Competition and Innovation Spillover

Jong Hwa Lee and Jungwook Kim

This study examines the relationship between the two sides of innovation of research and development (R&D) and competition. By analyzing the Korean firm-level data from 2000 to 2015, we find that competition is an important factor for innovation spillovers. In addition, decreasing competition magnifies the spillover effect. The net effect of the total spillover diminishes sales and productivity as competition decreases. Lack of competition weakens the commonly known relation that R&D exhibits a positive spillover effect on growth.

Keywords: Innovation, Productivity, Spillovers, Competition

JEL Classification: L6, O3, O4

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I. Introduction

Innovation and productivity are the core of economic growth. Given that numerous countries worldwide have experienced declining growth rate, innovation is important in many aspects. Technological advancements from research and development (R&D) endeavors play a crucial part in assisting aggregate economic growth and expanding a firm's market share and profit. Literature has exerted a substantial amount of theoretical and empirical effort to establish a direct link between R&D expenditure and firms' future growth. Another strand focuses on the indirect link, namely, the externality from innovations. This study contributes to literature by exploring the effects of innovations and spillovers on firm performance while considering the competition level within industries where firms coexist.

Spillover effects are inevitable from the technological progress during the process of creative destruction. Two contradicting effects of knowledge spillover exist. On the one hand, knowledge travels within an industry to improve productivity collectively. Several studies have revealed that a firm's R&D knowledge benefits itself and its competitors in the same industry, which is the positive side of knowledge spillover. On the other hand, when firms compete with one another within the same industry, a firm's knowledge enhancement from its own R&D efforts could induce negative effects on its competitors. In particular, a firm's knowledge advancement could hinder other competitors from succeeding by stealing market shares. Therefore, the negative and positive effects of R&D should be identified. We quantify the positive and negative spillovers using the similar methods published by Bloom *et al.* (2013) and observe the process of how market competition influence such effects. Positive spillover is measured by using the R&D stock of other firms in the same industry, whereas negative spillover is identified by using the market share of the competitors. Disparities in the degree of spillovers influenced by market competition are addressed in this paper.

This study contributes to literature by using two spillover measurements (computed with R&D stock and market share) and the time-varying Herfindahl Index (HI) for each industry. First, rather than measuring firm-level competitiveness, we control for the competition level of an industry in which firms operate by analyzing Korean data through HI. To measure the influence of spillovers, we use firm

Table 1
US, Japan, and Korea's Top 10 Firms and their Sales to GDP

Country	Firm	Sales		2017				Growth (Sales)
		2017	2015	Sales	GDP	% of GDP		
Korea	Samsung Electronics	224,217	170,406	677,812	1,530,751	44.30%	14.60%	2.3%p
	Hyundai Motors	90,198	78,097				5.90%	0.2%p
	LG Electronics	57,460	47,991				3.80%	0.3%p
	Posco	56,767	49,420				3.70%	0.1%p
	Korea Electric Power Corporation	55,980	50,070				3.70%	0.0%p
	Kia Motors	50,104	42,056				3.30%	0.2%p
	Hanwha	47,173	-				3.10%	-
	Hyundai Mobis	32,892	30,590				2.10%	-0.1%p
	Samsung Display	32,095	-				2.10%	-
	Hana Bank	30,928	-				2.00%	-
US	Wal-Mart Stores	500,343	482,130	2,294,358	19,390,604	11.80%	2.60%	-0.1%p
	ExxonMobil	244,363	259,488				1.30%	-0.2%p
	Berkshire Hathaway	242,137	210,821				1.20%	0.1%p
	APPLE	229,234	233,715				1.20%	-0.1%p
	McKesson	208,357	190,884				1.10%	0.0%p
	UnitedHealth Group	201,159	157,107				1.00%	0.2%p
	CVS Health	184,765	153,290				1.00%	0.1%p
	Amazon.com	177,866	-				0.90%	-
	AT&T	160,546	146,801				0.80%	0.0%p
	General Motors	145,588	152,356				0.80%	-0.1%p

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US, Japan, and Korea's Top 10 Firms and their Sales to GDP

Country	Firm	Sales		2017				Growth (Sales)
		2017	2015	Sales	GDP	% of GDP		
Japan	Toyota Motor	276,696	252,930	1,197,727	4,872,137	24.60%	5.70%	-0.1%p
	Honda Motor	144,671	130,023				3.00%	0.0%p
	Japan Post Holdings	121,684	126,963				2.50%	-0.4%p
	Nissan Motor	112,556	108,548				2.30%	-0.2%p
	NTT	111,129	102,773				2.30%	-0.1%p
	JXTG Holdings	97,015	-				2.00%	-
	Hitachi	88,233	89,355				1.80%	-0.2%p
	SoftBank Group	86,257	81,512				1.80%	-0.1%p
	Sony	80,467	72,181				1.70%	0.0%p
	AEON	79,017	-				1.60%	-

This table shows how concentrated Korean markets are. Top firms in Korea make up more percentage of GDP than those of US or Japan. The data were obtained from CEOscore.

revenue and total factor productivity (TFP) to assess firm performance. Second, we identify how the influence of R&D stock, positive knowledge spillover, and negative competition spillover on firm performance varies among industries with different competition intensity. This study contributes to the literature by observing the differences in positive and negative spillover effects from various competition intensity. Third, we observe how the exporting firms, which are exposed to the international market, differ in terms of sensitivity toward spillovers.

