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Technical Innovation and Export Activities of Small and Medium-Sized Firms in Korea

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Abstract This paper empirically analyzes the technical efficiency of small and medium-sized firms' R&D activities and the effect of the efficiency on those firms' export performance in Korea. Theoretically, since more efficient firms tend to be more competitive in the quality or price of their products, their sales on foreign markets would be relatively higher. Especially, this trend is likely to be deepened in the 4th industrial revolution era where cutting-edge technologies (e.g., AI and big data) are emphasized. Empirical results of the paper using Korean data show that the technical efficiency of small and medium-sized firms' R&D activities measured by the data envelopment analysis enhances their sales on foreign market. This relationship becomes more obvious as the firms become larger. However, as the size of a firm is larger, it is more likely to use technologies related with big data, cloud computing, IoT, and so on. These findings imply that the improvement of technical efficiency would gain more emphasis for the increase in the small and medium-sized firms' sales on foreign markets as the technologies representing the 4th industrial revolution are utilized more.

Keywords technical innovation · export, 4th industrial revolution · DEA · PSM
JEL classification L21 · L25

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Introduction

As more globalization make both consumption and production becomes more closely related among countries, international transactions would become more competitive. Meanwhile, the employment share of small and medium-sized firms in a national economy is higher than the globalized large enterprises. The importance of small and medium-sized firms with respect to job-creation becomes more emphasized as the concerns on jobs in the future become larger due to the 4th industrial revolution which represents the drastic change in technologies. Since small and medium-sized manufacturers tend to be less competitive in price, design, brand recognition, marketing channel, and so on, it is often argued that to obtain their competitiveness through the technical innovation in either products or production process is one of the realistic policy options in order to succeed on foreign markets. However, the empirical results that show the relationship among efficiency in R&D, export, and adaptation to 4th industrial revolution at the individual firm level are quite limited.

This paper empirically analyzes the relationship between technical innovation and export, then shows how it would change as the firms become more adaptive to 4th industrial revolution. The empirical findings of this paper would shed light on policy implications on the way for small and medium-sized firms to survive in the 4th industrial revolution era.

The next section reviews previous studies on the connection between technical innovation and export of SMEs and suggests identification strategies. Section 3 explains the data used for regression analyses with descriptive statistics of variables. Empirical findings are discussed in Section 4 and the last section concludes with key findings and policy implications.

Theoretic Background and Analytic Model

Theoretic Background

A firm's R&D investment would enhance its productivity, and thus it would experience an increase in profits and face a rise in demand for its product on foreign markets (Vuong et al., 2016). Technical innovation from R&D investment allows the firm to develop new products or improve the function or design of existing products. New innovative production process from the R&D activities brings about higher efficiency possibly through the reduction in production costs. Better quality or higher competitiveness in price leads to a rise in export of the products to other countries. Especially, export entails fixed costs that less efficient firms cannot bear. Empirical results from the developing as well as developed countries including US and Germany seem to be consistent to the theoretic arguments (e.g., Aitken et al., 1997; Bernard and Jensen, 1999; Bernard and Wagner, 1997; Clerides et al., 1998; Hong, 2015; Koenig, 2009; Roberts and Tybout, 1997).

However, D'Angelo (2012) argues that it is necessary to distinguish between input and outcome index of technical innovation when the effect of technical innovation on export is evaluated. His results on small- or medium-sized firms with high technology in Italy indicate that labor in R&D among input index show significant effects and the number of product innovations and the increase in sales induced by R&D activities significantly raise export.

Literature on this topic agrees that there would appear a strong positive relationship among technical innovation, export, and productivity (or growth). In particular, technical innovation and export have an influence of small- or medium-sized firms' productivity or growth, and they seem to be interdependent. Moreover, more efficient firms are likely to self-select by devoting more efforts to innovate technically and sale their product on foreign markets.

