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R&D, Trade, and Productivity Growth in Korean Manufacturing

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Abstract:

This paper investigates the effects of both R&D spillovers and trade patterns on productivity in Korean manufacturing, using industry-level data. Our results show that domestic and foreign R&D capital stocks have played an important role in productivity growth of Korean manufacturing over the period 1976-96, and that foreign R&D capital has had more effect than domestic R&D in improving the total factor productivity of Korean manufacturing. Moreover, productivity is greater in export industries and in the more opening industries, and the effects of foreign R&D capital are greater in the industries with large import shares or large intra-industry trade shares.

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Taegi Kim and Changsuh Park

Contents: I. Introduction. – II. Theoretical Background and Empirical Specifications. – III. Descriptive Summary of the Data. – IV. Empirical Resutls. – V. Concluding Remarks. – Appendix.

1. Introduction

Korea's rapid economic growth since the early 1960s has been due to the expansion of capital investment and international trade. Increases in physical and human capital investments, as inputs to production, can expand output directly, while the expansion of trade contributes to growth indirectly. Developing countries can gain the opportunity to absorb new technology developed in advanced countries through trade. Thus, trade can be considered as one of the main generators of productivity growth, especially for a country like Korea, where trade makes a relatively large contribution to economic growth.

Many studies have examined the relationship between trade and economic growth. Edwards (1998) showed that openness causes productivity, and Coe & Helpman (1995), Coe *et al*. (1997), and Keller (2002) demonstrated that international trade plays an important role as a channel for transmitting research and development (R&D) spillovers.

Remark: We would like to thank professors Frank S. T. Hsiao, Murat F. Iyigun, Robert F. McNown, and Keith E. Maskus for their comments and suggestion. We are also indebted to Dr. Sunmi Jang.for help in

Countpt4ds sfhjoy substantial benefits from the R&D undertaken by their trade partners.

Finally, we use two productivity indexes in this study: the Törnqvist and Malmquist productivity indexes. While most studies have used the Törnqvist productivity index, Färe *et al*. (1994) argued that the Malmquist productivity index is more general than the Törnqvist index, as it allows for inefficient performance and does not presume an underlying functional form for production technology.[1]

Our results show that there have been both domestic and foreign R&D spillovers in Korean manufacturing. Domestic other-industry R&D and foreign R&D played an important role in the productivity growth of Korean manufacturing from 1976 to 1996. Foreign R&D had a stronger effect, relatively speaking, than domestic R&D on the productivity growth of Korean manufacturing. The effect of Japanese R&D on Korean productivity was larger than that of other foreign R&D stocks, which is consistent with the results of Coe *et al*. (1997). Generally, productivity is greater in those industries that export more, and trade more, in comparison to other industries. This implies that exports and openness play a positive role in productivity growth. However, foreign R&D effects on Korean productivity are greater in industries that import more, because imports are a vehicle for foreign R&D spillovers. Foreign R&D capital stocks have more effect in industries that have a larger intra-industry trade share, because foreign technology is more easily absorbed by industries that can export and import simultaneously.

The remainder of this paper is organized in the following manner. Section 2 presents the theoretical background for understanding R&D, trade patterns, and productivity, and specifies the empirical framework. Section 3 is a descriptive summary of the main variables and presents estimates of the productivity indexes. The empirical

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[1] The differences between two indexes are discussed briefly in the next section.

results are discussed in Section 4. Concluding remarks are offered in Section 5.

II. Theoretical Background and Empirical Specifications

In traditional growth theory, exogenous technology shock is necessary for sustainable economic growth. In new growth theory (Romer, 1986; Grossman and Helpman, 1991a, 1991b and 1991c), however, innovation is determined endogenously, and this enables sustainable long-run growth without exogenous technology shock. There are two types of endogenous growth models: the varieties growth model (or horizontally differentiated model), and the quality-ladder growth model (or vertically differentiated model).

