knowledge, skills, inputs, demand etc. (Delgado, Porter, and Stern, 2016). Porter defines clusters as "geographical concentrations of interconnected companies and institutions in a particular field" (1998: 78). While clusters may or may not require government intervention in their development, clusters in South Korea have peculiarities in that they have been developed primarily through extensive government planning that manifests a top-down approach to national industrialization (Chung, 2002) and reflects a critical view that the development of clusters is a strategic imperative to regional development (Bathelt, 2001; Porter, 2003).

According to the Industrial Sites and Development Act (2018) of South Korea, a NIC refers to "an industrial complex designated [···] to promote national key industries, high-tech industries, etc. or to develop underdeveloped areas requiring the promotion of development or areas extending over at least two Special Metropolitan Cities, Metropolitan Cities, Special Self-Governing Cities or Dos as an industrial complex." These clusters are characterized by centrally planned agglomerations of factories, facilities, and resource reservoirs that are interrelated in terms of knowledge, culture, and information technology.

Prior studies suggest that firms in clusters capitalize on the advantages of labor market pooling, supplier specialization, and knowledge spillovers collectively engendering "economies of agglomeration" (Cortright, 2006; Marshall, 1920; Rosenthal and Strange, 2004) and experience higher rates of innovation than firms outside clusters (Audretsch and Feldman, 1996; Baptista and Swann, 1998). These studies highlight why being located in clusters can enhance interorganizational collaboration and OI. First, in clusters there are large groups of suppliers of labor and other inputs that are also willing to make specialized investments (Marshall, 1920; Williamson, 1985). These advantages of labor market pooling and supplier specialization increase the chances of collaboration by in-cluster firms since buyer-supplier relationships necessarily involve interactions with other firms (Cortright, 2006; Porter, 1990).

Second, not only do firms operating in different stages of the value chain collaborate vigorously, but also those in the same stage of the value chain do. These firms may be direct competitors to one another but can collaborate by partaking in partnerships in projects and a trade association and commit to market development jointly, given the geographical proximity to one another. Prior research has suggested that geographic proximity is related to higher interaction, networking, and innovation (Bathelt, Malmberg, and Maskell, 2004; Franco and Esteves, 2020; Howells, 2002). For R&D, in-cluster firms engage in OI with other firms in the cluster, in attempts to exploit knowledge spillovers that tend to be localized, as shown by empirical evidence of patenting activity closely linked to labor mobility (Almeida and Kogut, 1997) as well as clustered patent citations (Jaffe, Trajtenberg, and Henderson, 1993). Furthermore, firms that engage in OI in their clusters might better recognize the value of interorganizational collaboration and also be willing to collaborate with firms in other clusters, which engender inter-cluster relationships (Franco and Esteves, 2020; Goerzen, 2018). Lee and Chung (2014) have posited that a cluster's effectiveness in stimulating innovation manifests through promoted interorganizational collaboration.

Hypothesis 2. Firms located in clusters will be positively related to firm-level openness in innovation.

However, to the extent that clusters facilitate firms' OI, the effect of a wide range of government support measures on OI may diminish when firms are located in clusters. In light of a potentially substitutive relationship that may exist among various policy measures, government support measures can be redundant to membership in clusters for the purpose of enhancing OI because firms in clusters might plausibly have been already collaborating vigorously with one another, aided by the geographical proximity to related firms and social capital that has accumulated among the members of a cluster (Bathelt, Malmberg, and Maskell, 2004; Inkpen and Tsang, 2005). Furthermore, the imperfections in the markets for technology might plausibly be lower for firms in clusters, given the networks and infrastructure created in these clusters. Thus, providing an additional, different form of support may not increase OI as much as it would for firms that do not belong to clusters. A wider array of government-provided resources can be critical for firms outside clusters since they can use these resources to search for a larger set of potential collaborators, which otherwise might be prohibitively costly, and pursue a larger number of collaboration-driven R&D and commercialization projects. Hence,

Hypothesis 3. The positive relationship between the use of a wider range of government support measures and firm-level openness will be attenuated for firms located in clusters.