Analytic Model

To analyze the effect of the efficiency in technical innovation, the efficiency in R&D activities needs to be measured. In this paper, it is based on data envelop analysis (DEA).[1] As in Kim et al. (2013), the outcome from R&D activities can be distinguished into two parts: technical outcome and economic outcome. The former is measured by the number of successful R&D and the latter is measured by R&D-induced sales. As inputs of R&D activities, the number of full-time workers as well as technical level, stage of growth, years since its establishment, and characteristics of CEO. The measure of efficiency is input-oriented and assumed constant returns to scale.

The main hypothesis of this paper (i.e., the effect of technical innovation efficiency on the export of small- and medium-sized firms) is tested by estimating following regression equation:

$$E_j = \beta_0 + \beta_1 TE_j + \Sigma_g^{16} \gamma_g \, region_j + \Sigma_h^{23} \tau_h \, industry_j + u_j \quad (1)$$

Here, E_j indicates firm j's amount or share of export induced by the firm's technical innovation. TE_j belongs to the degree to which the firm is technically efficient and is measured by DEA on the firm's R&D activities. $region_j$ and $industry_j$ are metropolitan city/province where the firm locates and two-digit manufacturing industry to which the firm belongs, respectively. u_j represents the usual error term.

Data and Variables

Data

For the empirical analyses, this paper draws upon *Survey on Technology of SMEs* which includes information on R&D activities, type of organization, employment, level of technology, and so on for samples of small- or medium-sized firms mainly in manufacturing sector. The population is SMEs having at least five and less than 300 workers and belonging to manufacturing

[1] Technical efficiency can also be measured through a stochastic frontier model. However, DEA does not require an assumption on the functional form in estimating a firm's production function, does not distinguish ex ante the importance between output and input in a firm's decision making, and has an advantage of similarity in measuring efficiency between input-oriented and output-oriented cases (Gussoni, 2009). Since DEA derives the envelop curve from the most efficient a few firms' input-output combinations, the results are sensitive to the bias in measuring input and out itself. If too many inputs are considered, most of the firms can be judged to be efficient (Leibenstein and Maital, 1992).

or business service industries. There are 3,300 firms in 2015, but we restrict samples for analyses to manufacturing sector and it results in 2,463 firms.

Table 1 Relationship between technical level and export of small- or medium-sized firms

Year	Share of exporters (%)			Contribution of technical innovation in export (%)		
	High	Medium	Low	High	Medium	Low
2007	59.3	58.7	38.0	35.0	27.3	27.7
2009	44.6	41.3	25.9	33.6	22.9	25.1
2011	34.0	38.8	20.3	25.8	17.8	14.5
2013	31.0	29.8	21.3	30.4	25.6	25.3
2015	36.8	25.1	16.6	22.7	21.5	15.5

Note: Statistics on SME's Technology by KBIZ and MSS

Table 1 shows the relationship between technical level and export over 2007~2015. Although it is just based on repetitive cross-sectional observation, the tendency that higher technical level is linked to higher share of exporters seems to appear over the period except 2011. In additional, when we divide the total amount of export into one from exporting existing products and the other from export derived by technical innovation, the latter is likely to increase as the technical level becomes higher. It sheds light on the importance of technical innovation in SMEs' export.

Variables

Table 2 reports descriptive statistics of variables indicating characteristics of the firms drawn upon for our empirical analyses in this paper. About half of the samples belong to general SMEs having no certificates such as Venture or Inno-Biz. The shares of firms by the technical level are 11.1% for high, 61.0% for medium, and 27.9% for low. Based on the stage of growth, firms can be divided into subsamples at four stages: entry to market, growth, mature, and decay. Their shares are 4.3%, 47.0%, 46.2%, and 2.5%, respectively. Firms' age is 14.9 years on average, and the number of regular workers is approximately 50. About 92.3% of CEOs are male, and the average age of CEOs is 54.