Both the varieties model (Romer, 1990; Grossman and Helpman, 1991a) and the quality-ladder models (Grossman and Helpman, 1991c; Aghion and Howitt, 1992) emphasize the role of R&D investment in productivity or technology. However, there are also some channels of international technology spillovers[2]: trade, foreign direct investment and patent citation. This paper deals with domestic and international R&D spillovers as well as its own R&D activity in industry level of Korean manufacturing. Each industry uses not only intermediates invented by its own industry, but also intermediates invented by other industries. Scherer (1982) and Griliches and Lichtenberg (1984) examined inter-industry domestic R&D spillovers using an inter-industry technology flow matrix. Moreover, in an open economy, domestic industry uses intermediates imported from trade partners, along with those produced by domestic industries. As the development of foreign intermediate goods also depends on foreign R&D stock, we can consider foreign R&D spillovers in the context of an open economy.

Based on the theoretical background, we constructed an empirical framework. The basic empirical model will be as follows:

$$lnT_{it} = \beta_0 + \beta_1\, lnR\&D_{it}^{DS} + \beta_2\, lnR\&D_{it}^{DO} + \beta_3\, lnR\&D_{it}^{F} + \varepsilon_{it}$$

$$\varepsilon_{it} = \mu_i + \eta_t + \nu_{it} \tag{1}$$

where the subscripts *i* and *t* are the industry and year, respectively; lnT_{it} is the log of the total factor productivity (TFP) index; $lnR\&D^{DS}$ and $lnR\&D^{DO}$ are the logs of the domestic same- and other-industry R&D capital stocks, respectively; $lnR\&D^{F}$ is the log of the foreign R&D capital stock imported indirectly through trade; ε_{it} is an error term, which has three components; μ_i is an unobservable industry-specific factor that reflects the variation across industries; ιτ outputs, while the Törnqvist index does. Only quantities of inputs and outputs are required in the measure of productivity index in the Malmquist index. Thus, the method of the Malmquist index is less data-demanded relative to the Törnqvist index. Third, the Törnqvist productivity index suggested by Caves *et al*. (1982) is multilateral indexes in which the Törnqvist productivity index can compare the level of TFP between industries and time periods, but the Malmquist productivity index can not.

The United States and Japan are Korea’s most important trade partners, although Korea has different trade structures with each of these two countries. Korea imports machinery and equipment mainly from Japan, while the United States is Korea's largest market for its exports. Due to these different trade structures, the R&D stocks of the U.S. and Japan affect Korean productivity differently. To examine the different effects of foreign R&D stocks, we decompose the foreign R&D stocks ($lnR\&D^F$

estimates β_4 and β_5

III. Descriptive Summary of the Data

1. R&D and Trade

The data sources and variables are explained in Appendix B in detail. Here, we summarize some features of the data. Table 1 compares the real R&D investment per worker in terms of U.S. dollars based on the1990 purchasing power parity (PPP) for Korean, U.S., and Japanese corresponding manufacturing.

Table 1 shows that R&D investment per worker is smaller in Korea than in the U.S. and Japan. For the period 1976-80, the relative ratios of Korean R&D investment per worker to those of the U.S. and Japan were 0.05 and 0.14, respectively. The relative ratios, however, increased consistently, and had risen to 0.51 and 0.90, respectively, by the period 1991-96. This trend implies that even if R&D investments in Korean manufacturing are smaller than such investments in the U.S. and Japan, Korea's R&D investments grew rapidly when compared to those in the U.S. and Japan over the period 1976-96.

Table 1 - *Comparison of real R&D investment per worker: US $ of 1990 PPP*

	Average R&D investment per worker	Relative ratio

Table 2 shows shares and annual average growth rates of each sector in total R&D stock within Korea and 14 OECD countries in 1976 and 1996, respectively. First, in the case of OECD countries, the dominant sector of R&D stock is fabricated metal products (08) followed by chemical products (05) in both years. The shares of fabricated metal products (08) in total R&D stock are 71.9% in 1976 and 71.2% in 1996. The shares of chemical products (05) in total R&D stock are 19.4% in 1976 and 21.1% in 1996. The share of these two sectors is 90% of total R&D stock of 14 OECD countries. In case of Korea, the share of fabricated metal products (08) is highest but its share is only 38.4% in 1976 and the second largest share is textiles, apparel and leather sector (02), which is 22.3%. However, the trend of shares is almost the same as that of OECD countries in 1996.