Ⅲ. Data and Method

3.1. Data

In our examination of how government efforts relate to openness in innovation, we employ data from the Korea Innovation Survey (KIS) 2018 for the manufacturing sector, obtained from the Science and Technology Policy Institute (STEPI) of Korea.[1] The STEPI has been conducting the survey every two years since 1996, which it modeled after the EU Community Innovation Survey (CIS) by Eurostat. The KIS sample is randomly drawn from the population of Korean firms on the Census on Establishments conducted by the Statistics Korea, stratified by industry, size, and region. The final sample comprises firms that engaged in business activities in the prior three years and have a minimum of 10 employees. The KIS survey was administered through various means, in person as well as by phone, fax, and online, and the questionnaire responses were then cross-checked for accuracy by a separate division in charge of this task. The KIS 2018 data provide detailed information on the innovation activities of 3,500 Korean firms in the prior three-year period from 2015 through 2017 and are cross-sectional. This economy-wide dataset provides useful firm-level information on, for example, size, market, innovativeness, residence in a cluster, and government intervention. In our empirical analysis, we focus on 1,450 Korean manufacturing firms that are R&D active, as defined by R&D expenditures greater than a zero.

3.2. Variables

The outcome of interest is a firm's openness in innovation. We operationalize openness with two variables, Collaboration Breadth and External Search Breadth, following Laursen and Salter (2006, 2014) and many follow-on studies (e.g., Grimpe & Sofka, 2009; Leiponen & Helfat,

1) The STEPI conducts the survey for both the manufacturing and service sectors, but we focus on the manufacturing sector in this study.

2010; Love, Roper, & Vahter, 2013). First, Collaboration Breadth is constructed using a survey question that asked firms whether or not they had collaborated with each of the 8 possible types of external partner: 1) suppliers, 2) private clients or customers, 3) public clients or customers, 4) competitors, 5) consultants, 6) universities, 7) private research institutes, and 8) public research institutes.[2] We first code the responses as 8 dummy variables equal to 1 if the firm had collaborated with the particular type of external partner or 0, otherwise. In order to construct Collaboration Breadth, we then compute the sum of all these dummies for the firm and normalize it, dividing by the maximum possible number of collaboration partner types of 8, following Laursen and Salter's (2006, 2014) approach. The normalization procedure is needed to employ fractional response models in our empirical analysis (see the next section on model specification). Thus, the variable can range from 0 (if the firm collaborated with none of these external partner types) to 1 (if the firm collaborated with all types). The 8 items used to construct the variable suggest a high level of internal consistency (Cronbach's Alpha Coefficient=0.944).

The second dependent variable, External Search Breadth, is constructed using another survey question that asked firms to rate the importance (high, moderate, low, and no) of each of the 11 possible external sources of knowledge: 1) suppliers, 2) private clients or customers, 3) public clients or customers, 4) competitors, 5) consultants, 6) universities, 7) private research institutes, and 8) public research institutes, 9) conferences, 10) scientific publications, and 11) associations.[3] We take a similar approach and code dummy variables indicating the binary importance of each source, equal to 1 if the source was rated "high" and "moderate" importance or 0 if "low" and "no" importance. Then we sum up all these dummies for the firm and normalize it, dividing by the maximum possible number of external knowledge sources of 11. Thus, External Search Breadth takes a value between 0 (if the firm perceives all sources unimportant) and 1 (all sources important), inclusive. The 11 items used to construct the variable suggest a high level of internal consistency (Cronbach's Alpha Coefficient=0.892).

Key independent variables are concerned with government's role in fostering collaborative innovation. First, Government Support Breadth is constructed utilizing a survey question that asked firms to rate the importance (high, moderate, low, and no) of various government support measures they had used in the prior three years. There were 7 possible support items rated: 1) tax, 2) funding (such as subsidies), 3) financing (such as financial guarantees), 4) human resources, 5) technology, 6) certification (such as of enterprises and technologies), and 7) purchase (such as public purchasing and priority purchasing). Analogous to External Search Breadth, we first code binary importance dummies for each item, sum them up for the firm, and then normalize dividing the sum by the maximum possible number of important items, 7. The resulting variable Government Support Breadth takes a value between 0 (if all support measures are perceived by firms as unimportant) and 1 (if all measures are perceived as important), inclusive. The 11 items used to construct the variable suggest a high level of internal consistency (Cronbach's Alpha Coefficient=0.854). Second, Cluster is a dummy variable indicating whether or not a firm resides in a NIC the government designed.

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2) The survey question lists 9 possible collaboration partner types, including firms affiliated with the focal firm, but we focus on 8 excluding this type, in order capture collaboration with "external" partners. This approach is also in line with prior studies that use the measure.