Using firm-level panel data, we find that positive and negative spillover effects magnify if an industry is highly concentrated. However, the net effect of spillovers harms firm performance as market concentration increases. Furthermore, firms tend to have increased benefit from their own R&D efforts if the industry competition level is low. Results show that a firm's export status exhibits no statistically significant effect on the magnitude of spillovers. Lastly, R&D activities decrease as competitors accumulate additional R&D stock and competition declines.

TABLE 2
CONCENTRATION OF KOREAN FIRMS. (UNITS: 1 BILLION WON)

		2014	2015	2016	2017*
GDP		1,486,079	1,564,123	1,641,786	1,730,398
Conglomerates	Assets (%)	101.55	99.33	97.78	87.5
	Sales (%)	91.34	84.68	75.15	64.51
Top 10	Assets (%)	71.86	70.96	69.82	67.46
	Sales (%)	67.59	62.78	55.23	51.08
# of firms		49	49	53	31

This table lists the Korean conglomerates and the top 10 firms in terms of sales and assets as percentage of GDP in the recent years. Public firms are excluded. The data are obtained from the Bank of Korea, ECOS (Economic Statistics System), and Fair Trade Commission (groupopni.ftc.go.kr).

Korea is the optimal place for this study given that its market concentration varies significantly among industries. Additionally, Korea has one of the most concentrated markets. Table 1 lists the top 10 firms in United States, Japan, and Korea in terms of sales. The top 10 Korean firms earn 44.3% of the country's GDP through sales, whereas the US and Japanese firms earn 11.8% and 24.6%, respectively. Table 2 indicates that the top 10 conglomerates account for nearly 51% of the country's GDP in 2017, but this percentage has been decreasing recently.

This study investigates the impact of competition level on productivity spillovers and innovation. This paper is organized as follows. Section II reviews the literature on competition and innovation. Section III describes the data and method used. Section IV reports the results, and Section V concludes.

II. Literature Review

This study deals with two streams of research that should be reviewed. One addresses the controversial link between competition and innovation, whereas the other refers to technology spillovers.

A. Innovation and Competition

To understand the effects of competition on innovation, we discuss the incentives to innovate. Schumpeter (1942) stated that firm size and market concentration cause qualitative differences from innovative efforts. This topic has not come to a consensus. Several empirical studies have explicitly argued that large firms with high market power have more incentives to innovate due to imperfect capital markets, economies of scale, and economies of scope. However, any firm could gain higher market share through innovation. Thus, innovative activities could occur everywhere. Although these studies control for firm characteristic and market share, how industry competition levels are related to innovation should be evaluated. Firms within an industry interact through numerous channels. Firms pursue innovation through their own R&D efforts but also benefit from breakthroughs of their competitors. Due to firms' interaction, the level of competition and closeness among firms in a market affects the amount of effort they exert to outdo or to maintain dominance over one another.

Although Arrow (1962) demonstrated how competitive industries have greater incentives to invest in R&D, certain empirical studies have argued otherwise. Aghion and Griffith (2005) explained that the profit before and after innovation is determined by market power, thereby granting more incentives for monopolies to invest in R&D. In addition, Vives (2007) revealed that competition reduces incentives for investments. Aghion *et al.* (2005) showed an inverted-U relationship between innovation and competition intensity. Gilbert (2006) pointed out that the mixed results are due to limited data and incorrect identification of industry effects. Gutiérrez and Philippon (2017) proved that competition decreases investment and thus productivity. Cohen (2010) reviewed empirical literature on innovation and firm size, innovation and market power, and innovation and industry structure. Overall, various literature show that the relationship between competition and innovation is indefinite and depends on specific market conditions.

B. Spillovers

Given the accessibility of knowledge, spillover effects should be analyzed. For instance, Cohen and Levinthal (1989) argued that the degree of spillover depends on the firm's ability to assimilate the knowledge. Aghion and Jaravel (2015) provides a review of knowledge spillovers and growth. Moreover, Syverson (2011) overviewed the determinants of spillovers including the domestic and international factors.

