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Abstract

This paper examines R&D spillovers at the international level, looking at such spillovers from Japan to Korea. Our empirical findings show that the contribution of inter-industry R&D spillovers in the Korean manufacturing sector is low and insignificant, while Korean manufacturing industry benefits greatly from rent R&D spillovers from Japanese manufacturing industry.

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1. Introduction

International R&D spillovers are an important source of technological change and economic growth (Branstetter 2000; Keller 2001). Griliches (1979) suggests two main sources of potential externalities generated by R&D activities: rent spillovers and knowledge spillovers. Rent spillovers arise because quality improvements in intermediate and capital goods resulting from R&D investments in other countries are not fully captured in their prices due to competition and the impossibility of perfect price discrimination. Under these circumstances, the foreign inventor produces intermediate and capital goods that embody knowledge and unintentionally provides indirect benefits to the purchasers of the goods. Griliches (1979) has termed these spillovers ”pecuniary externalities” because they occur through market interactions. In principle, if the innovator could perfectly discriminate and there were no measurement errors in the price index, no rent spillovers would occur. Therefore, rent spillovers are not true spillovers in the sense that they materialize through market interactions and measurement errors.

In addition, knowledge spillovers occur because of the public goods characteristics of knowledge, i.e. the “non-exclusivity” and “non-rivalry” of knowledge. These characteristics of knowledge refer to the inability of knowledge producers to completely appropriate the surplus from a particular piece of knowledge generated by R&D investment. While rent spillovers occur through market transactions, knowledge spillovers are the result of non-market interactions. Knowledge spillovers are generated by the “paper trails” and patent citations that follow an innovation, by the mobility of scientists, etc. These are true spillovers, which contribute to endogenous growth and endogenous technological change.

However, while conceptually it is possible to make a clear-cut distinction between rent and knowledge spillovers, empirically it quite difficult to separate these two so clearly because knowledge spillovers are often associated with economic transactions.

Many empirical papers on inter-industry and intra-industry R&D spillovers have shown that total factor productivity is affected not only by the R&D activities within a firm or industry itself, but also by the R&D activities of other industries and firms. However, few studies have examined R&D spillovers in an international context. An exception is the influential paper on international R&D spillovers written by Coe and Helpman (1995). In this paper, the authors make use of a typical production function approach, which is used to examine the effects of other industries’ R&D on a given industry’s productivity in a closed economy.[1] They found international R&D spillovers mediated by trade to be strong and significant. Domestic total factor productivity was significantly correlated not only with domestic R&D but

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[1] Examples of studies on R&D spillovers in a closed economy using this production function approach are Nadiri (1993) and Griliches (1995).

also with import-weighted foreign R&D. Empirical studies on international R&D spillovers following in Coe and Helpman’s footsteps have proceeded in two directions.

First, some economists have tried to improve the analytical framework in order to estimate international R&D spillovers more accurately. Lichtenberg and van Pottelsberghe de la Potterie (1998), for example, used foreign R&D capital when estimating the effects of international R&D spillovers in order to avoid the problem of aggregation and indexation biases. They found that the more open to trade a country was, the more likely was it to benefit from foreign R&D. Kao, Chiang and Chen (1999) resolved some econometric problems regarding the absence of standard errors around Coe and Helpman’s coefficients. They also confirmed that import-weighted foreign R&D spillovers are significantly correlated with domestic productivity levels.

The second direction in which Coe and Helpman’s study has been extended is the inclusion of new variables. For instance, Engelbrecht (1997) included general human capital in Coe and Helpman’s basic model in order to estimate the effects of international R&D spillovers. Engelbrecht’s study obtains somewhat smaller estimates for the coefficients on domestic R&D capital and international R&D spillovers, but the estimated values remain highly significant. And Xu and Wang (1999), to give another example, extended the study by testing whether capital goods trade was a significant channel of international R&D spillover and found that this was indeed the case.

This literature studies the effects of international rent R&D spillovers on domestic productivity. Unfortunately, however, it does not estimate the impact of international knowledge R&D spillovers or identify the effects of domestic R&D spillovers.

To fill this gap, the present paper aims to examine the relative importance of domestic and international R&D spillovers by estimating their effect on productivity growth in the Korean manufacturing sector. Moreover**,** two types of spillovers are introduced and quantified in new ways.