3) Similar to the previous footnote, the survey question lists 12 possible knowledge sources, including "sourced internally from the focal firm and affiliated firms", but we exclude this internal source, in order to focus on external knowledge sources.

Several control variables are also included. Following Laursen and Salter (2014), we control for a number of variables that may potentially influence firm-level openness in innovation, namely, Appropriability Strategy Breadth, R&D Intensity, Size, Startup, Corporate Affiliation, and Market Size. Appropriability Strategy Breadth is constructed similar to the earlier constructed Collaboration Breadth, utilizing a survey question that asked firms whether or not they had protected innovations with each of the 8 appropriability mechanisms: 1) patents, 2) utility models, 3) design rights, 4) trademarks, 5) secrecy, 6) copyrights, 7) complex design, and 8) lead time advantage. The variable Appropriability Strategy Breadth takes a value between 0 (if none of the appropriability mechanisms were used) and 1 (all mechanisms used), inclusive (Cronbach's Alpha Coefficient=0.726). R&D Intensity is computed as R&D expenditures divided by sales (natural-logged). Size is computed as the number of employees plus 1 (natural-logged). Startup is a dummy indicating a firm less than 5 years old. Corporate Affiliation is a dummy indicating a firm that is affiliated with a business group. Market Size captures the breadth of product market, coded 1 if the firm sells a product in a regional market, 2 if in the national market, or 3 if in a foreign market. In our empirical analysis, we include industry fixed effects.

3.3. Descriptive Statistics

Table 1 reports the descriptive statistics for the variables. The average values for the two dependent variables of Collaboration Breadth and External Search Breadth are 0.158 and 0.664. Also, on average, 26.1% of firms are located in clusters. 7.4% of firms are startups, and 9.2% of firms are affiliated with business groups. Table 2 reports the correlations among the variables and suggests little evidence of potential multicollinearity problems.

Table 1. Descriptive statistics (N=1,450 firms)

Variables	Mean	Std. Dev.	Min	Max
Collaboration breadth	0.158	0.307	0.000	1.000
External search breadth	0.664	0.314	0.000	1.000
Cluster (dummy)	0.261	0.440	0.000	1.000
Government support breadth	0.461	0.359	0.000	1.000
Appropriability strategy breadth	0.146	0.192	0.000	1.000
R&D intensity (logged)	-2.778	4.198	-20.723	17.322
Size (logged)	4.013	1.151	2.159	10.419
Startup (dummy)	0.074	0.263	0.000	1.000
Corporate affiliation (dummy)	0.092	0.290	0.000	1.000
Market size	2.355	0.676	1.000	3.000

Table 2. Pairwise Correlations (N=1,450 firms)

	Variables	Correlations									
		1	2	3	4	5	6	7	8	9	10
1	Collaboration breadth	1.00									
2	External search breadth	-0.02	1.00								
3	Cluster (dummy)	0.09	0.06	1.00							
4	Government support breadth	0.10	0.25	0.05	1.00						
5	Appropriability strategy breadth	0.16	-0.02	0.02	0.17	1.00					
6	R&D intensity (logged)	-0.01	-0.02	0.01	-0.03	0.07	1.00				
7	Size (logged)	0.07	0.23	0.07	0.11	0.13	-0.08	1.00			
8	Startup (dummy)	-0.02	-0.04	-0.01	0.00	-0.03	0.08	-0.16	1.00		
9	Corporate affiliation (dummy)	0.06	0.06	0.07	0.08	0.06	-0.02	0.32	-0.02	1.00	
10	Market size	0.03	0.14	0.07	0.18	0.15	-0.07	0.33	-0.09	0.10	1.00

Figure 1 plots the mean of Collaboration Breadth by industry and suggests that the value is highest in other transportation (0.37), followed by beverage (0.33), paper (0.30) and wood (0.29). Similarly, Figure 2 plots the mean of External Search Breadth and suggests that the value is highest in furniture (0.92), followed by pharmaceutical (0.89), medical and optical products (0.86), and electronics (0.85). Since these figures show different patterns, it appears that the two variables of firm-level openness are distinct, each capturing the firm's openness to a wide range of collaboration partners and external sources of knowledge. For example, pharmaceutical firms are quite open to external sources of knowledge, yet nevertheless not as open to collaboration with others in innovation processes.

