An Estimation of Knowledge Production Function By Industry in Korea[1]

[1]Sung Tai Kim, [2]Byumg In Lim, [3]Myoung Kyu Kim,
[1, First Author] *Dept. of Economics, Cheongju University, stkim@cju.ac.kr*
[*2,Corresponding Author] *Dept. of Economics, Chungbuk National University, Korea, billforest@hanmail.net*
[3,] *Dept. of Economics, Cheongju University, koluso@naver.com*

Abstract In this paper we estimate the knowledge production function for 28 industries in Korea. The knowledge production function is a function between R&D investment and knowledge creation. Knowledge creation is measured in terms of patent application. We found that the R&D investments have played very important role in increasing the patent applications. The elasticity of patent applications with respect to R&D investment is 0.672 implying that 1% increase in R&D investments will increase 0.672% of patent applications.

Keywords: *Knowledge production function, R&D investment, Patent*

1. Introduction

Korea may be in the trap of a low potential economic growth without new economic growth strategy enhancing the total productivities of the economy as a whole. It will be necessary for Korea to develop the science and technology innovation and accumulate the knowledge capital and the human capital to keep sustainable growth. Korea must increase R&D investments and the efficiency of R&D investments as well to keep sustainable growth. We had better understand the channel of economic effects of R&D investments on the total factor productivity. The channel of economic effects of R&D investments on total factor productivity may be decomposed into several stages. In the first stage an increase in R&D investments increase patent applications. In the second stage an increase in patent applications increase the knowledge stock. In the third stage an increase in knowledge stock enhances the total factor productivity.

The purpose of the study is to estimate the knowledge production function for both all industries and eight groups of industry in Korea. The knowledge production function is a function between R&D investment and knowledge creation. Knowledge creation is measured in terms of patent application.

2. Literature Survey

There are many works on R&D and patents; Schumpeter(1942), Nordhaus(1969), Pakes and Griliches(1980), Bound et al.(1982), Hall et al.(1986), Griliches(1990), Kortum(1993), Lanjow and Schnkerman(2004), Benito(2006), Baudry and Dumont(2006), to name a few.

There are some views in which the patent should be considered as the intermediate output from R&D. It is because R&D serves to increase the GDP. Hall et al.(1986) found that he estimated a patent production function and there exists a constant returns to scale, standing for CRTS between R&D investment and the number of patents.

On the contrary, Bound et al.(1982) estimated a patent production function but found that there is a decreasing returns to scale(DRTS) between R&D investment and the number of patents.

Baudry and Dumont(2006) asserted that R&D investment, acting as the driving force for the innovation, finally raises the growth rate, irregardless of the growth stages. It implies that creating a knowledge and innovative activities is required to achieve the economy growth successively. In this respect, it is said that the reason EU has slower economy than USA results from the deficiency in the innovative components.

Also, there are many studies testing the hypothesis R&D investment increases the patent enrollments, for example, Griliches(1990), Kortum(1993), Lanjow and Schnkerman(2004), and so on. Pakes and Griliches(1980) found a strong correlation between a firm's R&D investment and a patent enrollment using firm

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data. Hall et al.(1986) showed that there is a time lag between R&D investment and patent enrollment.

3. Trends of R&D Investments and Patents

The raw patent data that we had was classified on the basis of 35 technologies, and we reclassified into 28 industries by using the technology code and the industry code. We created the data set, since we don't have the industry-specific raw data of the patent. Thus we made a useful data from the annual data released from Minister of Patent.

We used the patent applications in 28 industries and industry-specific data. The problem was that Korean patent applications differs in industry classification. We tried to match the industry classification of R&D investment to that of patent applications.

We analyzed the firm data during 1983–2010 periods. The total applications are estimated to be 998,609.

<Figure 1> shows the trends of both R&D investment and patent applications in Korea. The trends of two variables have been dropped drastically right after the second half of 1997 and the global financial crisis of 2008. It strikingly shows that patent respond on the economic fluctuations stronger than R&D investment.