The majority of the studies that cover international to firm-level spillovers have emphasized the positive side of R&D spillovers. Numerous empirical research provide evidence that support the existence of knowledge and technology spillovers (Baltagi, Egger, and Kesina 2014; Coe, Helpman, and Hoffmaister 2009). While one set of research is conducted at the country level, others focus on industry and firm-level spillover analyses (Chyi, Lai, and Liu 2012; Higón 2007; Liu and Buck 2007; O'Mahony and Vecchi 2009; Serrano Domingo and Cabrer-Borrás 2016). Previous studies have discovered factors that determine the magnitude of spillover, such as absorptive capacity, competitiveness, export status, and FDI (Foreign Direct Investment) status, among others. Bloom *et al.* (2013) identified the negative side of innovation, the product market rivalry effect. This considers the market stealing effect that arises from innovation efforts and tackles the two opposite sides of technological advances at the firm-level.

Numerous studies have been conducted using Korean data. Cho (2004) compared the elasticity of external investments to that of internal investments and discovered that return is greater from the outside knowledge than from the inside, particularly when employee count is greater than 200. Lee *et al.* (2016) found that R&D spillover effects are restricted to specific industries, and such effects depend on whether the investment is done by public or government-owned firms. Na (2014) summarized the role of parent–subsidiary relationship along with competitiveness on technology spillover and revealed that labor productivity is negatively associated with competitiveness. Furthermore, technology-concentrated industries possess higher marginal benefits from R&D investments. A firm with a parent company will obtain reduced payoff from R&D, while this effect exacerbates when the parent company was in the same industry. Kim and Kim (2013) evaluated the spillover effects through intermediate and capital goods at the industry level. Rather than looking at firm-level R&D expenditure, Kim and Kang (2007) used an alternative method developed through the patent data that was developed by Jaffe (1985). These studies have shown that firm governance characteristic, market competitiveness, technology spillover, and capital intensity fail to contribute to innovation, while human capital investments induces technological progress.

Although numerous studies have discussed spillover effects, innovation, and competition, this study measures the intensity of industry competition and observe how spillover effects and returns to innovation vary. To the best our knowledge, this study is the first to identify the positive and negative effects of spillovers and observe the influence of competition on such effects.

III. Data and Methodology

A. Data

We analyze using three main variables: sales, productivity, and R&D stock. All firm-related data are obtained from Korea Companies Information (KOCOinfo) using Total Solution 2000 (TS-2000). KOCOinfo releases financial statements of public firms and firms subject to external audit. We include firms that are listed under KOSPI or KOSDAQ from 2000 to 2015. Missing values or misreported data, such as sales showing a value of 0 or negative R&D expenditure, were excluded. This paper focuses on manufacturing firms, which constitute nearly two-thirds of the publicly-listed firms (over 1,000 firms) in South Korea. All variables are adjusted for inflation using a GDP deflator from Bank of Korea. Assuming that each firm is represented by Cobb-Douglas production function, labor, capital and sales are the primary control variables used. We subsequently construct R&D stock, positive spillover measurement, and negative spillover measurement for further analysis.

This paper uses 14 manufacturing industry classifications for the analysis. We consider industries that realistically experience spillovers. We refer to the Bank of Korea's Industry Input–Output standards in developing industry classifications. This classification provides a reasonable number of firms with nearly similar technology for each industry. Given that several industries hold only a few firms, we avoid dividing the industries too narrowly so that firms within each industry have technological overlap. Notably, although the number of firms within industries varies significantly, the number itself does not necessarily represent competitiveness.

TABLE 3

INDUSTRY CLASSIFICATION (MANUFACTURING INDUSTRIES ARE SHADED.)

Industry	Industry Code (Medium)	Average # of Firms	HI(2015)
Agriculture		6.73	0.233
Mining		1.77	0.601
Electric, Gas		11	0.448
Sanitary		4.87	0.241
Construction		52.62	0.089
Retail, Wholesale		111.3	0.072
Transportation		24.32	0.134
Food		2.96	0.689
Print, Media, Visual, Information		154.5	0.129
Finance, Insurance		58.66	0.06
Real Estate		5.41	0.382
Technology, Science		95.95	0.098
Food, beverage, tobacco	10, 11, 12	53.75	0.044
Apparel	13, 14, 15	37.77	0.068
Lumber, paper	16, 17	29.51	0.063
Print, recording	18	3.94	0.692
Coals, gas, oil	19	5	0.916
Chemical, medical	20, 21	185.51	0.052
Plastic, non-metal	22, 23	70.74	0.051
Primary metal	24	69.95	0.182
Metal processed products	25	39.9	0.086
Other equipment	29	120.33	0.061
Electronics	26	230.49	0.318
Medical, precise equipment	27	38.17	0.039
Automobiles, trailers	30, 31	99.89	0.117
Furniture, Electronic equipment	28, 32, 33	63.07	0.108

This table shows medium-level industry classifications in Korea. Average firm numbers and Herfindahl Index in 2015 are provided. Shaded cells indicate the manufacturing industries that were used in this paper's analysis.