Fig. 1. The mean of Collaboration Breadth by industry

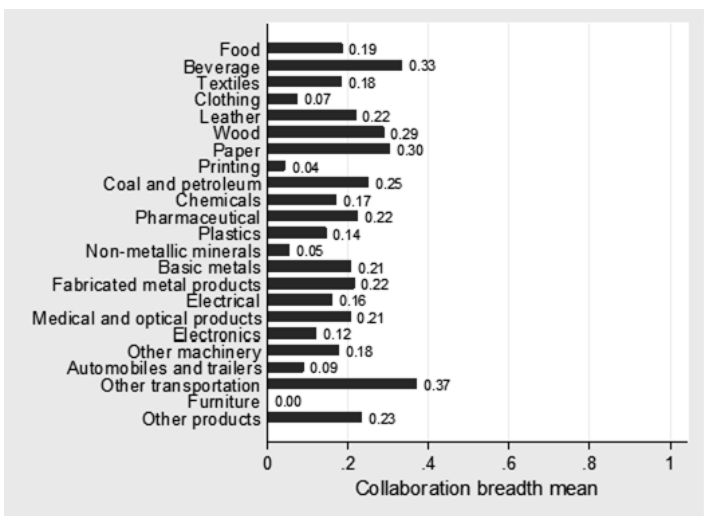


Fig. 2. The mean of External Search Breadth by industry

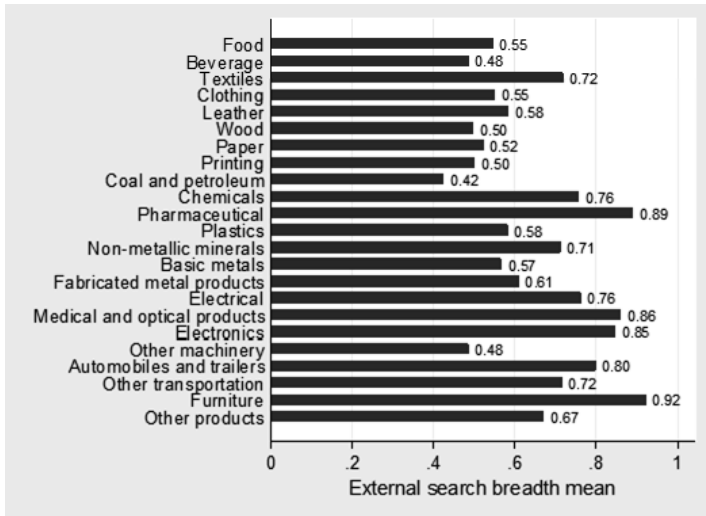


Fig. 3. The Fraction of Firms Located in Government-developed Clusters (NICs) by Industry

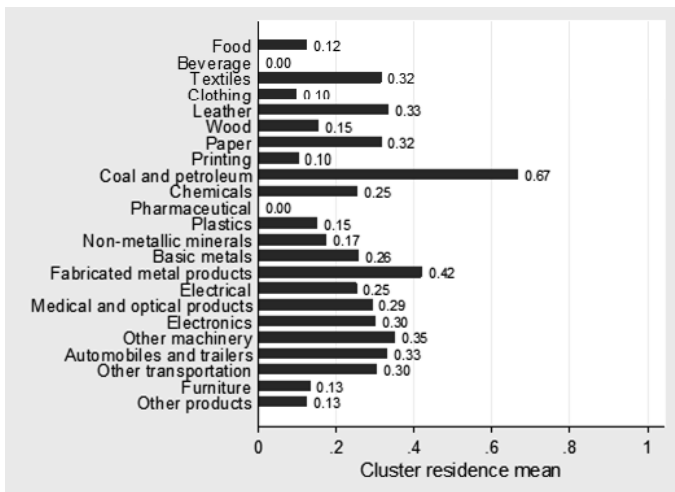


Figure 3 visually illustrates the fraction of firms in government-developed clusters by industry and suggests that membership in a cluster is highest in coal and petroleum (67%), followed by fabricated metal products (42%), other machinery (35%), leather (33%), and automobiles and trailers (33%). Membership in a cluster is lowest in beverage (0%) and pharmaceutical (0%), followed by clothing (10%) and printing (10%).

3.4. Model Specification

In our two-part empirical analysis on the two measures of openness in innovation, Collaboration Breadth and External Search Breadth, we employ fractional response generalized linear models (Papke & Wooldridge, 1996), essentially binary choice generalized linear models (e.g., logit and probit) adapted to estimate "proportion" dependent variables ranging from 0 to 1. Similar to binary choice models, fractional response models ensure that the predicted values lie within the range of 0 and 1. Formally, we estimate the following fractional logit model:

$$E(y\Big|x) = \frac{\exp(x'\beta)}{1+\exp(x'\beta)},$$

where y is the dependent variable, and x is a vector of explanatory variables.

