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MEASURING THE RATE OF RETURN TO R&D, INTERINDUSTRY R&D SPILLOVERS IN KOREAN MANUFACTURING INDUSTRIES*

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Abstract

This paper estimates the effect of R&D on total factor productivity using the panel data of Korean manufacturing industries during the period of 1987-1996. The rate of return to own R&D in Korea is slightly higher than that in developed countries. However, the effect of R&D spillovers on the productivity growth in Korea is lower than that in developed countries.

Key words: Total factor productivity, R&D spillover, Korea
JFL Classification: O30, O53, C23

I. *Introduction*

For the last several decades, many economists have focused on the role that R&D spillovers across industry play in generating increasing returns and stimulating productivity growth. A large majority of empirical studies on R&D spillovers provides supporting evidence that productivity is probably affected by the R&D spillovers. In other words, the growth of productivity achieved by one industry depends not only on its own R&D but also on other industry R&D effort (Nadiri, 1993 and Griliches, 1995). Unfortunately, relatively few studies on this subject in developing countries have been carried out so far. This study attempts to remedy such shortage of empirical studies on contribution of interindustry R&D spillovers in developing countries.

The purpose of this paper is to estimate the effects of knowledge spillover and rent spillover of between suppliers and buyers in the closed economy, using Korean manufacturing data.[1] In addition, this paper conducts a comparative analysis of the contribution of R&D spillover effects in advanced economies with that of R&D spillover in Korea as a developing country.

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[1] This study excludes international R&D spillover and foreign technology purchase, although they are as important as, if not more, R&D expenditure and domestic R&D spillover.

Section 2 will describe the model of R&D — productivity relationship used for empirical estimation. Data sources and R&D spillover variables used in this study explained in Section 3. Empirical findings are summarized in section 4 and concluding remarks are given in the last section.

II. *Model Specification*

A conventional approach to estimate the rate of return to R&D is to treat R&D investment as an alternative capital investment in a standard neoclassical model (Griliches, 1998).[2]

Consider the following standard Cobb-Douglas production function. By suppressing time subscripts, value-added can be stated as

$$Y_i = A_i R_i^{\beta} S_i^{\theta} L_i^{\alpha_1} K_i^{\alpha_2} e^{\mu_i t} \tag{1}$$

Where Y_i is value-added, R_i is own R&D capital stock, S_i is R&D spillover for industry, L_i is labor input, K_i is capital input, A_i is a constant, and μ is a time trend used to capture other trend influences.

Taking the logs of both sides gives us

$$\ln Y_i = \ln A_i + \beta \ln R_i + \theta \ln S_i + \alpha_1 \ln L_i + \alpha_2 \ln K_i + \mu_i t \tag{2}$$

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

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

Where $\dot{Y}/Y = \partial \ln Y_t / \partial t = (1/Y)(\partial Y_t / \partial t)$.

The growth accounting conventionally derives a total factor productivity growth from equation (3) by subtracting the growth of labor and the growth of capital from each side:

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

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

$$\beta = (\partial Y / \partial R)(R/Y) = \rho(R/Y), \ \theta = (\partial Y / \partial S)(S/Y) = \rho_s(S/Y) \tag{5}$$

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 capital to value-added.

We rewrite equation (4) by substituting equation (5) as:

$$TFPG_i = \rho(\dot{R}_i / Y_i) + \rho_s(\dot{S}_i / Y_i) + \mu_i \tag{6}$$

Where ρ is the net rate of return to own R&D,[3] ρ_s is the net rate of return to R&D

[2] Alternative approach, pursued by Bernstein and Nadiri (1989), is to compute the effect of R&D spillovers using estimated cost functions.

[3] Due to double counting and intraindustry R&D spillovers, the rate of return to R&D is interpreted excess rate of returns to R&D.

spillover.

If it is assumed that the depreciation rate of R&D stock is close to zero, the net R&D expenditure corresponds to the gross R&D expenditure.[4] In this case (6) can be rewritten as:

$$TFPG_i = \gamma (E_i / Y_i) + \gamma_s (E_{si} / Y_i) + \lambda_i \tag{7}$$

where E is the flow of R&D. Parameters γ, γ_s correspond to the gross rate of return to own R&D and R&D spillover respectively. Equation (7) is used to estimate the effect of R&D spillovers.