B. Measurements

Spillover effects are measured using productivity or sales. R&D investments are expected to increase future sales or productivity. Thus, spillover effects from other technology advancements also affect sales and productivity. Sales and R&D expenditure are obtained from each firm's financial statement. We apply the method employed by Levinsohn-Petrin (2003) to quantify TFP and observe the effects of spillover on sales and TFP. Following the study of Helpman and Coe (1995), the results are similar when simple OLS method is used to construct TFP.

R&D stock positively affects firm's sales, which serve as the main factor that increases productivity. Using perpetual inventory method with a depreciation rate of 5%, we determine the amount of R&D knowledge that each firm has accumulated. R&D stock increases with additional R&D expenditure and depreciates at a constant rate. For firms with long R&D history prior to the year 2000, we calculate the average growth rate of R&D expenditure and estimate the R&D stock at the first sample period suggested by Coe and Helpman (1995).

Pool R&D stock (PoolSP), which measures positive knowledge spillover within an industry, is positively correlated with firms' revenues in previous studies. This variable measures the sum of all other firms' R&D stock in the same industry. Thus, firm's own R&D stock is excluded from the pool. This method differs from the method used by Bloom *et al.* (2013) given that patent data is not utilized. Previous studies have focused on firm level interaction and overlap using patent data. This study focuses more on the industry in which firms operate. Furthermore, Kogan *et al.* (2017) pointed out that patents with citations do not always indicate knowledge spillover nor patents of high value. We view the pooled R&D stock as knowledge that is accessible to all firms. Thus, each firm is exposed to the common technology that all firms could exploit.

$$\text{PoolSP}_{\text{i,t}} = \sum_{j \in I \setminus i} \text{R\&D}_{j,t} \tag{1}$$

where $\text{R\&D}_{j,t}$ is R&D stock of firm j at year t. I is the industry that firm i is in. Notably, the amount of positive spillover measure for firm i excludes its own R&D stock. Coe and Helpman (1995) weighed the firms' R&D exposure in terms of trade openness and degree of international trade interaction and measured the amount of knowledge spills across borders. Keller (1998) pointed out that results are similar when R&D stock is not weighted. The same weighing method could be used for firm-level data but is unnecessary because all firms in our data use the same language and operate within the country. This makes their exposure to knowledge similar.

Another spillover measure is identified for product–market rivalry (PMRSP). Although we do not have a detailed firm-level sales data as Bloom *et al.* (2013), we attempt to identify the product–market rivalry (the negative spillover effect) using their approach as the benchmark. We construct our negative spillover measurement considering two channels, namely, sales and R&D. Negative spillover works by removing market shares, thereby decreasing sales. That is, when one's competitors acquire additional knowledge and innovate, their sales consequently increase. When their sales increase, other firms' sales are affected by the business stealing effect, which is the channel of negative spillover. This measure is PMRSP, which is the direct channel. To identify the effect, we first find the market share (s_i) of each firm in its industry and identify the total weighted sales of the industry. The extent of one firm's technological advancements affects other firms relies on that firm's exposure and market power. Own firm's revenue is excluded from this spillover measure. Not weighing other firms' sales to measure the negative spillover effect would be incorrect as that measure simply indicates industry's total sales from last year. Another approach aims to use R&D instead of sales with market share. This method considers an additional step to measuring spillover effect with sales. Bloom *et al.* (2013) introduced this method, which we call PMR_R&D. Consistent with the previous assumption, this paper hypothesizes that as rival firms acquire their own additional knowledge stock, their sales increase, thereby negatively affecting other firms. Rather than looking at sales directly, we observe how the R&D knowledge weighted by a firm's market share affects other firms' sales to measure the negative side of R&D. PoolSP captures the positive side by R&D. By contrast, PMR_R&D represents the negative side, which is the channel through which the sales of non-innovating firms suffer from losing their own market shares. Notably, every firm will be affected differently. For instance, firms with more technological overlap with other rivals will suffer more. To account for that, we scale it to how much a firm is negatively exposed to other firm's R&D stock by multiplying their R&D share (w_i)

in the industry.

$$\text{PMRSP}_{\text{i,t}} = \sum_{j \in I \setminus i} y_{j,t} s_{j,t} \tag{2}$$

$$\text{PMR\_R\&D}_{\text{i,t}} = w_{i,t} \sum_{j \in I \setminus i} \text{R\&D}_{j,t} s_{j,t} \tag{3}$$

PMRSP measures the negative spillover through sales channel, whereas PMR_R&D considers the R&D channel. Both exclude firm *i*'s values. $y_{i,t}$ represents sales of firm *i*, $w_{i,t}$ is the percentage of firm *i*'s R&D stock over the industry's total R&D stock, and $s_{j,t}$ is the market share of firm *j* in industry *I* in year *t*.