IV. Results

Table 3 reports the results of fractional logit estimation. Columns 1 and 3 contain the estimation results for the two dependent variables of Collaboration Breadth and External Search Breadth, respectively, while Columns 2 and 4 contain the marginal effects of each explanatory variables, computed using the estimation results in Columns 1 and 3, respectively, and holding all other variables at their means.

Table 3. Fractional Logit Models on Openness in Innovation (Measured by Collaboration Breadth and External Search Breadth)

Variables	Model 1 Collaboration Breadth	Model 1 Marginal Effects Collaboration Breadth	Model 2 External Search Breadth	Model 2 Marginal Effects External Search Breadth
Cluster (dummy)	0.509**	0.049***	0.507***	0.026
	(0.246)	(0.018)	(0.159)	(0.019)
Government Support Breadth	0.610**	0.061***	0.982***	0.164***
	(0.238)	(0.021)	(0.143)	(0.027)
Cluster * Government Support Breadth	-0.201		-0.834***	
	(0.371)		(0.272)	
Appropriability Strategy Breadth	1.216***	0.133***	-0.387*	-0.083*
	(0.294)	(0.032)	(0.212)	(0.045)
R&D Intensity (logged)	-0.011	-0.001	0.005	0.001
	(0.016)	(0.002)	(0.011)	(0.002)
Size (logged)	0.097	0.011	0.231***	0.050***
	(0.064)	(0.007)	(0.047)	(0.010)
Startup (dummy)	-0.135	-0.015	-0.050	-0.011
	(0.253)	(0.028)	(0.129)	(0.028)
Corporate Affiliation (dummy)	0.224	0.025	-0.153	-0.033

	(0.211)	(0.023)	(0.145)	(0.031)
Market Size	-0.106	-0.012	0.005	0.001
	(0.108)	(0.012)	(0.060)	(0.013)
Constant	-2.178***		-0.951***	
	(0.329)		(0.208)	
Industry dummies	Yes	Yes	Yes	Yes
Observations	1450	1450	1450	1450

Robust standard errors in parentheses
* p < 0.10, ** p < 0.05, *** p < 0.01

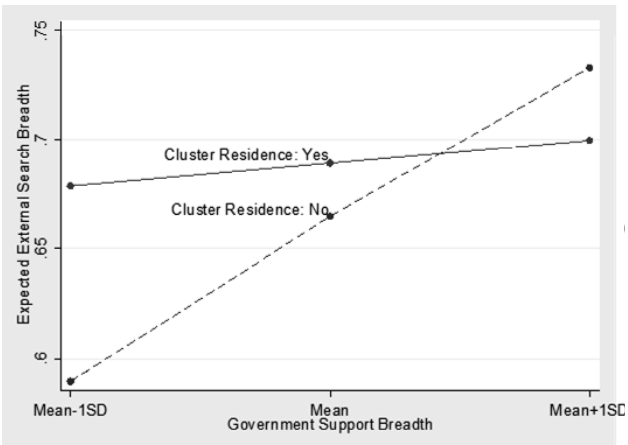
Column 1 suggests that firms work with a broader set of external collaborating partners when they were provided with a broader array of government support ($p<0.05$) and when they were located in government-developed clusters ($p<0.05$). Column 2 suggests that in terms of economic significance, when firms benefited from all 7 types of government support measures-tax, funding, financing, human resources, technology, certification, and purchase-and viewed them as important, Collaboration Breadth was 6.1 percentage points higher, relative to the case in which they benefited from none. Similarly, when firms were located in clusters, Collaboration Breadth was 4.9 percentage points higher, relative to the case in which they were located outside clusters. However, in Column 1, the interaction of a broader set of government support and membership in a cluster was negative for Collaboration Breadth, as hypothesized, but statistically insignificant. It appears that firms' membership in government-developed clusters does not significantly weaken the positive relationship between broader government support and Collaboration Breadth, counter to Hypothesis 3. Thus, government may not need to differentiate support measures it provides for firms inside and outside clusters, for the purpose of enhancing firm-level openness in collaborating with a broader set of external partners.