The remainder of this paper is organized as follows. Section 2 summarizes the empirical methodology; section 3 presents the sources and the construction of the data used in the analysis, and section 4 reports the main empirical results. Section 5 concludes this paper.

2. Empirical methodology

Total factor productivity depends not only on R&D efforts and domestic R&D spillovers but also on international R&D spillovers. To measure the R&D spillover effect, we consider a standard Cobb-Douglas production function using R&D and the R&D spillovers as input. Suppressing time subscripts, value added in industry *i* can then be written as:

$$Y_i = A_i L_i^{\alpha_1} K_i^{\alpha_2} R_i^{\beta} S_i^{\gamma_s} e^{\mu_i t} \qquad (1)$$

where A is a constant, and K, L, R, S are capital input, labor input, own R&D stock, and R&D spillover stocks, while μ is a time trend used to capture other trend influences.

Taking the logs of both sides yields

$$\ln Y_i = \ln A_i + \alpha_1 \ln L_i + \alpha_2 \ln K_i + \beta \ln R_i + \gamma_s \ln S_i + \mu_i t \qquad (2)$$

Differentiating equation (2) with respect to time, we obtain

$$\frac{\dot{Y}_i}{Y_i} = \alpha_1(\frac{\dot{L}_i}{L_i}) + \alpha_2(\frac{\dot{K}_i}{K_i}) + \beta(\frac{\dot{R}_i}{R_i}) + \gamma_s(\frac{\dot{S}_i}{S_i}) + \mu_i \qquad (3)$$

Conventional growth accounting derives total factor productivity growth from equation (3) by subtracting the growth in labor and the growth in capital from each side.[2]

$$TFPG_i = \frac{\dot{Y}_i}{Y_i} - \alpha_1(\frac{\dot{L}_i}{L_i}) - \alpha_2(\frac{\dot{K}_i}{K_i}) = \beta(\frac{\dot{R}_i}{R_i}) + \gamma_s(\frac{\dot{S}_i}{S_i}) + \mu_i \qquad (4)$$

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[2] We assume that the production technology is characterized by constant returns to scale because of the difficulties involved in obtaining the exact price information that would be necessary to separate out the effects of scale economies.

In equation (4) we can interpret β and γ_s as the elasticity of output with respect to own R&D stock and R&D spillover stock. That is, by definition, the output elasticity of R&D stock and R&D spillover is given by:

$$\beta = (\frac{\partial Y}{\partial R})(\frac{R}{Y}) = \rho(\frac{R}{Y}), \qquad \gamma = (\frac{\partial Y}{\partial S})(\frac{S}{Y}) = \lambda(\frac{S}{Y}) \qquad (5)$$

This equation shows that the elasticities of R&D are the rate of return or the marginal product of R&D multiplied by the ratio of R&D to output.

Using (5), we rewrite equation (4) as:

$$TFPG_i = \rho(\frac{\dot{R}_i}{Y_i}) + \lambda_s(\frac{\dot{S}_i}{Y_i}) + \mu_i \qquad (6)$$

where ρ is the net rate of return to own R&D and λ_s is the net rate of return to R&D spillovers.

This specification allows us to examine the effects of R&D spillovers on total factor productivity growth. This approach provides the *rate of return* to R&D spillovers as the parameter of interest instead of the *elasticity* of R&D spillovers, which represents the relationship between R&D spillovers and TFP level.

The two different types of R&D spillovers are measured as follows. First, rent R&D spillovers are measured based on the assumption that R&D is embodied in intermediate goods. The intermediate goods purchase matrix is used as a weight function and the amount of R&D

obtained through spillovers is the weighted sum of other industries' or other countries' R&D expenditures. Rent R&D spillovers in Korean industry are divided into domestic spillovers and those obtained from Japan. Domestic rent R&D spillover is defined as follows:

$$S_{dri} = \sum_j b_{ji}^0 R_j^K \qquad (7)$$

where b_{ji}^0 is the proportion of sales to industry *i* relative to the total sales of industry *j*. This weight is calculated by dividing the cell values by the corresponding row sums in the input-output tables. R_j^K is the R&D stock of Korean industry *j*. When calculating the domestic R&D spillover stocks, the within-industry effect was eliminated by setting the main diagonals equal to zero to avoid double-counting of own R&D.