Table 2 Summary statistics

	Mean	Standard deviation
Level of technology		
High	0.111	
Medium	0.610	
Low	0.279	
Stage of growth		
Entry	0.043	
Growth	0.470	
Mature	0.462	
Decay	0.025	
Age	14.9	9.9
Employment	49.8	56.0
CEO		
Male	0.923	
Age	54.3	8.6

Empirical Results

Effect of technical innovation on export

Table 3 presents the estimation results for the effect of efficiency in technical innovation on export. The dependent variable is technical innovation-oriented foreign sales in Column (1) and (2) but in Column (3) and (4) it is divided by total foreign sales.[2] Since the data used for regression analyses in this paper are not panel, it is possible to track down individual firm's foreign sales up to two years in the past. Also, the firms which have already been exporting their products would have more information on the technologies required to increase their foreign sales. In this case, the contribution of technical innovation to export seems to be relatively larger. Due to these two plausible reasons, the amount of total foreign sales is controlled for in the last two columns.

According to the result in Column (1), the firms with high technical level, belonging to mature stage in life-cycle, employing more full-time workers tend to have relatively larger foreign sales caused by technical innovation. In Column (2) where the characteristics of firms are replaced by the technical efficiency measured by DEA, the more technologically efficient firms are likely to achieve more foreign sales. However, as seen in Column (3) the contribution of technical innovation to export is higher when firms and CEO are older. The result reported in the last column confirms the key fining of this paper that firms which are more efficient with respect to technologies tend to have higher portions of foreign sales indebted to technical innovation.

The results in Table 3 need additional analyses in two aspects. In general, the outcomes of R&D activities show up with time lag. Especially, when the outcome is economic one (e.g., sales) rather than technical one (e.g., patents), it can be observed with longer time lag. Thus, it is not clear whether the results in Table 3 show the effect of technical innovation on export or the improvement of technical efficiency through export.[3] Also, 1,746 firms out of 2,463 firms (i.e., 70.9%) do not export and it would negatively affect the explaining power of the variables.

Table 4 shows the mean difference in efficiency between exporters and non-exporters based on propensity score matching to tackle two possible limits on Table 3.[4] Table A1 in the appendix shows the estimation results of a logit model to match exporters with non-exporters having similar characteristics. The probability for firms to export their products is relatively lower when they belong to market-entry in growth stage, but higher when they are older or larger with respect to employment. The technical level also affects the likelihood to export significantly. According to the results in Table A2, the remarkable reduction in heterogeneity between the

[2] Column (3) and (4) are estimated by Tobit model because the dependent variable ranges between 0 and 100 and is censored on both sides.

[3] The former indicates self-selection in which more efficient firms would have higher probability to participate in foreign markets while the latter implies learning-by-doing effect in which exporters would confront more competitive business environment in foreign markets and be forced to learn tacit knowledge including new technologies in order to survive.

[4] The data used in this paper do not include individual firms' information both before and after export. Thus, more sophisticated techniques like difference-in-differences are not applicable. The results based on PSM as an alternative method still contain the bias from unobservable heterogeneity.

two groups through matching is noticed. As seen in Table 4, the statistically significant difference in efficiency in R&D activities between exporters and non-exporters before matching does not appear. But after matching exporters compared to non-exporters seem to have relatively higher efficiency and this result is consistent to those shown in Table 3.

Table 3 Estimation results for the effect of efficiency in technical innovation on export