We used both measures to construct foreign R&D capital stocks and compared both estimates of the 1996 foreign R&D capital stocks in Table 2. First, as in the first column, the third column shows share of each sector in imported total foreign R&D stock for both measures for 1996, but the trend is similar for 1976. The share of each sector in foreign R&D stock shows the similar pattern with that for domestic R&D stock for 9 industries and light and heavy sectors. This result suggests that the magnitude of imported foreign R&D stocks in heavy industry is much greater than that of light industry and that R&D spillovers are more predominant in heavy industry than in light industry.

Secondly, we considered how much of 14 OECD's R&D capital stock was indirectly imported into Korea. Columns (B/A) and (C/A)[9] in Table 2 show that in the CH method, 27.5% of the total foreign R&D stock was imported in all manufacturing in 1996, but in the LP method, only 0.8% of 14 OECD's total R&D stock was imported in the same year. The results are similar for light and heavy industries. In the CH method, 27.0 and 27.6% of the total foreign R&D stock was imported into Korean light and heavy industries, respectively. By contrast, only 0.3 and 0.8% of the total foreign R&D stock was imported into the same industries in the LP method.

Table 3 presents the trends in trade volume and the intra-industry trade (IIT) index for Korean manufacturing with the 14 OECD countries. The average annual growth rates of exports and imports for all manufacturing are 11.24 and 13.50%, respectively and the growth rate for heavy industry (15.95 and 14.09%, respectively) was larger than that for light industry (5.22 and 10.85%, respectively) over the period 1976-96. In particular, the

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[9] We can calculate the level of each R&D stock using each total volume reported in the row, All. Then (B/A) and (C/A) can be replicated.

export growth rate of heavy industry was almost triple that of light industry. With regard to Korean manufacturing, there has been a rapid expansion in trade with the 14 OECD countries in heavy industry relative to such trade in light industry.

Table 3 - *Trends of Trade Volume and IIT Index (in percent per year)*

Industry	Growth rates		Export share	Import share	IIT index		
	Export	Import			1976	1996	1976-96
01	8.06	11.75	4.16	4.47	16.74	31.61	25.03
02	4.59	7.51	38.40	7.39	19.99	36.77	24.95
03	-3.71	23.29	11.72	3.53	22.53	37.56	38.36
04	10.18	12.79	2.32	10.60	33.73	48.61	44.00
05	15.25	12.89	5.37	14.54	21.47	36.93	29.67
06	8.31	17.78	5.45	5.74	59.98	47.45	45.23

2.-.48 -12.-.48 07-12.-.5.8811n-76(t314401209 0.4992.891 951972 0.48 -830648 348 -161 500 manufacturing, especially in heavy industry, have become similar to the trade patterns of the OECD countries. Finally, IIT index of every industry except industry 06 has been increased in 1996 relative to that of 1976.

2. Total Factor Productivity

We estimated the Törnqvist and Malmquist productivity indexes for 28 Korean manufacturing sectors over the period 1970-96, using one output and three inputs as follows: labor, physical capital stock, and intermediates. The Törnqvist productivity index is based on the method of Caves *et al* over time. These results are consistent with the arguments of Young (1995) and Krugman industry, in particular, light industry experienced a negative growth rate in output and productivity (Törnqvist productivity index) over the period 1990-96. These trends may have resulted from the Korean government's heavy/chemical industry promotion policy, which has been in effect since the early 1970s.

IV. Empirical Results

1. Domestic and Foreign R&D stock

A two-way fixed-effect method (considering industry-specific and time-specific effects) has been used to treat the panel data in regression models testing the determinants of TFP.[12] Since Korean R&D data are only available for 9 manufacturing sectors over the period 1976-96 in its entirety, all the variables for the 28 sectors are aggregated into 9 sectors in the regressions.