The measurement of the R&D stock requires historical R&D expenditures data, depreciation rate, lags, an initial stock of R&D, and deflator of R&D expenditures. The main difficulties in constructing R&D stock are uncertainty of depreciation rates and lags.

Because the appropriate depreciation rate of R&D is seldom known and sufficiently long time series on R&D expenditures are not usually available, we assumed zero depreciation rate as most commonly observed in previous studies. When a zero depreciation rate is assumed, the rate of return specification does not require the computation of R&D capital stocks.[5]

As in the case of the depreciation rate, the correct length of the lag also remains problematic. However, empirical results tend to be insensitive to the choice of length of lag (Hall and Mairesse, 1995). The most commonly used in the previous studies the length of lag is one period or no lag. In this paper, no lagged relation is assumed.

III. *Data Sources and the Variables*

Our sample consists of 15 manufacturing industries in Korea during the period of 1987-1996. The data on annual R&D expenditures are drawn from "Report on the Survey of Research and Development in Science and Technology" and deflated by the GDP deflator (1990=100) from OECD STAN database.

The dependent variable is TFP (Total Factor Productivity). We compute the growth of TFP for industries i in period t.

$$\Delta TFP_{it} = \ln Y_{it} - \ln Y_{it-1} - \alpha_{it} (\ln L_{it} - \ln L_{it-1}) - (1 - \alpha_{it})(\ln K_{it} - \ln K_{it-1}) \tag{8}$$

Y, L and K are the value added, labor input and the net capital stock respectively. α is the share of labor compensation in value added. The value added was drawn from the OECD STAN database and deflated with GDP deflator (1990=100). The labor input was calculated by multiplying the number of employees by average monthly hours of work. The number of employee and the share of labor compensation were taken from OECD STAN database. The average monthly work hours is reported in the Yearbook of Labor of Korea. The source of net capital stock is taken from Pyo (1998).

Griliches (1979) suggests the existence of two different types of R&D spillovers: rent spillover and knowledge spillover. The rent spillover has to do with the fact that producers of

[4] For a short mathematical proof (Griliches (1998, p.221))

[5] In the industry level studies, researchers have found that results of regression are not sensitive to alternative assumptions about the depreciation rate.

Also, in an early version of this paper, submitted to the Hitotsubashi University as a Master's thesis, the estimated results with depreciation rate of 15 percent lead largely to the same results of this paper.

knowledge and innovations are unable to set their full quality price because of its inability to exercise price discrimination, competition, and measurement errors of official price indices. In this case, the producers of R&D embodied goods unintentionally provide some returns to the purchasers of goods.[6] By contrast, the knowledge spillover occurs because of public characteristics. These characteristics emerge when the producer of knowledge cannot completely appropriate benefits derived from the R&D activities.

We investigate the effects of knowledge spillover and rent spillover between suppliers and buyers in the closed model in the following. We use two different weight functions to characterize distinct features of two R&D spillovers.[7] The weight function of R&D spillovers are estimated from interindustry transaction tables. In the first, rent R&D spillover is measured in the following way (Terleckyj, 1980; Wolff and Nadiri, 1993):

$$IRDB_i = \Sigma_j b^0_{ji} E_j / y_i$$

where b^0_{ji} is the proportion of industry j's output accounted for by its sales to industry i. E_j and y_i are R&D expenditures of industry j and value-added of industry i, respectively. b^0_{ji} shows the zero diagonals elements. This weight function shows that the amount of returns accrued to i industry through R&D embodied intermediate goods are proportional to the purchases from industry j. This weight corresponds to rent R&D spillover from suppliers to buyers.

The second weight used to compute the knowledge R&D spillover is input coefficient (Wolff and Nadiri, 1993). The amount of R&D spillovers is measured by

$$IRD_i = \Sigma_j a^0_{ji} E_j / y_i$$

where a^0_{ji} is identical to a_{ji} except that the diagonal elements are set to zero to eliminate double counting of R&D expenditures. a^0_{ji} is an average input coefficient calculated from the Korean input-output tables, 1987, 1990, 1995. This weight implies the knowledge R&D spillover in the relationship between suppliers and buyers. The extent of knowledge R&D spillover is proportional to input j's importance in i's production structure.