Rent R&D spillover from Japan is described as follows:

$$S_{jri} = \sum_j b_{ji}^{JK} R_j^J \qquad (8)$$

where b_{ji}^{JK} is the proportion of Japanese industry *j*'s sales accounted for by sales to Korean industry *i*. This weight is computed by using the international input-output table (Japan-Korea). R_j^J is the R&D stock of Japanese industry *j*.

The second type of R&D spillover that is measured is knowledge spillover. The measurement adopted here follows the method first suggested by Griliches (1979) and further developed by Jaffe (1986) and Goto and Suzuki (1989), which treats R&D spillovers between industries or countries as proportional to the similarity or relatedness of these industries or countries. It is expected that knowledge developed in one industry or country is used most quickly and efficiently by those industries or countries whose technology composition displays the greatest similarity.

Jaffe (1986) measures R&D spillovers as the weighted sum of other industries' R&D, with weights proportional to the technological proximity of the industry. Jaffe defined the technological proximity between industries as follows:

$$P_{ij} = F_i F_j^{'} / [(F_i F_i^{'})(F_j F_j^{'})]^{1/2}$$

where F_i and F_j are the technological position vectors of the respective firm. F is composed of the *k*-dimensional patent data of an industry.

Goto and Suzuki (1989) used the similarity of the distribution of R&D expenditures across research fields (n=26) instead of the patent distribution in order to measure the technological proximity between industries.

However, instead of following these examples, this paper employs the measure of knowledge spillovers developed by Los (2000), which uses input coefficient vectors instead of patent profiles and the distribution of R&D expenditures. In input-output tables, an input coefficient is regarded as the technology level of the corresponding industry, because it represents the amounts of the various inputs required to produce one value-unit of the output of that industry.[3] Therefore, the technological proximity between two industries can be measured using input coefficient vectors rather than patent profiles and the distribution of R&D expenditures across research fields. If the input structures of industry *i* and industry *j* perfectly coincide, the R&D spillover of both industries includes the other's R&D completely. If they have completely different input structures, they are unable to benefit from one another's research efforts.

This paper uses input coefficients as elements of the weight function to capture intra-national and international knowledge R&D spillovers. Domestic knowledge R&D spillovers enjoyed by one industry are defined as the weighted sum of the R&D performed by all the other industries. Domestic knowledge R&D spillover can be described as:

$$S_{dki} = \sum_{j} P_{ij} R_j^K \qquad (9)$$

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[3] Nelson and Winter (1982) point out that the input coefficient vectors can be considered as proxying knowledge spillovers.

where R_j^K is the R&D stock of Korea's industry *j*. A list of the industries used in this study and the R&D proximity matrix for Korea's manufacturing industries is provided in table 2-1.[4]

(Insert Table 2-1)

Similarly, international knowledge R&D spillovers can be computed as:

$$S_{jki} = \sum_j P_{ij}^{JK} R_j^J \qquad (10)$$

where P_{ji}^{JK} represents the technological proximity between Korean industry *i* and Japanese industry *j*. R_j^J is the R&D capital stock of Japanese industry *j*. Table 2-2 presents the correlation matrix between Korean industry and Japanese industry.

(Insert Table 2-2)

Table 2-2 indicates that the greatest technological proximity between Korean industry and the corresponding Japanese industry can be found in the electrical machinery, textiles and apparel, food and beverages, and transport equipment sectors. In contrast, Japanese and Korean industry display the least technological proximity in non-metallic mineral products, professional goods, non-electrical machinery, fabricated metal products, and chemical products.[5]

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[4] Industry classifications appear too broad to capture technological proximity.

[5] This may be due to differences in the composition of commodities manufactured by industry in

3. Data

The growth in total factor productivity of Korean manufacturing industry is defined as:

$$TFPG_{it} = \ln Y_{it} - \ln Y_{it-1} - \alpha_{it}(\ln L_{it} - \ln L_{it-1}) - (1-\alpha_{it})(\ln K_{it} - \ln K_{it-1})$$

where Y is value-added, K is the stock of capital, and L is labor input. α is the share of labor compensation in value-added. Data on these variables are obtained from the *OECD STAN database* (1998) with the exception of workers' average monthly working hours, which are taken from Korea's *Yearbook of Labor*.