We calculate HI to measure the competitiveness of an industry. This index varies across time leaving room for industries to change the level of competition. An HI close to 1 suggests a monopoly market, whereas its value close to 0 indicates a competitive market.

C. Empirical Specification

Our empirical specification is as follows.

$$\begin{aligned} \log\left(y_{i,t}\right) = \alpha_0 + \alpha_1 \log\left(L_{i,t}\right) + \alpha_2 \log\left(K_{i,t}\right) + \alpha_3 \log\left(\text{R\&D}_{i.t-1}\right) \\ +\alpha_4 \log\left(PoolSP_{i,t-1}\right) + \alpha_5 \log\left(PMR_{i,t-1}\right) + \gamma_i + \delta_t + \varepsilon_{i,t} \end{aligned} \tag{4}$$

$$\begin{aligned} \log\left(y_{i,t}\right) = \alpha_0 + \alpha_1 \log\left(L_{i,t}\right) + \alpha_2 \log\left(K_{i,t}\right) + \alpha_3 \log\left(\text{R\&D}_{i.t-1}\right) \\ +\alpha_4 \log\left(PoolSP_{i,t-1}\right) + \alpha_5 \log\left(PMR_{i,t-1}\right) + \alpha_6 HI_{i,t-1} \\ +\alpha_7 HI_{i,t-1} * \log(PoolSP_{i,t-1}) + \alpha_8 HI_{i,t-1} * \log\left(PMR_{i,t-1}\right) + \alpha_9 HI_{i,t-1} \\ * \log(\text{R\&D}_{i,t-1}) + \gamma_i + \delta_t + \varepsilon_{i,t} \end{aligned} \tag{5}$$

$y_{i,t}$ represents sales, L denotes labor, and K represents capital for firm *i* in year *t*. We lag R&D stock and spillover effects to avoid endogeneity issues and because innovations require time to influence the firm's own sales. Previous research (Bloom *et al.* 2013; Coe and Helpman 1995, 2010) have applied the same measurements and found meaningful results. In addition to identifying the two spillover effects using equation (4), we add HI to conduct further analysis in equation (5). Interaction terms indicate how spillover effects change as competition level varies at the industry level. Previous studies have found reasonable results for coefficients α_1, α_2, α_3, α_4, and α_5. Moreover, debates on α_9 exist. To the best of our knowledge, no paper that we are aware of identifies α_7 and α_8 which is the key objective of this paper.

Industry level domestic competition intensity is measured by HI. In addition to domestic competition, we consider whether export status induces changes in the domestic spillovers. Exporters are exposed to international competition in the global market. Thus, they are likely to devote more passion into R&D to survive. We analyze the level of domestic competition and the effects of global competition on domestic spillovers.

Although multiple studies have used sales or value-added for firm-level productivity, which is similar to the study of Bloom *et al.* (2013), several research used a measure of TFP. After running the Levinsohn-Petrin regression, we quantify firm-level TFP by finding the residual.

IV. Results

A. Competition and Spillovers

Table 4 reports two panels, namely, Panel A with PMRSP and Panel B with PMR_R&D. Results are from the fixed-effect Panel regression. Column 1 is nearly the same empirical specification as Bloom *et al.* (2013) and the results are consistent with theirs finding. First column excludes the level of competition. Column 2 includes HI and the association among HI, R&D stock, and spillover effects.

Positive spillover measurement is positively and consistently associated with sales. This finding is expected given that it is consistent with numerous previous studies. As an industry accumulates knowledge from their R&D investment efforts, firms within the industry benefit from increasing sales through innovation. In addition, negative spillover exists through sales channel but not as significantly as through the R&D channel. This suggests that other firm's R&D policy does not directly affect sales, only the relative sales with market share does. Interaction term between HI and R&D stock indicates that as competition decreases, firms benefit more from their own R&D. This supports the claim that monopolies have greater incentives to innovate. The positive and negative spillover effects increase by reducing competition. Markets with high HI hold few firms that dominate the market. Thus, their innovations are easy to observe. Firms in industries with high concentration and low competition produce similar products, thereby magnifying the spillover effects. We see that the coefficients of two spillover interaction terms sum up to a negative number. Ultimately, if HI increases and the market becomes less competitive, one firm's innovation negatively affects sales of other rival firms even after identifying the positive and negative roles separately. The results