Table 5 shows the regression results using the foreign R&D stocks calculated by the LP method.[13] The estimated coefficients of $lnR\&D^{DS}$ are all positive and statistically significant at a 1% level. This implies that R&D investment in an industry increases the TFP of that industry. The elasticity of the TFP indexes with respect to own-industry R&D ranges from 0.034 to 0.100.[14]

The coefficients of domestic other-industry R&D ($lnR\&D^{DO}$) are positive and statistically significant, and are larger than those of the domestic same-industry R&D stock. These results show that there are domestic R&D spillovers in Korean

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[12]

manufacturing, and that the domestic spillover effects are greater than the effects of own-R&D stock on productivity.

All of the coefficients of $lnR\&D^F$ are positive and statistically significant at the 1% level. Moreover, the coefficients are larger than those for $lnR\&D^{DS}$ and $lnR\&D^{DO}$. Thus, foreign R&D capital stocks have a greater effect on productivity than domestic R&D capital stocks in Korean manufacturing. These results are contrary to Coe *et al*. (1995) and Keller (2002). In both studies, domestic R&D capital stocks had a greater effect on productivity than foreign R&D capital stocks. The differences in the results may come from the different datasets used. Coe *et al*. (1995) and Keller (2002) dealt with R&D spillovers within OECD countries, while this paper examines R&D spillovers in Korea, a developing country. This implies that the domestic R&D stocks of advanced countries, making the predominant R&D investment in the world, are more effective than foreign R&D stocks. By contrast, in developing countries like Korea, R&D investment is relatively small compared with OECD countries (Refer to Table 2); thus, foreign R&D stocks can be more effective than domestic R&D stocks.

We tested the hypothesis that the coefficients of the domestic and foreign same-sector R&D stocks are equal. The F-value for testing the hypothesis $lnR\&D^{DS} = lnR\&D^F$ in Table 5 shows that we can reject the hypothesis. Thus, the coefficients of $lnR\&D^F$ are significantly larger than those of $lnR\&D^{DS}$, except in equation (M.4). Here, we must note that the empirical models do not consider the effect of foreign other-sector R&D stock because of data limitations. In Keller (2002), the effect of foreign other-sector R&D stock (0.150) is much larger than the effect of foreign same-sector R&D stock (0.047).

Table 5 - *Regression Results Using the Foreign R&D Stocks Based on the LP method: Dependent variable = lnTFP*

Model	Using Törnqvist productivity index					Using Malmquist productivity index				
	(T.1)	(T.2)	(T.2)’	(T.3)	(T.4)	(M.1)	(M.2)	(M.2)’	(M.3)	(M.4)
$lnRD^{DS}$	.084 *** (7.69)	.100 *** (8.30)	.065 *** (5.77)	.052 *** (5.17)	.034 *** (3.37)	.077 *** (5.80)	.091 *** (6.22)	.065 *** (4.37)	.056 *** (4.16)	.037 *** (2.92)
$lnRD^{DO}$	.111 ***	.122 ***	.129 ***	.127 ***	.137 ***	.079 **	.093 ***	.085 ***	.076 **	.109 ***

Next, we decompose foreign R&D capital stocks into three groups--the U.S., Japan, and the other OECD countries--and use these segmented foreign R&D stocks instead of $lnR\&D^F$ in regression equations (T.2), (T.2)', (M.2), and (M.2)' in Table 5. In patents are much more likely to cite Japanese patents than U.S. patents (Hu and Jaffe, 2001); this implies that Korea adopts more Japanese technology than U.S. technology. Hence, we expect Japanese R&D stock to play a relatively larger role in Korean manufacturing than U.S. R&D stock. However, this evidence is only found in the regressions using the Malmquist productivity index.

2. Trade-Related Variables

As we expected, the coefficients of the variable *lnIMP*

The coefficients of $IIT*lnR\&D^F$ are positive and significant at the 1% level, showing that foreign R&D has a greater effect on productivity in an industry with more intra-industry trade. This confirms the argument of Hakura and Jaumotte (1999), who held that an industry with a large intra-industry trade share faces more competition and absorbs foreign technology more easily than do industries with more inter-industry trade.