Industry characteristics are summarized table 3-1.

The average of TFP growth rates over the 1987-1996 period varied from a high of 8.6% in electrical machinery to a low of −11.0% in petroleum refineries and products. The all industry average is 1.3%.[8]

The average value for own R&D intensity ranges from 19.5% in electrical machinery to 0.2% in wood products and furniture. As might be expected, the average value of own R&D intensity is highest in high-tech industries, followed by medium-tech and low-tech industries, respectively. The correlation coefficient between TFPG and own gross R&D intensity is 0.145.

The R&D spillovers calculated by input coefficient (IRD) range from 0.2% in food, beverage and tobacco to 37.8% in professional goods. IRD is positively correlated with TFP growth. In contrast, the R&D spillovers calculated by output coefficient (IRDB) is negatively correlated with TFP growth.

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[6] In principle, rent spillover become less pronounced if perfect price deflators are used.

[7] Differences in the two weights are explained in Wolff and Nadiri (1993)

[8] This average falls within the range of previous estimates by Pyo and Kwon (1991), Kim and Lau (1994) and Young (1995) showing the TFP growth rates of Korea 1.6%, 1.2%, and 1.7% respectively.

TABLE 3-1. MEAN VALUES OF SELECTED VARIABLES FOR KOREAN MANUFACTURING INDUSTRIES, 1987-1996

Industry	TFPG(%)	RD(%)	IRD(%)	IRDB(%)
Food, Beverage and Tobacco	−2.5	1.4	0.2	9.1
Textiles, Apparel and Leather	−0.2	1.3	1.4	41.0
Wood products and Furniture	−0.9	0.2	5.6	50.8
Paper, Paper products and Printing	1.8	0.9	1.4	41.9
Chemical Products	2.3	8.9	0.3	54.5
Petroleum refineries and products	−11.0	3.5	0.7	83.2
Rubber and Plastic products	3.8	2.8	5.7	115.3
Non-Metallic Mineral products	2.1	1.6	1.4	70.7
Basic metal industries	5.0	1.8	0.3	96.8
Metal products	−0.8	2.1	2.7	125.9
Non-Electrical machinery	4.8	5.2	2.9	7.4
Electrical machinery	8.6	19.5	0.4	126.1
Transport equipment	0.9	12.3	1.8	231.5
Professional goods	2.8	5.7	37.8	588.5
Other manufacturing	3.3	1.5	16.2	309.1
Average	1.3	4.5	5.3	130.1
Correlation with TFP growth		14.5	5.9	−0.1

IV. *Empirical Findings*

The equation (9) as given below is used to estimate the direct return to R&D, as well as spillover effects of R&D.[9]

$$TFPG_{it}=\lambda+\gamma RD_{it}+\gamma_s IRDs_{it}+\varepsilon_{it} \qquad (9)$$

where γ is the rate of return to own R&D expenditure,[10] γ_s denotes the rate of return to inter-industry R&D spillover and ε_{it} is a stochastic error term. RD is R&D intensity and IRDs is R&D spillover intensities.

In estimation of panel data, pooled OLS, fixed effect model and random effect model are usually used. We choose among the pooled OLS or fixed effect model, pooled OLS or random effect model depending upon which model yields the best estimate of the parameters. We can choose between pooled OLS and fixed effect model testing a hypothesis that the constant terms are all equal with an F test. Furthermore, LM test by Breusch and Pagan is use in choosing the between pooled OLS and ranom effect model. As a result of these tests, the pooled OLS is finally adopted.[11] Moreover, ε_{it} is assumed to be independently distributed but not identically distributed. This assumption makes it possible to use feasible GLS estimation. As a result, equation (9) is to be estimated by feasible GLS.