Table 4
Competition and Productivity Spillover

Panel A

VARIABLES	(1) ln(Sales)	(2) ln(Sales)
ln(Labor)	0.673***	0.674***
	(59.57)	(59.66)
ln(Capital)	0.111***	0.111***
	(16.01)	(16.10)
Lag.ln(R&D stock)	0.029***	-0.006
	(5.09)	(-0.74)
Lag.ln(PoolSP)	0.215*	0.608***
	(1.68)	(3.80)
Lag.ln(PMRSP)	-0.062***	-0.054***
	(-6.95)	(-4.90)
Lag.HHI_sales		0.834
		(0.59)
Lag.HHI*R&D		0.201***
		(6.51)
Lag.HHI*PoolSP		0.344***
		(3.66)
Lag.HHI*PMRSP		-0.487***
		(-4.95)
Constant	11.299***	0.455
	(3.06)	(0.10)
Observations	10,960	10,960
R-squared	0.6142	0.6164
Number of id	1,015	1,015
Year Effect	Yes	Yes

This panel uses PMRSP to show the spillover effects through sales channel. Year effect is considered in this fixed-effect panel regression. The dependent variable is log of sales. T-statistics are enclosed in parentheses, and *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel B

VARIABLES	(1) ln(Sales)	(2) ln(Sales)
ln(Labor)	0.686***	0.687***
	(62.06)	(62.16)
ln(Capital)	0.106***	0.107***
	(15.63)	(15.84)
Lag.ln(R&D stock)	0.033*	-0.036
	(1.81)	(-1.59)
Lag.ln(PoolSP)	0.306**	0.545***
	(2.38)	(3.83)
Lag.ln(PMR_R&D)	-0.001	0.050**
	(-0.04)	(2.27)
Lag.HHI_sales		-4.103***
		(-3.97)
Lag.HHI*R&D		0.110***
		(4.01)
Lag.HHI*PoolSP		0.751***
		(6.25)
Lag.HHI*PMR_R&D		-0.710***
		(-6.35)
Constant	7.095*	0.687
	(1.94)	(0.17)
Observations	11,501	11,501
R-squared	0.6125	0.6149
Number of id	1,038	1,038
Year Effect	Yes	Yes

This panel uses PMR_R&D to show the spillover effects through sales channel. Year effect is considered in this fixed-effect panel regression. The dependent variable is log of sales. T-statistics are enclosed in parentheses, and *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

differ slightly in Panel B where net effect is positive with respect to HI.

B. Export Status and Spillover

Korea is an export-oriented country. Thus, Korean firms are highly active in the global market. We assess whether exporting firms are more susceptible to spillover effects than non-exporting firms. First, we distinguish export-leaders and export-followers by looking at their export amount within the industry. We classify a firm as export-leader if its export value is greater than 1% of total industry's export amount. If a firm exports less than 1% or does not export at all, then that firm is an export-follower. We use this method to identify significant exporters in the industry. Subsequently, we assign a value of 1 for export-leaders and 0 for export-followers. A total of 351 export-leaders and 967 export-followers are identified. This method is time varying, which means that firms could change their status annually. We include their

Table 5
Exporters and Spillover

Panel A

VARIABLES	(1) ln(Sales)	(2) ln(Sales)
ln(Labor)	0.669***	0.668***
	(59.17)	(59.13)
ln(Capital)	0.108***	0.108***
	(15.70)	(15.70)
Lag.ln(R&D stock)	0.025***	0.025***
	(4.42)	(4.41)
Lag.ln(PoolSP)	0.053**	0.054**
	(2.50)	(2.52)
Lag.ln(PMRSP)	-0.069***	-0.070***
	(-7.29)	(-6.64)
Export Dummy	0.095***	0.094***
	(7.56)	(6.41)
Lag.Export*PoolSP		-0.003
		(-0.31)
Lag.Export*PMRSP		0.003
		(0.32)
Constant	16.376***	16.387***
	(31.81)	(31.75)
Observations	10,960	10,960
R-squared	0.6165	0.6165
Number of id	1,015	1,015
Year Effect	Yes	Yes

This panel explores the spillover effects through sales channel with consideration of the export status. Export leaders are firms that export more than 1% of the industry's exports. This panel uses PMRSP. Year effect is considered in this fixed-effect panel regression. The dependent variable is log of sales. T-statistics are enclosed in parentheses, and *, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

export status in the interaction terms. Table 5 reports the findings. Export-leaders are assumed to have higher sales than export-follower firms. Coefficient of export-leader dummy that shows a positive value indicates that exporting firms tend to have higher sales than non-exporting firms. Column 2 shows the relationship between export status and spillovers. In both panels, the positive and negative effects are insignificantly related to competition. This finding is reasonable given that our measurements for spillover effects included only domestic firms. Whether firms export or not have no significant influence on