After deflating gross fixed capital formation with the GDP deflator (1990=100), the capital stock is estimated using the perpetual inventory method. The capital stock in the benchmark year (1980) can be computed as follows:

$$K_t=I_t/(g+\delta)$$

where I is gross fixed capital formation in constant prices, g is the average annual logarithmic growth rate over the period 1980–1996, and δ is the depreciation rate of capital. We use a value of 6.6% for δ following Pyo (1998). Labor input was calculated by multiplying the number of

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Japan and Korea.

employees by the average monthly working hours per worker.

The data on annual R&D expenditure in Korea and Japan were drawn from the *Report on the Survey of Research and Development in Science and Technology* and the *Report on the Survey of Research and Development*, respectively. The data were converted to real values using the GDP deflator (1990=100) from the *OECD STAN database*. The rate of depreciation of the R&D stock is set at 15% for Korea and 10% for Japan. The average annual logarithmic growth rate is used during the period of 1985–1996 in Korea and the period of 1980–1996 in Japan. Japanese R&D stock is converted into Korea won using OECD purchasing power parity rates.

The weights used to construct the data series on domestic R&D spillovers and foreign R&D from Japan are estimated using the input-output tables of Korea (1990), the international input-output tables of Japan-Korea (1990), and the input-output tables of Japan (1990). In the estimation of domestic R&D spillovers, we do not consider lags, while international R&D spillovers from Japan were lagged by one year.

(Insert Table 3-1)

Table 3-1 presents descriptive statistics on R&D and R&D spillovers. These show that own R&D stock increased significantly in all industries during the period 1987–1996, but this growth was not uniform across industries. For example, in the fabricated metal products, transport equipment, and professional goods sectors, the R&D stock grew more than tenfold during this period, indicating that these industries play an important role in Korean manufacturing industry as a source of knowledge. In contrast, the change of R&D stock in the textile and the paper industries are comparatively low. Overall, the own R&D stock in Korean manufacturing industries was eight times greater in 1996 than it was in 1987.

The table also shows that there is no significant difference in the variance of changes in R&D spillover stocks and R&D stocks. Moreover, the rate of growth of domestic R&D spillover is as large as that for own R&D stock. These domestic R&D spillover stocks expanded sevenfold on average, irrespective of the type of R&D spillover.

Compared with these large increases in own R&D and domestic R&D spillovers, changes in R&D spillovers from Japanese to Korean industry are less spectacular: they grew only twofold over the sample period.

4. Empirical results

In order to identify the relative importance of the contribution of domestic and international R&D spillovers to productivity in Korean industry, we regress following equation.[6]

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[6] This study excludes foreign technology purchase and FDI, although they are as important as, if not

$$TFPG_i = \beta_1 + \beta_2 (\frac{\dot{R}}{Y})_i + \beta_s (\frac{\dot{S}_s}{Y})_i + \varepsilon_i \qquad (11)$$

where β_2 denotes the rate of return to own R&D, β_s denotes the rates of return to R&D spillovers, and ε_i is a stochastic error term. Using LM (Lagrange multiplier) test, we can also test a hypothesis that ε_i is independently distributed but not identically distributed. We obtain LM test statistics of 82.37, 83.26, and 87.14. The critical value from the chi-squared distribution with eleven degrees of freedom is 19.68, so on the basis of the LM test, we reject that ε_i may be identically distributed. Therefore, we use feasible GLS with heteroscedasticity across panels as the estimation procedure.[7] In order to control for differences in business cycles, all regressions include year dummy variables.

(Insert Table 4-1)

(Insert Table 4-2)

(Insert Table 4-3)

Table 4-3 reports the estimation results of five regression specifications based on equation (11). Specification (i) is based on the assumption that productivity depends only on the domestic R&D.

The impact of own R&D stock and international R&D spillover is estimated in

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more, international R&D spillover.

[7] See Greene (1997:653–58).

specifications (ii) and (iii). Finally, in specifications (iv) and (v), we estimate the rates of return to own R&D stock, domestic R&D spillovers, and international R&D spillovers simultaneously.