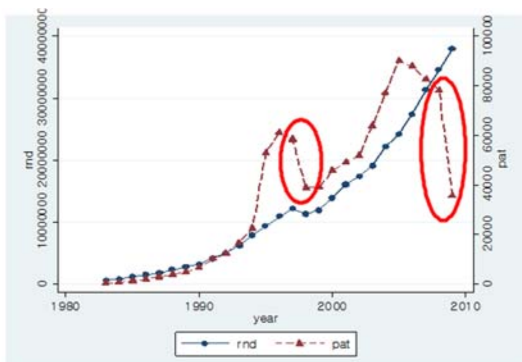

Figure 1. Trends of total R&D investments and Patent applications

<Figure 2> and <Figure 3> show the trends of both R&D investment and patent applications for 28 industries in Korea. The trends of two variables have been dropped drastically right after the second half of 1997 and the global financial crisis of 2008. It strikingly shows that patent respond on the economic fluctuations stronger than R&D investment.

4. Estimation Results of Knowledge Production Function

A knowledge production function that we use is based on the following R&D-based growth model is shown in equation (1).

$$\dot{A} = \delta(R\&D)^{\lambda}A^{\phi} \quad (1)$$

We may derive the following estimation equation (2).

$$log\,PAT = \alpha + \beta logRD + \gamma_1 TREND + \gamma_2 log\frac{K}{L} + u \quad (2)$$

where PAT=number of the patent applications, RD=R&D investment, TREND=the time trend, and =capital equipment ratio.

The estimation result for whole sample is shown in <table 1>.

Table 1. Estimation Results of Knowledge Production Function : All Industries

Dependent Variable: $log\,PAT$			
	Pooled	**FE**	**RE**
$logRD$	0.871868*** (26.085)	0.672171*** (20.319)	0.693975*** (21.232)
$log\frac{K}{L}$	0.178013** (2.698)	1.234081*** (15.828)	1.156222*** (15.120)
Constant	5.541907*** (55.861)	6.839315*** (67.421)	6.732157*** (25.574)
R^2	0.563978	0.747426	0.747060
log likelihood	-1.15e+03	-7.46e+02	
N	642	642	642

Note: t-values in parentheses. * p<0.1, ** p<0.05, *** p<0.01.

The first column shows the estimation results for OLS and the second column shows the ones for fixed effect model, and the third column for random effect model. By Hausman test, the fixed effect model is the best one with 1% significance level.

The coefficient of R&D investment variable is 0.672, implying that R&D investment increase by 1% increases 0.67% of patent applications. When we compare our elasticities with the previous ones, ours is a little bit higher than 0.37～0.52 in HHG(1984), 0.208 in Abdih and Joutz(2005), 0.1～0.6 in Kortum(1993).

The fact that R&D investment productivity is less than 1 means that R&D investment shows decreasing returns to scale(DRTS). It says that attribute of R&D investment is due to an imitativeness.

The coefficient of the capital labor ratio per$(\frac{K}{L})$ has a positive value with a high statistical significance. It implies that, other things being equal, the higher the capital equipment ratio the more the patent and the higher the productivity of R&D investment.

We classify 28 industries into 8 industry groups in Table 2. The estimation results for eight industry groups are as follows.

Table 2. Bank of Korea 28-Industry classifications resort to 8-Industry groups

Industry Group	Bank of Korea 28-Industry classifications
Group Ⅰ	1.Agriculture, forestry and fishing, 2.Mining and quarrying, 3.Food, beverages and tobacco products
GroupⅡ	4.Textile and apparel, 5.Wood and paper products, 6.Printing and reproduction of recorded media
GroupⅢ	7.Petroleum and coal products, 8.Chemicals, drugs and medicines, 9.Non-metallic mineral products
GroupⅣ	10.Basic metal products, 11.Fabricated metal products except machinery and furniture, 12.General machinery and equipment, 15.Transportation equipment
GroupⅤ	13.Electronic and electrical equipment, 14.Precision instruments, 16.Furniture and other manufactured products
GroupⅥ	17.Electrictity, gas, steam and water supply, 18.Construction
GroupⅦ	21.Transportation, 22.Communications and broadcasting
GroupⅧ	24.Real estate and business services, 25.Public administration and defense, 26.Education, health and social work, 27.Other services, 28.Dummy sectors

Table 3 show the estimation results for eight industrial groups. The optimal model varies in industry in Table 3.