Panel B

VARIABLES	(1) ln(Sales)	(2) ln(Sales)
ln(Labor)	0.684***	0.683***
	(61.98)	(61.88)
ln(Capital)	0.104***	0.104***
	(15.33)	(15.31)
Lag.ln(R&D stock)	0.029	0.030
	(1.60)	(1.64)
Lag.ln(PoolSP)	0.376***	0.385***
	(2.93)	(2.99)
Lag.ln(PMR_R&D)	0.001	0.001
	(0.05)	(0.05)
Export Dummy	0.095***	0.091***
	(8.02)	(6.50)
Lag.Export*PoolSP		0.006
		(1.13)
Lag.Export*PMR_R&D		-0.007
		(-1.07)
Constant	5.183	4.932
	(1.42)	(1.34)
Observations	11,501	11,501
R-squared	0.6148	0.6149
Number of id	1,038	1,038
Year Effect	Yes	Yes

This panel explores the spillover effects through sales channel while considering export status. Export leaders are firms that export more than 1% of the industry's exports. This panel uses PMR_R&D. Year effect is considered in this fixed-effect panel regression. The dependent variable is log of sales. T-statistics are presented in the parenthesis and *, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

domestic spillovers as shown by Panel A and Panel B.

C. Productivity, Spillovers and Competition

We use the Levinsohn-Petrin methodology to calculate our measure of TFP. This method allows us to address the endogeneity issues underlying in capital, which were addressed by Olley and Pakes

Table 6
Total Factor Productivity and Spillover

VARIABLES	(1) TFP	(2) TFP	(3) TFP	(4) TFP
Lag.ln(R&D stock)	0.081***	0.059***	0.087***	0.040
	(10.91)	(5.78)	(3.51)	(1.26)
Lag.ln(PoolSP)	0.674***	1.142***	0.831***	0.869***
	(3.82)	(5.66)	(4.68)	(4.87)
Lag.ln(PMRSP)	-0.090***	-0.081***		
	(-7.34)	(-5.33)		
Lag.HHI_sales		-0.247		-1.283***
		(-0.70)		(-3.95)
Lag.HHI*R&D		0.121***		0.021
		(2.98)		(0.58)
Lag.HHI*PoolSP		0.497***		0.328*
		(3.75)		(1.75)
Lag.HHI*PMRSP		-0.536***		
		(-4.01)		
Lag.PMR_R&D			-0.000	0.044
			(-0.01)	(1.44)
Lag.HHI*PMR_R&D				-0.332*
				(-1.74)
Constant	0.479	-12.789**	-6.398	-7.241
	(0.09)	(-2.19)	(-1.27)	(-1.43)
Observations	9,430	9,430	9,839	9,839
R-squared	0.2433	0.2458	0.2376	0.2395
Number of id	941	941	964	964
Year Effect	Yes	Yes	Yes	Yes

This table shows how TFP is related to spillover effects. In addition, spillover effects with competitiveness is considered. Year effect is considered in this fixed-effect panel regression. Dependent variable was a measure of total factor productivity. T-statistics are enclosed in parentheses, and *, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

(1996). Intermediate input costs along with labor and capital are used to calculate TFP in this study. Those variables are excluded from the regression because they have been used to find the residual.

Table 6 presents the analysis results using TFP as the dependent variable. Columns 1 and 3 include the R&D stock and spillover effects. Column 1 uses PMRSP, whereas Column 3 uses PMR_R&D. Columns 2 and 4 use the interaction terms with HI. Results are slightly parallel with that in Table 4. Evidently, positive effects are represented by positive coefficients across the columns, whereas negative spillover effects appear only for PMRSP. Therefore, negative spillover effect is evident on TFP channels through sales and not through R&D. Coefficients of R&D stock and HI*R&D in Column 2 suggest that competition intensity reflects the amount of a firm's return from its own innovation effort. Returns on R&D stock to TFP increases as HI increases. The effect of positive and negative spillover strengthens as HI increases. Furthermore, the net effects of total spillover effects (-0.04 from Column 2 and -0.006 from Column 4) are negative as competition decreases.

D. Competition and R&D

In this section, we determine how a firm's innovating behaviors change due to competition level and spillover measures. Here, we evaluate R&D stock as the dependent variable. R&D expenditure was not used because there are many internal factors not related to competition that drive changes in yearly R&D spending. To smooth out that effect, R&D stock is used for our analysis. Following the previous method, we initially use HI to measure an industry's competitiveness and observe that firms in industries with high HI tend to have low R&D stock. The effects of spillovers vary depending on the construction. Columns 1 and 2 of Panel A under Table 7 report the analysis results including HI. R&D stock decreases as an industry accumulates knowledge. This finding can be explained by the firms' lack of interest to invest in R&D because a substantial amount of knowledge is already accessible. The interaction terms illustrate inconsistent patterns for R&D stock.

An alternative measure for competitiveness is used to explore observable patterns for R&D stock. We use the number of firms in the industry as a substitute for competition level in Panel B. When number of firms in the industry is used, results are slightly different from when HI is utilized. In particular, positive spillover measure is positively associated with R&D stock. We observe that the relationship between R&D stock and spillover measurements are sensitive to empirical specification. Negative spillover measure negatively influences R&D stock through the sales channel, while it positively affects R&D through R&D channel. For both channels, an increase in the number of firms slightly strengthens spillover effects.