The result of the estimation of equation (i) is shown in the first column of table 4-3. We find that the coefficients on domestic knowledge and rent R&D spillover intensities are not significant, whereas the coefficient on own R&D intensity is significant at the 10 percent level. These results suggest that the effects of R&D spillovers in Korean manufacturing industries are weak.[8]

In specification (ii), the rate of return to own R&D intensity is found to be insignificant. The value obtained is less than that of specification (i). Specification (ii) also yields insignificant rates of return to international rent R&D spillover and international knowledge spillover. These values are 6.303 and –0.084, respectively. The coefficient on international rent R&D spillover is positive but insignificant. While the estimation suggest that knowledge R&D spillovers from Japan may have a negative effect on productivity growth in Korean manufacturing industry, the results are by no means significant.

Table 4-2 provides the coefficients of correlation between the main variables used in this regression. We find the correlations between own R&D intensity and international R&D spillover from Japan to be positive and significant at the 5 percent level. We also find that the

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[8] This finding is consistent with Kwon (2003).

correlation with rent spillovers from Japan is stronger than that with knowledge spillovers from Japan. This suggests that the role of own R&D investment in Korean manufacturing industries may be to absorb embodied R&D spillovers through imported intermediate goods from Japan rather than to improve own productivity. Therefore, to examine whether part of the effect of international rent R&D spillover is to improve the productivity of own R&D, we add an interaction term between own R&D and international rent R&D spillover intensity as an explanatory variable. The estimation result is reported in specification (iii). When we add the interaction term to the regression, the coefficients for own R&D and rent international rent R&D spillover intensity become significant. This result suggests that rent R&D spillover from Japan improved the productivity of own R&D. When the international rent spillover intensity is at the mean (0.001), the slope of the line relating TFP growth and own R&D intensity is estimated to be 0.291 (=0.525+(-179.426*0.001)). This implies that, on average, the estimated effect of a unit increase in own R&D intensity is to increase TFP growth by 0.291. This coefficient is of a similar size as that on own R&D intensity obtained in specification (i).

In specification (iv), we consider all R&D and R&D spillover variables, i.e. own R&D, domestic R&D spillovers, and foreign R&D spillovers.[9] We find that the rate of return to own R&D intensity is insignificant, while the estimation results of domestic R&D spillovers are

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[9] The estimation results of specifications (iv) and (v) may be contaminated by multicollinearity because knowledge R&D spillover from Japan is highly correlated with other regressors.

significant at the 10% level. We obtain a negative rate of return to domestic rent R&D spillover. However, the coefficient on domestic knowledge R&D spillover is positive and larger than that of own R&D intensity. The impact of international rent R&D spillovers is significant at the 10% level. However, the coefficient on international knowledge R&D spillover is negative and insignificant, which is the same result as in specification (ii). This finding weakly supports the view that disembodied knowledge spillover is not an international phenomenon but an intranational one.[10] Specification (v) confirms the above findings, with the exception that the coefficient on domestic knowledge spillover becomes insignificant and the coefficient on own R&D intensity becomes significant.

The empirical results presented here can be interpreted as follows: first, we confirmed that the effect of domestic rent R&D spillovers is significantly negative, while the impact of domestic knowledge R&D spillovers on productivity in Korean manufacturing industry seems to be positive and insignificant in most specifications. This result suggests that Korea’s domestic knowledge pool for sustained long-run growth is weaker than that of other developed countries.

The second major conclusion following from the estimation results is that total factor productivity in Korean manufacturing industry depends not only on own R&D but also on rent R&D spillovers from Japan. The impact of rent R&D spillover from Japan is much stronger

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[10] For an explanation why knowledge spillover is an intranational phenomenon, see Branstetter (2000).

than own R&D. This indicates that the reliance on Japanese intermediate goods is a source of technological progress for the Korean manufacturing sector, confirming studies by Kim (1997, 2000) who pointed out that the importation of foreign capital and intermediate goods have served as an important means to improving productivity growth in Korean manufacturing firms. This finding lends support to the creation of a Japan–Korea FTA, which would further enhance Korea's absorption of R&D spillovers from Japan through the importation of intermediate goods. In particular, we confirm that rent spillovers from Japan play an important role not only in productivity growth but also in raising the efficiency of own R&D activities.