	Export due to technical innovation (in billions of Korean Won)		Contribution of technical innovation in export (%)	
	(1)	(2)	(3)	(4)
Level of technology				
High	0.1675^{+}		9.544	
	(1.82)		(1.56)	
Low	-0.1290		-14.984**	
	(-1.41)		(-6.54)	
Stage of growth				
Entry	0.1743		-15.131	
	(1.17)		(-1.63)	
Growth	0.3160^{+}		3.839^{+}	
	(2.12)		(1.67)	
Decay	-0.0610		-3.560	
	(-0.41)		(-0.38)	
Age	0.0042		0.325**	
	(0.55)		(2.67)	
Employment	0.0106**		0.029	
	(5.05)		(0.92)	
CEO				
Male	0.1140		4.665	
	(1.56)		(0.93)	
Age	0.0070		0.223^{+}	
	(1.44)		(1.84)	
Efficiency		1.0401**		18.315**
		(5.85)		(4.82)
Export			0.001**	0.001**
			(5.16)	(5.28)
Constant	-1.2855**	-0.2655**	-55.065**	-35.806**
	(-4.58)	(-1.54)	(-5.82)	(-5.76)
Fixed Effect				
Region	15	15	15	15
Industry	23	23	23	23
Number of Observations	2,463	2,463	2,463	2,463
Left censored			1,878	1,878
Right censored			14	14
Adj. R^2 / Pseudo R^2	0.0965	0.0407	0.0716	0.0655

Note: Numbers in parentheses are White-Huber's robust t-values assuming errors are correlated within a region. **, *, and $^{+}$ indicate statistical significance at 1%, 5%, and 10%, respectively. The reference groups for the level of technology and the stage of growth are medium-technology and matured stage, respectively.

Table 4 Difference in efficiency in R&D activities between exporters and non-exporters

	Exporters	Non-exporters	Difference
Unmatched	0.3645	0.3568	0.0077
			(0.53)
ATT	0.3646	0.3137	0.0509
			(2.27)
Number of firms	717	1,746	
Off support	2	63	

Note: Numbers in parentheses are t-values.

Relationship between efficiency and 4th industrial revolution

The empirical results shown above implicitly assume that technical innovation would be more important for small- and medium-sized firms' export in the era of 4th industrial revolution where technologies play a key role in almost all parts of the human life, let alone the production activities. This underlying assumption could be justified if the effect of the efficiency on export becomes larger as firms are more adaptive to the technologies representing 4th industrial revolution such as AI, big data, IoT, and so on. For this, firms are divided into three groups based on the degree to which firms are adaptive to 4th industrial revolution. Then Eq. (1) is estimated by groups and the estimates of the coefficient of efficiency are compared. Table A3 presents the share of firms that use technologies by groups based on employment size. Overall, larger firms tend to be more adaptive to 4th industrial revolution.

Table 5 Difference in the effect of efficiency in technical innovation on export by the degree to which firms are adaptive to 4th industrial revolution

	Export due to technical innovation (in billions of Korean Won)			Contribution of technical innovation in export (%)		
	15 or below	16~45	46 or more	15 or below	16~45	46 or more
Efficiency	0.1361^{+}	0.2776*	2.2702**	20.612*	21.539**	14.684**
	(2.27)	(2.74)	(4.08)	(2.26)	(3.10)	(2.86)
Export				0.005*	0.006**	0.001**
				(2.55)	(8.58)	(4.57)
Constant	0.2021**	0.0237	-1.2193*	-44.635**	-48.752**	-29.827**
	(14.14)	(0.47)	(-2.70)	(-3.18)	(-4.57)	(-3.13)
Fixed Effect						
Region	15	15	15	15	15	15
Industry	23	23	23	23	23	23
Number of Observations	840	782	841	840	782	841
Left censored				722	613	543
Right censored				4	3	7
Adj. R^2 / Pseudo R^2	0.0403	0.0328	0.0705	0.0902	0.0915	0.0685

Note: Numbers in parentheses are White-Huber's robust t-values assuming errors are correlated within a region. **, *, and $^{+}$ indicate statistical significance at 1%, 5%, and 10%, respectively. The reference groups for the level of technology and the stage of growth are medium-technology and matured stage, respectively.

Table 5 shows the effect of efficiency in technical innovation on export by groups. The results imply that larger firms (i.e., firms that are more adaptive to 4th industrial revolution) have a greater effect of technical efficiency on export.

Conclusions

In the era of 4th industrial revolution, it is predicted that there would be a drastic change in all aspects of human life from production to consumption. The development of new technologies would exacerbate firms' competition in the international markets. As an empirical study on this perspective, this paper examines the relationship between efficiency in technical innovation of small- and medium-sized firms and their sales on foreign markets.