In <Table 3> the coefficient of variable $logRD$ represents the elasticity of the patent applications with respect to R&D investments. The highest elasticity of the patent applications is 0.889 in industry group Ⅷ. The reason why the elasticity is bigger than the other sectors may be that R&D sector belongs to one of these industries.

The second highest elasticity is 0.869 for industry group Ⅶ. The third highest elasticity is 0.846 for industry group Ⅴ. The fourth highest elasticity is 0.738 for industry group Ⅳ. The least elasticity of patent applications with respect to R&D investment belongs to industry group Ⅰ.

5. Conclusion

Findings from knowledge production function estimations are as follows. It turns out that the R&D investments have played very important role in increasing the patent applications. The elasticity of patent applications with respect to R&D investment is 0.672 implying that 1% increase in R&D investments will increase 0.672% of patent applications. Our estimate of the elasticity of patent application with respect to R&D investment is a little bit higher than previous studies such as Hausman et al.(1984) (0.37~0.52) and Kortum(1993) (0.1~0.6).

We found that the higher the capital-labor ratio, the higher the productivity of R&D investment. We estimated the elasticity of patent application with respect to R&D investment for eight industrial groups considering the panel data characteristics.

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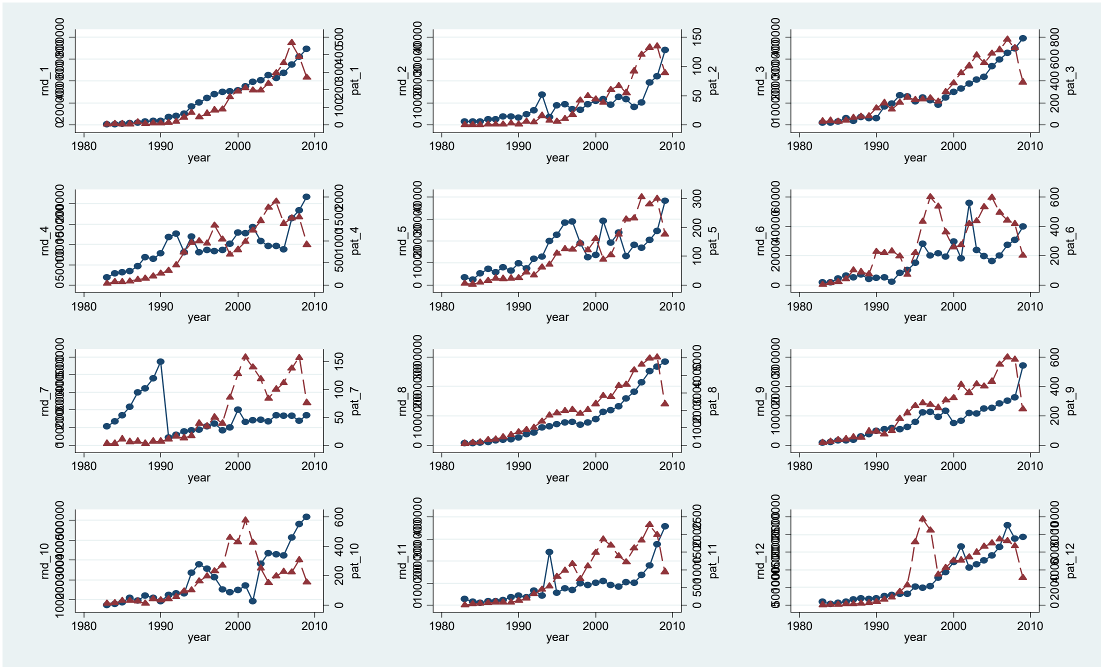

Figure 2. Trends of total R&D investments and Patent applications for industry 1 ~ industry 12: 1983-2009