Third, there is no evidence that Korean manufacturing industries benefit from the Japanese knowledge pool. The effect of disembodied knowledge spillover from Japan is insignificant and negative. This result suggests that there must be a in our specification or some effect that we are not picking up. This may be attributable to the prohibition of imports of Japanese pop culture and certain finished goods (in particular, consumer electronics and automobiles). Our estimation result may suggest that these regulations act as a barrier to the transfer of knowledge across national boundaries between Korea and Japan.

5. Conclusion

The main findings of the empirical analysis can be summarized as follows. First, we confirm that the contribution of R&D spillovers in Korean manufacturing industries is low and insignificant, no matter which kind of R&D spillover is considered. Second, there is strong evidence that Korean industries benefit greatly from rent R&D spillovers from Japanese industries. In particular, we find that the role of own R&D investment in Korean manufacturing industry is to absorb embodied R&D spillovers from Japan rather than to improve its own productivity.

The policy implications of these findings are straightforward. Policies that promote domestic R&D spillovers should be set up. Korea needs to develop efficient producers of intermediate goods. Another implication for public policy to which the empirical findings point is that measures should be introduced that encourage faster growth of international R&D spillovers from Japan in order to generate higher productivity in Korean industry.

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Table 2-1. R&D proximity matrix for Korean manufacturing industries

Code	Industry	1	2	3	4	5	6	7	8	9	10	11	12
1	Food, beverages	1											
2	Textiles, apparel	0.052	1										
3	Paper, paper products and printing	0.145	0.075	1									
4	Chemical products	0.179	0.320	0.179	1								
5	Petroleum refineries and products	0.165	0.408	0.173	0.963	1							
6	Non-metallic mineral products	0.108	0.071	0.186	0.267	0.187	1						
7	Basic metal industries	0.014	0.009	0.027	0.059	0.044	0.117	1					
8	Fabricated metal products	0.042	0.024	0.047	0.088	0.092	0.115	0.985	1				
9	Non-electrical machinery	0.068	0.047	0.050	0.126	0.146	0.160	0.685	0.732	1			
10	Electrical machinery	0.061	0.045	0.067	0.120	0.141	0.220	0.272	0.302	0.541	1		
11	Transport equipment	0.074	0.050	0.044	0.091	0.116	0.167	0.335	0.364	0.430	0.255	1	
12	Professional goods	0.108	0.062	0.119	0.173	0.212	0.289	0.349	0.398	0.601	0.906	0.377	1

Table 2-2. R&D proximity matrix for Korean and Japanese manufacturing industries

Code	Industry	1	2	3	4	5	6	7	8	9	10	11	12
1	Food, beverages	**0.993**	0.046	0.111	0.042	0.185	0.016	0.010	0.038	0.030	0.037	0.039	0.022
2	Textiles, apparel	0.032	**0.995**	0.064	0.138	0.290	0.052	0.009	0.126	0.101	0.025	0.019	0.074
3	Paper, paper products and printing	0.134	0.072	**0.852**	0.117	0.150	0.044	0.025	0.107	0.086	0.036	0.025	0.063
4	Chemical products	0.096	0.229	0.145	**0.111**	0.796	0.042	0.045	0.101	0.081	0.056	0.038	0.060
5	Petroleum refineries and products	0.079	0.316	0.154	0.118	**0.888**	0.044	0.038	0.108	0.086	0.079	0.053	0.064
6	Non-metallic mineral products	0.087	0.065	0.138	0.047	0.216	**0.018**	0.090	0.043	0.034	0.086	0.115	0.025
7	Basic metal industries	0.012	0.005	0.006	0.176	0.029	0.066	**0.990**	0.160	0.128	0.207	0.150	0.095
8	Fabricated metal products	0.035	0.019	0.024	0.119	0.081	0.045	0.986	**0.109**	0.087	0.236	0.165	0.064
9	Non-electrical machinery	0.030	0.021	0.024	0.085	0.112	0.032	0.525	0.077	**0.062**	0.515	0.176	0.046
10	Electrical machinery	0.025	0.026	0.041	0.116	0.116	0.044	0.205	0.106	0.085	**0.995**	0.159	0.063
11	Transport equipment	0.032	0.037	0.026	0.088	0.156	0.033	0.346	0.080	0.064	0.250	**0.951**	0.047
12	Professional goods	0.046	0.032	0.067	0.071	0.180	0.027	0.239	0.065	0.052	0.626	0.174	**0.038**