Next, Column 3 suggests that firms source knowledge from a broad set of external sources when they were provided with a broader array of government support ($p<0.01$) and when they were located in government-developed clusters ($p<0.01$). Column 4 suggests that in terms of economic significance, when firms benefited from all 7 types of government support measures and viewed them as important, External Search Breadth was 16.4 percentage points higher, relative to the case in which they benefited from none. This number is much larger than the one we saw earlier for Collaboration Breadth, 6.1 percentage points, which suggests that broader government support makes the use of external knowledge sources more heterogeneous, compared to that of external collaborating partners. This finding may be potentially explained by the relatively greater difficulty of undertaking diverse collaborative partnerships, even in the presence of government support. When firms were located in clusters, External Search Breadth was 2.6 percentage points higher, relative to the case in which they were located outside clusters.

Furthermore, in Column 3, the interaction of broader government support and membership in a cluster was negative significant for External Search Breadth ($p<0.01$), in support of Hypothesis 3. In order to facilitate interpretation of the result, Figure 4 plots an interaction graph for the effect of Cluster and Government Support Breadth on External Search Breadth. The graph visually illustrates that the effect of broader government support is steeper for firms outside clusters, which indicates that firms' membership in clusters dampens the positive relationship between broader government support and more diversified external search. As Government Support Breadth increases by one standard deviation from the mean, External

Search Breadth increases by 1.1 percentage points (0.011=0.700-0.689) for firms in clusters and 6.8 percentage points (0.068=0.733-0.665) for firms outside clusters. Given the striking difference in the numbers, government may need to differentiate the scope of support measures it provides for firms inside and outside clusters if it seeks to increase firm-level openness in knowledge search.

Fig. 4. Interaction Graph for the Effect of Residence in a Cluster and Government Support Breadth on Openness in Innovation



Other interesting findings are also noteworthy, although not hypothesized previously in this study. First, Appropriability Strategy Breadth is positively related to Collaboration Breadth (Column 1, $p<0.01$) and negatively weakly related to External Search Breadth (Column 3, $p<0.1$). Firms' use of diverse IP and appropriability mechanisms may be positively associated with their collaboration with diverse external partners because protection of knowledge is a strategic imperative to collaboration with others, which entails vigorous exchange of knowledge and puts the firms at risk of knowledge misappropriation by these collaborating partners. However, such knowledge misappropriation risks may be less prominent in firms just sourcing knowledge externally, and thus these firms may not need to employ diverse IP and appropriability mechanisms to protect their own knowledge against others. Moreover, the results suggest that Size is not related to Collaboration Breadth (Column 1) but positively related to External Search Breadth (Column 3, $p<0.01$). Large firms tend to have plenty of resources and thus might be more capable of searching for knowledge from more diverse external sources, which can be prohibitively costly for small firms. However, Size may not be positively or negatively related to a broader set of collaborating partners since both small and large firms might have incentives to collaborate with diverse external partners. Outbound OI can be important for small firms that lack resources and seek to commercialize their own knowledge, while inbound OI can be important for large firms that seek to benefit from the ideas of knowledge-intensive small innovators (Alvarez and Barney, 2001; Gentile-L?decke, Torres de Oliveira, and Paul, 2020).

Taken together, the results of this study suggest that firms' receipt of government support-in forms of either various support measures or membership in government-developed clusters-can explain their openness in innovation processes. The results are even more interesting, given that various firm-level attributes-such as firm size, market size, R&D intensity, the dichotomous indicators for a startup and a corporate affiliate, and industry dummies-have been controlled for in the estimation. The effects of government support mechanisms were quite significant, relative to the effects of these firm-level controls.

Ⅴ. Discussion and Conclusion

In this study, we have examined how government support measures are related to firm-level openness in innovation activities. Drawing from the literature in OI and NIS, this study specifically focuses on the relationships of the breadth of government support measures and a firm's membership in a government-developed cluster with firm-level openness. We use the KIS 2018 data that contain information about the detailed innovation activities of Korean manufacturing firms and test our hypotheses by employing fractional logit estimation. The results suggest that a firm is more open to collaborating with external partners and exploiting external sources of knowledge in innovation processes when it relied on a wider range of government support measures and is located in a government-developed cluster. These findings are consistent with Hypotheses 1 and 2. Furthermore, the results show that the positive relationship between a wide range of support measures and External Search Breadth weakens for a firm that is located in a cluster, in support of Hypothesis 3. However, membership in a cluster did not significantly weaken the positive relationship between a wide range of support measures and Collaboration Breadth.

