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R&D Effects on Firm Productivity, Exports, and OFDI: Korean Firm-Level Analysis

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1. Korean R&D Investment Trends After 2000

A firm's investment in research and development (R&D) activities is considered a crucial factor in the survival of a firm in the global market. In order to maintain its competitiveness in an industry that is changing swiftly, firms are required to innovate, by rolling out a range of new products, as well as improve product quality. In acknowledgement of R&D's significant influence, a large number of countries are implementing policies that can encourage firms to invest in R&D activities, for instance by subsidizing or allowing tax deduction on firms that operate R&D activities. In addition to financial support, countries are also amending systems or abolishing regulations that impede R&D investment. For instance, Korea is allowing deduction on income and corporate taxes for small and medium enterprises and venture firms that invest in technology innovation, and also supporting educational training programs for employees in small and medium enterprises.

As for the Korean case, Korean R&D investment can be divided into government and private sector R&D; private sector R&D accounted for an average 75% of total R&D investment and showed rapid increase during the last decade, while government sector R&D experienced slow growth during the same period. Within private sector R&D investment, in particular, firm R&D investment accounted for an average 78%, and showed an annual increase of 12.7% during the last decade; a large part of firm R&D investment being made from manufacturing industry sectors, which accounted for more than 90% of total firm R&D investment. Table 1 shows the top five R&D intensive Korean manufacturing sectors in 2012.

Table 1: Top five R&D intensive manufacturing sectors in 2012 (billion Korean won, %)

Rank	Industry sector	R&D investment amount	Share
1	Electronic components	20,391	56.9
2	Motor vehicles and trailers	4,752	13.3
3	Chemical products	3,016	8.4
4	Other machinery equipments	2,396	6.7
5	Electrical equipment	923	2.6

It can be observed from the table that most R&D intensive sectors are also capital-intensive, such as the electronic components, motor vehicles and trailers, chemical products, and electrical equipment sectors, where the electronic components sector accounts for more than half of total manufacturing R&D investment. While Korea shows a high level of firm R&D investment, mostly from manufacturing firms, which surpasses that of the United States, Japan, and China, little work has been done on analyzing its effects on firm performance. Using Korean firm-level data, this report analyzes the effects of firm R&D on firm performance, particularly on firm productivity, exports, and outward foreign direct investment (OFDI).

2. Firm R&D Effects on Firm Performance

There exist substantial bodies of work on examining the effects of firm R&D on firm growth and firm performance. In analyzing firm R&D effects on firm growth, for instance, prior studies have found that firm R&D has a positive impact on firm growth, with a time gap, in terms of sales and employment growth (Banbury and Mitchell, 1995; Yang and Lin, 2008; Coad and Holzl, 2009). In regards to firm performance, substantial empirical literature have found that firm R&D investment is positively and significantly associated with firm productivity growth (Griliches and Mairesse, 1981; Miresse and Sassenou, 1991), with firm exports (Basile, 2001; Tomiura, 2007; Yang and Chen, 2012), and with the probability that firms engage in OFDI (Kogut and Chang, 1991, Lin and Yeh, 2005; Lu et al., 2011), respectively. While this report lies in line with aforementioned studies by empirically analyzing firm R&D effects on firm performance, this report further explores the pathway connection between the two. That is, we not only examine firm R&D effects on particular firm performance, but also study the significance of firm productivity as a pathway that links firm R&D with firm exports and OFDI by using Korean firm-level data.

To evaluate the effects of Korean firm R&D effects on productivity, exports, and OFDI, we use Korean manufacturing firm data listed on the Korea Composite Stock Price Index (KOSPI) and Korea Securities Dealers Automated Quotations (KOSDAQ) between 2003 and 2011. We consider firms that are listed on the KOSPI and KOSDAQ since information on these firms, such as account variables and R&D expenditures, are most complete and reliable for empirical analysis. Furthermore, we examine firm R&D effects after 2000, due to the revision of Korean firm accounting standards in 1998. In particular, while R&D investment was reported as firm asset before the revision, it is now being captured by firm expense.

For empirical specification, we use firm's R&D expenditures that are reported on profit and loss statements and manufacturing statements to measure firm R&D investment and use firm export sales to represent firm exports. To measure firms' engagement in OFDI, on the other hand, we additionally use foreign affiliate-level data of Korean firms that includes the full list of Korean worldwide investment from 2003 to 2011, where all foreign affiliates that operate business abroad are linked to Korean parent firms. By matching these foreign affiliates to their parents firms, we use the total amount of investment transferred from parent firms to foreign affiliates to represent firms' engagement in OFDI. To capture firm productivity, we estimate total factor productivity (TFP) by using the Olley and Pakes (1996) methodology, which introduces a semiparametric method to correct simultaneity and selection biases that arise from estimating the Cobb-Douglas production function through the Ordinary Least Squares method.

3. Results

Using firm account measures that represent firm performance, Table 2 presents the results from estimating firm R&D effects on firm productivity, exports, and OFDI. Taking account of prior studies that found firm R&D has a significant impact on firm growth and internal performance with a time gap, we additionally included lagged R&D variables to evaluate how firm R&D affects firm performance over the time period. Our estimation results indicate that firm R&D has positive and significant effects on firm productivity and exports over time, while firms' prior R&D investment only has a significant impact on OFDI. The magnitude of firm R&D effects implies that firm R&D becomes more effective on firm performance over time.