Table 7
R&D and Spillovers

Panel A HI

VARIABLES	(1) R&D	(2) R&D
Lag.ln(PoolSP)	-1.445***	-0.656***
	(-5.06)	(-3.08)
Lag.ln(PMRSP)	-0.045**	
	(-2.21)	
Lag.HHI_sales	-9.761***	-5.165***
	(-3.74)	(-3.30)
Lag.HHI*PoolSP	0.459***	0.186
	(2.66)	(1.04)
Lag.HHI*PMRSP	-0.103	
	(-0.61)	
Lag.PMR_R&D		0.095***
		(70.03)
Lag.HHI*PMR_R&D		-0.018
		(-0.11)
Constant	61.096***	36.422***
	(7.39)	(6.00)
Observations	11,958	12,514
R-squared	0.5187	0.6596
Number of id	1,074	1,096
Year Effect	Yes	Yes

This table shows how R&D stock is related to spillover effects. In addition, the influence of competitiveness on spillover effects is considered. Herfindahl Index is used to measure competitiveness. Year effect is considered in this fixed-effect panel regression. The dependent variable is R&D stock. T-statistics are enclosed in parentheses, and *, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

Panel B Number of Firms

VARIABLES	(1) R&D	(2) R&D	(3) R&D	(4) R&D
Lag.ln(PoolSP)	0.520*	0.916***	1.806***	1.387***
	(1.77)	(3.76)	(4.84)	(4.75)
Lag.ln(PMRSP)	-0.100***		-0.022	
	(-6.03)		(-1.03)	
Lag.PMR_R&D		0.094***		0.119***
		(69.38)		(42.97)
Lag.Num of firms	0.007***	0.005***	-0.024***	-0.019***
	(14.22)	(11.53)	(-3.24)	(-3.35)
Lag.Num*PoolSP			0.003***	0.001***
			(6.77)	(4.88)
Lag.Num*PMRSP			-0.002***	
			(-6.29)	
Lag.Num*PMR_R&D				-0.000***
				(-10.40)
Constant	5.927	-8.829	-32.337***	-22.420***
	(0.70)	(-1.27)	(-3.02)	(-2.70)
Observations	11,958	12,514	11,958	12,514
R-squared	0.5267	0.6629	0.5288	0.6663
Number of id	1,074	1,096	1,074	1,096
Year Effect	Yes	Yes	Yes	Yes

This table shows how R&D stock is related to spillover effects. In addition, the influence of competitiveness on spillover effects is considered. The number of firms in an industry is used to measure competitiveness. Year effect is considered in this fixed-effect panel regression. The dependent variable is R&D stock. T-statistics are enclosed in parentheses, and *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

V. Conclusion

Knowledge is omnipresent in a computerized and cloud-based world. Firms may face legal boundaries from imitating a technology or a product. Thus, firms continuously exert efforts to adapt to new competitive environments and search for new consumer markets. However, these interactions exhibit benefits and consequences to firms. Benefits arise from aggregate technological knowledge accumulation that incentivizes all firms to pursue innovation and induces improved productivity for all. Consequences occur when a firm increases market share, thereby negatively affecting rival firms in their individual efforts to innovate. Therefore, the positive and the negative spillover effects are evaluated.

Using the data on Korean firms, we find that the positive and negative effects of spillover exist and the magnitudes of such effects are affected by the market's competitiveness. Sales, productivity, and R&D behaviors are all affected by spillovers and competitions. In general, the decrease in market competition, which is indicated by an increase in HI, increases the spillover effects. Oligopolistic markets experience increase in positive effect because they may overlap in technology. Moreover, one observable discovery may induce other additional findings. In a competitive industry, a firm's R&D stock may not be as influential as the others'. By contrast, negative effects may be stronger for oligopolistic markets than for other market types owing to a firm's dominance over its competitors and the business stealing effect. When a firm innovates, increasing sales and productivity may not be obvious in competitive industries. Thus, oligopoly firms may suffer significantly from its competitors' success through innovation.

Competition and spillovers are significant in the context of Korea, particularly because of its highly concentrated markets. Historically, R&D has helped economies grow and firms expand into new frontiers. Needless to say, Korea has benefitted from being at that frontier in the international market for the last few decades. How Korean firms continue to make their stand against new competitive, global rising stars now is an issue. Local policies and regulations should be developed by precisely looking at the competition level and spillover channels to correctly identify the benefits from innovation and returns of R&D investments.

Further research could explore the difference and determine which is more significant between domestic and international spillover effects. Furthermore, studies that clarify the relationship between R&D behavior and spillover measurements would certainly enrich the literature.

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