This study contributes to research in OI and NIS by highlighting the interplay between them, which has been relatively understudied by prior work. Although the two strands of research share the common interest of interorganizational collaboration, OI and NIS researchers have taken distinct approaches to it. OI researchers have focused on the phenomenon of interorganizational collaboration itself, mostly illuminating the antecedents and consequences of it at the firm level (Bogers, Chesbrough, Heaton, & Teece, 2019; Huizingh, 2011). NIS researchers have focused on government planning to enhance interorganizational collaboration at national and regional levels, which might lead to the ultimate goal of national economic growth (Asheim & Isaksen 1997; Cooke, 1992; Cooke, Uranga, & Etxebarria 1997; Freeman, 1988; Howells, 1999; Lundvall, 1988; Nelson, 1993). This study contributes to both strands of research by providing valuable empirical evidence of firm-level openness related to government support. Furthermore, this study provides novel evidence of the substitutive interaction between the government support mechanisms of a wide palette of support measures and national industrial complexes.

This study also has rich implications for policy, in view of how these findings can be put into practice. The findings of this study suggest that policymakers seeking to catalyze OI need to understand the substitutive relationship between government support measures and firms' membership in clusters. The interaction of these two support mechanisms highlight that a wide range of government support measures are less effective for enhancing OI-specifically, as shown with diminishing external search breadth-when firms are in clusters. In other words,

firms in clusters will engage in more diversified external search when they are provided with a more focused set of support measures. These novel and interesting findings help policymakers to make informed decisions in expending limited resources and providing support for firms. Policymakers that seek to facilitate interorganizational collaboration in the NIS can consider differentiating the scope of support measures for firms inside and outside clusters, such that in-cluster firms are provided with a more focused set of support measures that are most critical. For example, policies aimed at supporting firms in clusters can be shaped to be more focused, comprising a few support measures that are widely viewed as important by these firms. Appendix Figure 1 provides a useful insight by suggesting that the largest share of in-cluster firms viewed the tax support as important (68.3%), followed by the funding support (53.6%) and the certification support (52.8%).

Furthermore, this study makes empirical contributions by investigating the implications for firms' OI by using an up-to-date dataset on South Korean manufacturing firms. Studies examining the innovation activities of firms have mostly employed data from European contexts as the CIS was first developed in early 1990s providing a detailed quantifiable description of the innovation inputs and outputs of firms in European countries. The CIS was modelled after by similar firm-level innovation surveys for several non-European countries (Arundel and Smith, 2013), including the East Asian countries of China, Japan, and South Korea. Although increasingly many studies have sought to understand innovation activities in these non-European contexts, their focus have been largely on the performance implications of firm-level OI strategies (Kim, Kim, and Kim, 2016; Son and Zo, 2021; Wang, Chang, and Shen, 2015), in efforts to replicate prior studies in European contexts. This study differs from prior work in that it examines a Korean context and provides novel insights into the linkages between government support, clusters, and OI, which have direct policy implications.

Despite the contributions of this study, it is not without limitations, which also point to potentially fruitful avenues for future research. The most prominent limitation might be that the sample of this study consists of Korean manufacturing firms, and the findings of this study cannot be generalized to firms in other countries and service firms. Clusters in South Korea tend to be government-developed ones and the results of central planning, and thus may differ from those in other countries in their characteristics. A still substantial proportion of clusters in the U.S. and Europe have developed organically, and government support measures may not particularly be related to firm-level openness for firms in these clusters. While this study provides an initial look at the relationships between government support mechanisms and firm-level openness, these relationships are potentially worth exploring in other regional contexts. Similarly, service firms might also differ from manufacturing firms in their reliance on the scope of government support measures (potentially narrow) and in their inclusion in clusters, and thus it might be useful for future research to examine the OI implications for service firms and compare them with those for manufacturing firms.

Moreover, methodologically, this study examines correlations between government support mechanisms and firm-level openness and does not show causal relationships between them. Thus, one cannot convincingly argue that the government support mechanisms of support measures and clusters drive firm-level openness. Future studies may exploit quasi-exogenous shocks in government support mechanisms-such as unexpected changes in support policy and firms' sudden relocation to clusters-and investigate their causal effects on firm-level openness, which are isolated from the potential influences of confounding factors.

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Appendices

Appendix Fig. 1. Fraction of in-cluster firms viewing each government support measure as important