Table 2: Estimation results of firm R&D impact on firm performance

Variables	TFP			Exports			OFDI		
$R\&D_t$	0.062** (0.01)			0.067** (0.015)			0.151 (0.207)		
$R\&D_{t-1}$		0.175** (0.026)			0.075** (0.015)			-0.172 (0.127)	
$R\&D_{t-2}$			0.047** (0.01)			0.082** (0.015)			0.143* (0.074)
Number of observations	7644	6653	5156	10233	10108	9863	5980	6019	5071
R^2	0.395	0.384	0.388	0.2309	0.2336	0.2322	-	-	-

Note: R&D effects on TFP and exports were estimated through the two-stage tobit regression, while R&D effects on OFDI were estimated through difference GMM. All regressions include time- and industry-fixed effects and control variables that represent firm characteristics. We do not report these estimates in the table to save space. **/* denote statistically significant at the 1% and 10% level, respectively.

Our estimation results on firm R&D effects suggest that firm R&D significantly heightens firm performance, particularly by showing stronger impact on firm performance over time. However, firm R&D may have different consequences on firm performance through different channels. In regards to firm exports and OFDI, for instance, firm R&D may have direct effects on exports and OFDI, while it may trigger other processes in prior to affecting exports and OFDI. To provide an in-depth analysis on firm R&D effects, we use a triangular structural equation model to consider firm productivity as a mediator variable that links firm R&D with firm exports and OFDI and estimate direct and indirect firm R&D effects with and without incorporating firm productivity in the model. Therefore, direct firm R&D effects measure how firm R&D affects exports and OFDI without firm productivity change, while indirect firm R&D effects measure how firm R&D affects exports and OFDI through firm productivity change. Table 3 presents the estimation results of direct and indirect effects of firm R&D on exports and OFDI.

Table 3: Direct and indirect effects of firm R&D through TFP estimates

R&D Effects	Exports					OFDI				
	Full Sample	Electronic components	Motor vehicles	Food	Textile and apparel	Full Sample	Electronic components	Motor vehicles	Food	Textile and apparel
Total Effects	0.405**	0.285**	0.45**	0.735**	-0.07	0.273**	0.335**	0.378**	0.24*	-0.035
	(0.024)	(0.054)	(0.041)	(0.075)	(0.16)	(0.019)	(0.037)	(0.04)	(0.12)	(0.157)
Direct Effects	0.231**	0.255**	0.41**	0.732**	-0.005	0.157**	0.245**	0.168**	0.21	-0.05
	(0.023)	(0.056)	(0.042)	(0.072)	(0.142)	(0.019)	(0.038)	(0.045)	(0.13)	(0.188)
Indirect Effects	0.174**	0.03**	0.039**	0.002	-0.065	0.116**	0.089**	0.21**	0.03	0.014
	(0.014)	(0.014)	(0.014)	(0.02)	(0.07)	(0.011)	(0.019)	(0.033)	(0.04)	(0.093)
Share of TFP (%)	42.9	10.7	8.7	0.35	93.1	42.4	26.6	55.6	12.2	38.2
Number of obs	1735	352	268	27	33	1075	310	203	34	16

Note: Share of TFP implies percentage of firm productivity (TFP estimates) that explains total R&D effects on exports and OFDI that are mediated by firm productivity change. **/* denote statistically significant at 1% and 10% level. All standard errors in parenthesis are calculated by using delta method (Sobel (1986) and MacKinnon et al. (2002)). All regressions include year- and industry-specific fixed effects.

Using a full sample, we find that firm R&D has significant effects on export and OFDI increase directly and indirectly through TFP estimates increase, where its magnitude of effectiveness is stronger on exports than OFDI and the magnitude of direct effects are larger than indirect effects through firm productivity. On the other hand, estimation results from dif-

ferent industry sectors imply that firm R&D has a different effectiveness on exports and OFDI across industry sectors. For instance, while firm R&D appears to be effective on export and OFDI increase among capital-intensive sectors, such as electronic components and motor vehicles sectors, directly and indirectly through firm productivity, it does not exhibit a significant influence among labor-intensive sectors.

4. Policy Implications

Our estimation results provide significant implications on firm R&D activities. The results on firm R&D increasing firm productivity, exports, and OFDI suggest that R&D promotion policies towards the private sector are effective for improving firm performance in which could contribute to trade and economy growth at the country-level. While firm R&D promotion policies are recommended, these policies would yield more effective consequences if they are targeted at specific industry sectors. In regards to our results, for instance, R&D promotion polices towards firms inside capital-intensive sectors would be better off than polices towards firms inside labor-intensive sectors. Furthermore, it should be noted that different R&D activities have different effects across different sectors. For instance, policies that support firms to invest in R&D activities that can improve firm efficiency may see greater impact on export and FDI increase for sectors that require complicated production process, such as the motor vehicles and trailers, while supporting firms to invest in R&D activities that directly affects exports and OFDI sales would be better off for sectors that produce high-quality goods, such as the electronic components. KIEP

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