[9] Equation (9) assumes that R&D expenditures are exogenous. It should be noted, however, that if exists a feedback effect from high TFP growth to R&D expenditure, estimates will be biased. Because of the lack of appropriate instrumental variables, we could not take account of this problem.

[10] It was not possible to avoid double counting of labor and capital inputs used in the R&D activities. Thus, the rate of return to R&D may be biased downwards. Schankerman (1981) reports that eliminating for double-counting raises the rate of return by about 0.1.

[11] see Greene (1997) pp.612-pp.642

TABLE 4-1. ESTIMATES OF RATES OF RETURN TO R&D AND R&D SPILLOVERS

	FGLS with year dummies			FGLS without year dummies		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.023 (1.58)	0.022 (1.51)	0.011 (0.59)	0.004 (0.74)	0.001 (0.18)	0.0004 (0.07)
RD	0.259** (2.57)	0.272* (2.70)	0.259** (2.51)	0.314* (3.24)	0.319* (3.27)	0.329* (3.39)
IRD		0.078 (1.17)			0.071 (1.14)	
IRDB			0.003 (1.25)			0.004** (2.01)

Notes: Figures in parentheses are z-values. *, ** indicate statistical significance at 1%, 5% levels for two-tailed tests.

The estimation results are summarized in Table 4-1.

The rate of return to own R&D becomes statistically significant irrespective of year dummies. The estimated own return to R&D varies from 26 percent to 33 percent. The estimated coefficient indicates that the increasing R&D expenditure by 1 percent of value-added would be associated on the average with an increase the annual growth rate of total factor productivity by 0.3 percent in 1987-1996. Note that the average TFP growth rate for all industries was only 1.3 percent. The marginal contribution of own R&D expenditure to productivity growth was significant. When only own rate of return to R&D is compared to that of other developed countries as shown in Table 4-2, the value of Korea is higher than most developed countries.

Let us turn to the effect of R&D spillovers. The estimated results by feasible GLS with year dummies are not statistically significant for two R&D spillover intensities.[12] But the coefficient of IRDB is positively significant in feasible GLS without year dummies. The coefficient is very low compared with estimated results by most studies on the effect of R&D spillover (see Table 4-2).

The sample mean of RD and IRDB are 0.045 and 1.301 respectively. Let us consider a hypothetical economy whose RD and IRDB are identical with these sample means. Suppose this economy increase their annual R&D expenditure by 10 percent. According to the coefficients of equation (9) in Table 4-1, TFP growth rate of this economy will be increased by 0.2 percent. Of this, 0.15 percent increase is due to own R&D expenditure effects (0.045*0.1 *0.329*100) and only 0.05 percent increase from rent R&D spillovers (1.301*0.1*0.004*100). According to these calculations we can conclude that R&D spillovers do not play important role in productivity growth of Korea manufacturing industries.

Table 4-2 summarizes selected estimated rates of return to R&D and R&D spillover in industry level from the previous R&D-productivity studies. The average of rates of the above studies around 23% when only own R&D is considered. The average for the combined value of R&D and R&D spillovers is nearly 72 %. The average for the combined values of R&D and R&D spillovers in the case of Korean manufacturing industries is around 33%, almost 40% less than the average of all developed countries except U.K. Furthermore the table 4-2 shows that the rate of return to R&D spillovers is higher than the rate of return to own R&D in all

[12] This has been the case in several other studies (see, Odagiri, 1985; Wolff and Nadiri, 1993).

TABLE 4-2. SELECTED EMPIRICAL RESULTS OF THE ESTIMATED RATES OF RETURN

Study	Own R&D (1)	R&D Spillovers: I−O weighted (2)	(1)+(2)
Terleckyj (1974), USA	0.28	0.48	0.76
Sveikauskas (1981), USA	0.1−0.23	0.50	0.6−0.73
Wolff (1997), USA	0.1−0.13	0.41	0.51−0.54
Goto and Suzuki (1989), Japan	0.26	0.80	1.06
Sterlacchini (1989), UK	0.12−0.20	0.09−0.12	0.21−0.32
van Meijl (1997), France	0−0.19	0−1.29	0−1.48

Sources: Nadiri (1993), B.Van Pottelsberghe De La Potterie (1997)

cases except U.K. Perhaps, we need to explain why the opposite results are obtained in the Korean case, namely R&D spillover effects lower than own R&D efforts and R&D spillover effect in Korean manufacturing industries is lower than the advanced countries.