3. Sensitivity Analysis [16]

Table C1 in Appendix C shows the regression results using the foreign R&D capital stocks based on the CH method. We briefly summarize the similarities and dissimilarities between these two results in Tables 5 and C1. In general, the estimates in while the degree of significance is lower in the Malmquist productivity index models. The significance of the trade-related variables is essentially the same as in Table 5.

Comparing the results of the CH and the LP methods, we can say that the LP method is better for constructing foreign R&D stock because, as shown in Tables 5 and C1, the LP method improves R^2, which means that the LP method fits the model well. Moreover, all the coefficients of $lnR\&D^{DO}$

Korea, foreign R&D stock has had a greater effect on productivity than domestic R&D, and foreign R&D stock from Japan has been more important than that of the U.S or other OECD countries. This may have been due to the different trade structures that pertain between Korea and these trade partners. We also observed that domestic other-industry R&D contributed more to productivity than domestic own-industry R&D in Korean manufacturing. This suggests that there have been both domestic and foreign R&D spillovers in Korean manufacturing.

In examining the relationship between trade patterns and productivity, our s 2omanufure6(indu.-2.8 T
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Appendix A - *Industry Classification of Manufacturing Sectors*

9 Ind	28 Ind	ISIC Rev. 2	STAN industry category	SITC classification
01		**(31)**	Food, Beverages & Tobacco	
	01	311/2	Food	01-09 (0482), 211, 2232, 2239, 2632, 2681, 291, 4(4314), 5921.
	02	313	Beverages	0482, 11.
	03	314	Tobacco	12.
02		**(32)**	Textiles, Apparel & Leather	
	04	321	Textiles	2223, 261, 263(2632), 2667, 2672, 2682, 2686, 2687, 65(6576), 8451, 846(8465).
	05	322	Wearing Apparel	6576, 842, 843, 844, 845(8451), 8465, 847, 848.
	06	323	Leather & Products	61(6123), 831.
	07	324	Footwear	6123, 851.
		(33)		

B.2 R&D and Trade Data

The Korean R&D data are from various issues of Science and Technology Statistics published by the Korea Ministry of Science and Technology, while the R&D data for the 14 OECD countries are from the OECD ANBERD database, which maintains a flow of R&D expenditure by economic activity for the 15 largest OECD R&D performing countries for the period 1973-1998. Since the STAN database does not report production for Ireland, 14 countries were used to construct the foreign R&D capital stock.

R&D investment was disaggregated into 9 industries common to each country. The nominal value of these R&D outlays in the national currency were converted into a constant 1990 value using the GDP deflator from the OECD Economic Outlook (2002). Then, these constant R&D expenditures were converted into U.S. dollars using the 1990 purchasing power parity exchange rates. Data for Korean R&D investment were only available for 9 industries after 1976. Therefore, we reclassified the variables for all 28 sectors (ISIC 3-digit) into the 9 sectors (2-digit ISIC) that corresponded to the Korean R&D data for 1976-96 (see Appendix A for details).

We calculated the domestic R&D capital stock of each industry from the R&D

$$S_{it}^{f-CH} = \sum_{j \neq i} S_{ijt}^{f-CH} = \sum_{j \neq i} \frac{m_{ijt}}{m_{it}} S_{ijt}^{d} \qquad \text{for each industry } i \qquad \text{(B1)} \quad \text{i}$$

Appendix C. Alternative Empirical Result

Table C1: *Regression results using the foreign R&D stocks based on the CH method: Dependent Variable = lnTFP*