Table 3-1. Descriptive statistics on R&D stocks

Code	Industry	$R_o(96)/R_o(87)$	$S_{dr}(96)/S_{dr}(87)$	$S_{dk}(96)/S_{dk}(87)$	$S_{Jr}(96)/S_{Jr}(87)$	$S_{Jk}(96)/S_{Jk}(87)$
1	Food, beverage	4.6	6.3	6.6	2.0	2.0
2	Textiles, apparel	2.0	5.8	5.8	1.5	1.5
3	Paper, paper products and printing	4.9	6.4	6.4	2.2	2.2
4	Chemical products	5.8	7.3	7.4	2.0	2.0
5	Petroleum refineries and products	8.4	6.5	6.5	1.9	2.0
6	Non-metallic mineral products	6.7	7.7	8.0	2.1	2.2
7	Basic metal industries	8.0	7.3	7.2	2.1	2.2
8	Fabricated metal products	10.1	7.0	7.2	2.3	2.4
9	Non-electrical machinery	4.1	7.9	7.9	2.5	2.5
10	Electrical machinery	8.1	6.1	6.1	2.2	2.2
11	Transport equipment	18.6	6.5	6.8	2.9	2.9
12	Professional goods	13.4	7.7	8.0	2.8	2.5
	Unweighted mean	7.9	6.9	7.0	2.2	2.2

4-1. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
TFPGi	120	0.018	0.070	-0.152	0.243
(Ri /Yi)	120	0.030	0.037	-0.007	0.172
(Sdri /Yi)	120	0.006	0.006	0.001	0.026
(Sdki / Yi)	120	0.019	0.049	0.000	0.289
(Sjri /Yi)	120	0.001	0.001	0.000	0.005
(Sjki /Yi)	120	0.025	0.046	0.000	0.228

Table 4-2. Correlation matrix

	TFPGi	(Ri /Yi)	(Sdri /Yi)	(Sdki / Yi)	(Sjri /Yi)	(Sjki /Yi)
TFPGi	1					
(Ri /Yi)	0.1515	1				
(Sdri /Yi)	-0.0101	0.0712	1			
(Sdki / Yi)	0.0256	0.0373	0.5828*	1		
(Sjri /Yi)	0.1626	0.4952*	0.1033	0.2874*	1	
(Sjki /Yi)	0.0202	0.1903*	0.4051*	0.8490*	0.5970*	1

Note:* significant at the 5% level

Table 4-3. R&D spillover regressions

Variables	(i)		(ii)		(iii)		(iv)		(v)	
constant	0.034		0.031		0.028		0.037		0.035	
	(2.37)	**	(2.10)	**	(1.94)	*	(2.53)	**	(2.45)	**
R_i /Yi	0.306		0.203		0.525		0.196		0.519	
	(1.78)	*	(0.92)		(1.79)	*	(0.88)		(1.78)	*
S_{dri} /Yi	-1.755						-1.978		-2.218	
	(-1.54)						(-1.75)	*	(-2.04)	**
Sdki / Yi	0.173						0.579		0.537	
	(0.98)						(1.65)	*	(1.57)	
Sj_{ri} /Yi			6.303		15.134		11.279		20.091	
			(1.14)		(2.14)	**	(1.77)	*	(2.66)	***
(Ri /Yi)*(Sjri /Yi)					-179.426				-187.065	
					(-1.72)	*			(-1.80)	*
S_{jki} /Yi			-0.084		-0.145		-0.613		-0.621	
			(-0.42)		(-0.74)		(-1.49)		(-1.54)	
LM statistics	82.37		83.26				87.14			
Obs.	120		120		120		120		120	

Note: 1) The dependent variable is growth of TFP.
2) The numbers in parentheses are z-statistics
3) *P=.10, **P=.05, ***P=0.01 (two-tailed test
4) In each estimation, we assumed a model with heteroscedasticity across panel
5) All regressions include year dummies