There are two possible reasons. The first reason is that the Korean manufacturing industries are strongly linked to foreign manufacturing industries, especially to Japanese manufacturing industries. It is well known that the Korean economy is highly dependent on imported intermediate goods and capital goods with which they produced manufactured goods for export and domestic consumption. For the period of 1987 to 1996, in the total imports from Japan, the share of machinery products accounted for over 60% every year.[13] Data from the Economic White Paper of Korea for the fiscal year 1996 shows that, Korea recorded the bilateral trade deficit of capital goods against Japan of 16.7 billion dollars, compared to the overall bilateral trade deficit of 15.6 billion dollars. Obviously, Korea is extremely dependent on capital goods from Japan. To remedy this dependency problem, Korea launched a localization program to produce domestic capital goods since 1986. As a result, the share of imported machinery parts and components from Japan was down from 57.4% in 1986 to 38.7% in 1994. Although the import substitution of capital goods was successful in terms of quantity, such import substitution was confined to relatively simple low-tech products. Therefore, Korea had to import for almost all highly sophisticated key parts and components from Japan. This means that the embodied R&D spillover effects through the imported capital goods from Japan to Korea were likely to be very substantial.[14] Hanel (1994) suggest also a similar conclusion that relatively low R&D spillover effects in Canada is mainly due to its highly dependence on USA.

The second and more important reason is inter-firm relationship, and this is particularly strong in Korea by the existence of Chaebols. Although 30 largest Chaebol groups combined share of value added was 15.2% of GNP in 1994, their share of the manufacturing sector was 37.79%. In 1999, Korea Fair Trade Commission discovered that 5 Chaebol groups carried out illegal internal transactions of 12.3 trillion won with which their subsidiary companies.[15] More specifically these Chaebol groups purchased intermediate goods from their subsidiary companies at higher prices than normal market prices. Rent R&D spillover realizes when the quality improvement of products by R&D is not reflected in price by competition. There is the

[13] Annual White Paper on international trade of Japan (various years)

[14] A study by Kwon (2001) also showing that the productivity growth of Korean manufacturing industries depend not only on own R&D expenditure but also the R&D spillovers from Japan.

[15] Samsung, Hyundai, Daewoo, LG, SK

possibility of a lower interindustry R&D spillover effect when higher prices are paid for these intermediate goods compared to improved quality by R&D by utilizing exclusive business relationships. Furthermore, there is also a lower interindustry R&D spillover effect when companies cannot purchase higher quality intermediate goods from other companies, due to restricted business relationships. Of course, rent R&D spillover will occur when Cheabol groups purchase intermediate goods from outsiders or other Chaebol group companies because they usually buy them at the market prices. In such a case, however, there is the possibility that this positive rent R&D spillover effect may be hindered by the above mentioned restricted business relationship.

V. *Conclusion*

In this paper, we have attempted to estimate the rate of return to R&D and R&D spillover using panel data of Korean manufacturing industries during the period of 1987-1996.

The main findings of empirical analysis can be summarized as follows.

First, own R&D intensity as explanatory variable is highly correlated with TFP growth. The estimated rate of return to R&D is found within a range of 26-33 percent. This result suggested that the rate of return to own R&D in Korea is slightly higher than developed countries.

Second, the contribution of R&D spillovers to the productivity growth in Korean manufacturing industries is very low or not statistically significant. The rate of return to knowledge R&D spillover measured using input coefficients is statistically insignificant. The return to rent R&D spillover estimated using by output coefficients, which are obtained by dividing each cell value by its corresponding row sum is very low but statistically significant. These results indicate that the effect of R&D spillover on the productivity growth in Korea is less pronounced than advanced economies.

Recent endogenous growth theory has emphasized the importance of R&D spillovers for the economy's sustained long run growth. Therefore, a key policy agenda for accelerating growth of the Korean economy is to deepen and widen interindustry R&D spillover effects.

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