Model	Törnqvist productivity index					Malmquist productivity index				
	(T.1)	(T.2)	(T.2)'	(T.3)	(T.4)	(M.1)	(M.2)	(M.2)'	(M.3)	(M.4)
$\ln RD^{DS}$	.056 ***	.073 ***	.044 ***	.034 ***	.031 ***	.053 ***	.057 ***	.038 **	.043 ***	.039 ***
	(5.08)	(6.34)	(3.22)	(2.86)	(2.92)	(3.88)	(3.98)	(2.23)	(2.82)	(2.99)
$\ln RD^{DO}$	.061 **	.067 **	.065 **	.059 **	.063 **	.042	.047	.031	.023	.060 *
	(2.21)	(2.44)	(2.43)	(2.18)	(2.41)	(1.21)	(1.37)	(0.91)	(0.67)	(1.88)
$\ln RD^{F}$	.185 ***			.193 ***	.227 ***	.110 **			.117 ***	.036
	(4.76)			(5.32)	(4.18)	(2.27)			(2.51)	(0.53)
$\ln RD^{F\_USA}$		.080 ***	.085 ***				.022	.025		
		(4.29)	(4.79)				(0.95)	(1.12)		
$\ln RD^{F\_JPN}$		.060 ***	.045 ***				.065 ***	.048 **		
		(3.53)	(2.74)				(3.06)	(2.29)		
$\ln RD^{F\_OTH}$		.021	-.007				-.005	-.029		
		(1.27)	(0.42)				(0.26)	(1.30)		
LnIMP			-.121 ***	-.127 ***	-.772 ***			-.118 ***	-.113 ***	-.423
			(4.16)	(4.76)	(3.50)			(3.21)	(3.31)	(1.56)
LnOPEN			.108 **	.133 ***	.063			.194 ***	.213 ***	.137 **
			(2.19)	(2.76)	(1.43)			(3.09)	(3.46)	(2.52)
$\ln IMP*\ln RD^{F}$					.046 ***					.024
					(3.07)					(1.32)
$IIT*\ln RD^{F}$					.182 ***					.282 ***
					(6.14)					(7.74)
R^2	.631	.644	.685	.682	.756	.922	.925	.931	.929	.950
F(28, •) value for no fixed effect	3.44 ***	3.31 ***	3.64 ***	4.07 ***	6.71 ***	42.22 ***	30.98 ***	14.23 ***	13.82 ***	21.14 ***
F(1, •) value for $R\&D^{DS} = R\&D^{F}$	9.14 ***	7.45 ***	6.52 ***	15.43 ***	12.01 ***	1.12	0.37	0.02	2.02	0.00
F(1, •) value for $RD^{F\_USA} = RD^{F\_JPN}$	-	0.70								

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(* Appendix D is only for referees, not for publication.)

Appendix D: Estimation Methodology of Total Factor Productivity Index

D.1 The Törnqvist Productivity Index

In this paper, we use two methods for the estimation of TFP: the Törnqvist and the Malmquist productivity indexes. The main differences between these two are as transformation function in Caves et al. (1982) is as follows:

$$\ln \delta_{kl} = {}^{1}\!\!/\!_{2} \sum_{i} (R_i^k + \overline{R}_i)(\ln Y_i^k - \overline{\ln Y_i}) - {}^{1}\!\!/\!_{2} \sum_{i} (R_i^l + \overline{R}_i)(\ln Y_i^l - \overline{\ln Y_i}) \tag{D1}$$

where ln

where $W_{Ii} = p_i I_i \big/ \sum X_i$, where $I = L$, K, and M. p is price of each input and $\sum X_i$ is total output of all industries.

Using the output index and single multilateral input index, the multilateral productivity index is defined as