The findings of this paper can be summarized as follows. First, foreign sales induced by technical innovation are larger for the firms that are more efficient in R&D activities. This relationship is still supported even after observable heterogeneity is controlled for through propensity score matching. Second, the importance of efficiency in technical innovation is much more emphasized for the firms that are more adaptive to 4th industrial revolution.

To our knowledge, empirical studies on the relationship technical efficiency and export are limited. Moreover, this paper examines if this relationship would be strengthened further in the era of 4th industrial revolution by incorporating the degree to which firms are adaptive to the drastic change in technologies. However, due to the restriction on available data the degree of being adaptive is evaluated simply by the employment size. Thus, following studies need to examine this aspect more thoroughly.

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Appendix

Table A1 Estimation results for matching between exporters and non-exporters based on a logit model

	Dependent variable: 1 for exporters, 0 for non-exporters
Level of technology	
High	0.6441**
	(4.18)
Low	-0.4879**
	(-3.79)
Stage of growth	
Entry	-0.7935*
	(-2.23)
Growth	0.1675
	(1.52)
Decay	-0.1295
	(-0.41)
Age	0.0224**
	(3.76)
Employment	0.0059**
	(6.28)
CEO	
Male	0.2760
	(1.38)
Age	0.0053
	(0.84)
Constant	-2.2470**
	(-4.71)
Number of Observations	2,463
Pseudo R^2	0.1694

Note: Numbers in parentheses are White-Huber's robust t-values assuming errors are correlated within a region. **, *, and + indicate statistical significance at 1%, 5%, and 10%, respectively. The reference groups for the level of technology and the stage of growth are medium-technology and matured stage, respectively.

Table A2 Changes in differences between exporters and non-exporters by PSM

	Matched	Mean		Bias	Reduction in bias (%)	t-test
		Exporter	Non-exporter			
Level of technology						
High	No	0.192	0.078	34.0		8.33**
	Yes	0.190	0.186	1.2	96.3	0.20
Low	No	0.180	0.320	-32.8		-7.12**
	Yes	0.180	0.183	-0.7	98.0	-0.14
Stage of growth						
Entry	No	0.015	0.054	-21.4		-4.36**
	Yes	0.015	0.014	0.8	96.4	0.22
Growth	No	0.473	0.469	0.7		0.17
	Yes	0.474	0.442	6.4	-762.1	1.22
Decay	No	0.025	0.024	0.3		0.07
	Yes	0.025	0.025	0.0	100.0	0.00
Age	No	17.5	13.9	35.3		8.19**
	Yes	17.4	18.0	-6.0	83.0	-1.05
Employment	No	67.1	42.7	42.2		10.40**
	Yes	66.6	62.8	6.5	84.6	1.16
CEO						
Male	No	0.941	0.914	10.4		2.26*
	Yes	0.941	0.958	-6.5	37.3	-1.45
Age	No	55.3	53.9	16.1		3.66**
	Yes	55.2	56.5	-15.1	6.5	-2.81**

Note: **, *, and + indicate statistical significance at 1%, 5%, and 10%, respectively.

Table A3 Relationship between size of firms measured by employment and adaptiveness to 4th industrial revolution

Employment categories	Mobile equipment	Big data	Cloud computing	IoT	Investment on information	Telecommuting	Public open data	e-commerce
1~4 workers	49.9	0.4	2.9	0.4	68.4	1.2	9.3	17.4
5~9	43.9	1.3	7.0	0.7	96.1	2.3	19.7	31.3
10~49	47.1	3.1	12.1	1.6	99.4	4.9	29.0	35.4
50~249	31.8	5.7	15.8	3.1	100.0	8.4	35.4	42.2
250 or more	46.1	13.4	25.1	9.6	99.9	17.1	46.8	45.2

Note: Survey on Information Statistics (2016) by National Information Society Agency.