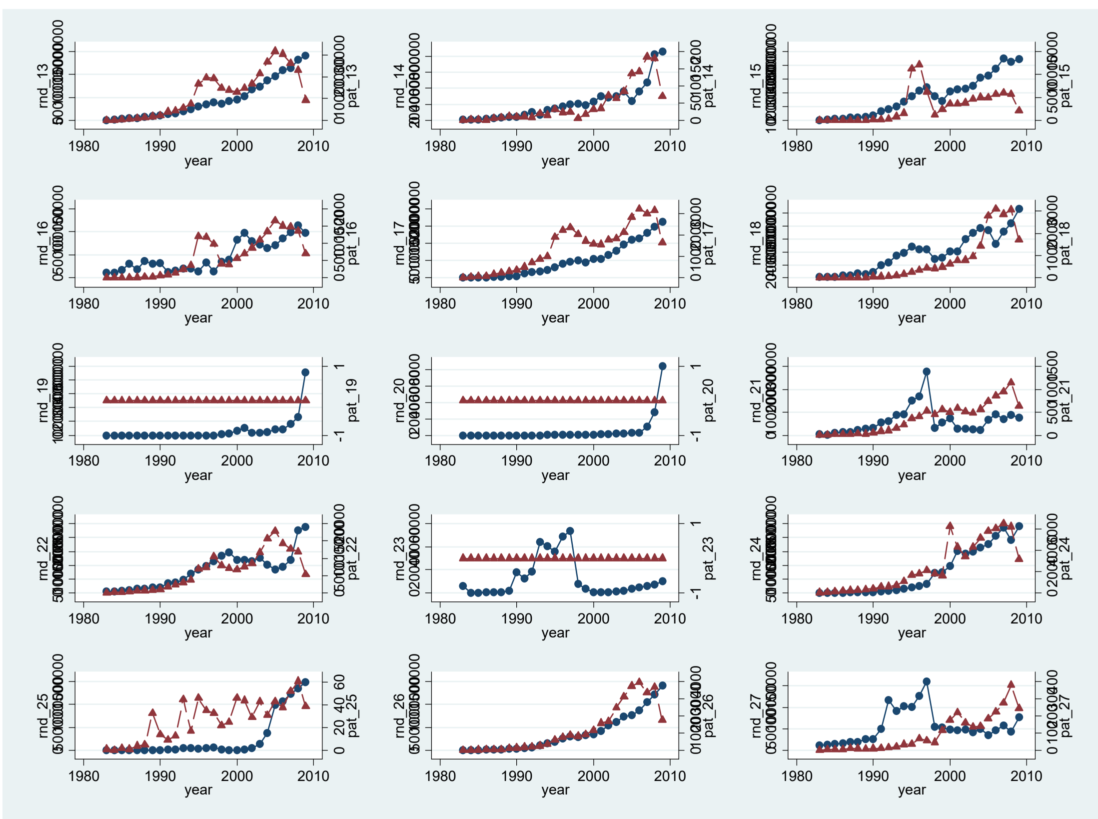

Figure 3. Trends of total R&D investments and Patent applications for industry 13 ~ industry 27: 1983-2009

Table 3. Estimation Results of Knowledge Production Function By Industries

Dependent Variable: $log\,PAT$	Group Ⅰ	Group Ⅱ	Group Ⅲ	Group Ⅳ	Group Ⅴ	Group Ⅵ	Group Ⅶ	Group Ⅷ
Optimal Model	Fixed Effect	Fixed Effect	Fixed Effect	Fixed Effect	Random Effect	Fixed Effect	Random Effect	Random Effect
$logRD$	0.421*** (4.93)	0.586*** (4.64)	0.571*** (4.21)	0.738*** (5.36)	0.846*** (5.99)	0.707*** (4.71)	0.869*** (11.11)	0.889*** (12.42)
$log\frac{K}{L}$	2.212*** (9.966)	1.525*** (7.395)	0.455 (1.584)	1.534*** (5.363)	0.673 (1.87)	-1.940*** (-5.00)	0.995*** (5.12)	0.580* (2.54)
Trend			0.031 (1.28)			0.176*** (6.44)		
Constant	7.486*** (28.06)	8.151*** (40.93)	-5.66e+01 (-1.17)	6.995*** (16.75)	5.879*** (10.10)	-3.48e+02*** (-6.36)	7.810*** (23.17)	6.187*** (14.27)
R^2	0.891	0.792	0.880	0.809	0.657	0.917	0.824	0.681
log likelihood	-5.03e+01	-6.54e+01	-2.73e+01	-1.27e+02		-3.92e+01		
N	78	81	73	108	80	54	54	106