Definition (D5) can be rewritten equivalently as the following way:

$$M(\mathbf{z}^{t+1}, \mathbf{z}^{t}) = \frac{D^{t+1}(\mathbf{z}^{t+1})}{D^{t}(\mathbf{z}^{t})}\left[\left(\frac{D^{t}(\mathbf{z}^{t+1})}{D^{t+1}(\mathbf{z}^{t+1})}\right)\left(\frac{D^{t}(\mathbf{z}^{t})}{D^{t+1}(\mathbf{z}^{t})}\right)\right]^{1/2} \qquad \text{(D5)}'$$

where the ratio outside the brackets measures the change in relative efficiency between t

$$\sum_{k=1}^{K} w_k^t x_{n,j}^t \leq x_{n,j}^t \qquad n = 1, \ldots, N \tag{D6-2}$$

$$w_k^t \geq 0 \qquad k = 1, \ldots, K \tag{D6-3}$$

where n = 1,…, N are inputs, m = 1, …, M, outputs and w_k^t, an intensity variable indicating at what intensity a particular activity (here, each industry is an activity) may be employed in production. These intensity variables will be used as weights in taking convex combinations of the observed outputs and inputs in both (D6-1) and (D6-2), respectively. From equation (D6), the reciprocal of output distance function is to find maximum, θ which gives the maximal proportional expansion of output given constraints, (D6-1) - (D6-3).

Among other distance functions, the computation of $D^{t+1}(\mathbf{z}^{t+1})$ is exactly like (D6), where t+1 is substituted for t. Two other distance functions require information from two periods. $D^t(\mathbf{z}^{t+1})$ can be computed by replacing $y_{m,j}^t$ and $x_{n,j}^t$ in equation (D6-1) and (D6-2) with $y_{m,j}^{t+1}$ and $x_{n,j}^{t+1}$, respectively, and $D^{t+1}(\mathbf{z}^t)$ is the same as $D^t(\mathbf{z}^{t+1})$, where the t and t+1 superscripts are exchanged.[21]

Appendix E: An Alternative Regression Result

Appendix E is an alternative regression result using every 5-year observation to avoid simultaneous bias or endogeneity problem between domestic R&D investment and productivity. Basically, there is no significant difference between Table 5 and Table E1.

Table E1: Regression results using the foreign R&D stocks based on the LP method

Model	Törnqvist productivity index					Malmquist productivity index				
	(T.1)	(T.2)	(T.2)'	(T.3)	(T.4)	(M.1)	(M.2)	(M.2)'	(M.3)	(M.4)
Dep. Var Indep. var	lnTFP					lnTFP				
lnRD^{DS}	.125 *** (5.46)	.122 *** (4.74)	.108 *** (4.17)	.110 *** (4.59)	.084 *** (2.92)	.123 *** (4.81)	.117 *** (4.44)	.125 *** (5.27)	.135 *** (5.53)	.116 *** (4.77)
lnRD^{DO}	.109 ** (2.30)	.096 * (2.04)	.083 * (1.80)	.094 ** (2.09)	.108 ** (2.58)	.120** (1.21)	.118 ** (2.44)	.075 * (1.78)	.074 (1.62)	.095 ** (2.26)
lnRD^{F}	.159 *** (3.86)			.182 *** (4.50)	.222 *** (3.49)	.137 *** (2.97)			.130 *** (3.18)	.071 (1.10)
lnRD$^{F\_USA}$		.080 *** (3.26)	.087 *** (3.76)				.045 * (1.78)	.045 ** (2.13)		
lnRD$^{F\_JPN}$		.055 ** (2.21)	.059 ** (2.44)				.093 *** (3.58)	.081 *** (3.65)		
lnRD$^{F\_OTH}$		.004 (0.13)	.006 (0.23)				.008 (0.26)	.002 (0.08)		
lnIMP			-.125 ** (2.40)	-.142 ** (2.61)	-.389 ** (2.15)			-.107 ** (2.24)	-.118 ** (2.14)	-.042 (0.23)
lnOPEN			.178 * (1.78)	.214 ** (2.12)	.188 * (2.04)			.329 *** (3.60)	.374 *** (3.66)	.360 *** (3.86)
lnIMP*lnRD^{F}					.028 (1.60)					-.004 (0.22)
IIT* lnRD^{F}					.046 * (1.80)					.068 ** (2.65)
R^2	.817	.844	.878	.860	.895	.960	.971	.982	.975	.981
F(28, •) value										

Table E2: Regression results using the foreign R&D stocks based on the CH method

Törnqvist productivity index	Malmquist productivity index