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An Estimation of Knowledge Production Function by Industry in Korea

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Abstract: Korea may be in the trap of low potential economic growth without a new economic growth strategy. We examined that how much R&D investment in Korea has on effect on patent. We estimate the knowledge production function for 28 industries in Korea using pooled OLS, fixed effect model and random effect model with panel data. The knowledge production function is a function between research and development (R&D) investment and knowledge creation. Knowledge creation is measured in terms of patent application. We found that the R&D investments have played a very important role in increasing patent applications. The elasticity of patent applications with respect to R&D investment is 0.672, implying that a 1% increase in R&D investments will result in a 0.672% increase in patent applications. It means that R&D investment shows Decreasing Return to Scale (DRTS) and that attribute of R&D investment is due to the imitativeness. The higher the capital-labor ratio, the higher the productivity of R&D investment. These implies that R&D investment increases patent and thus it helps the economy grow in Korea.

Key word: Knowledge production function, R&D investment, patent, panel data analysis, elasticity, function

INTRODUCTION

Korea may be in the trap of low potential economic growth without a new economic growth strategy enhancing the total productivity of the economy as a whole. It will be necessary for Korea to develop scientific and technological innovations and accumulate knowledge and human capital to keep sustainable growth. Korea must increase R&D investments as well as the efficiency of R&D investments 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 increases patent applications. In the second stage, an increase in patent applications increases knowledge stock. In the third stage, an increase in knowledge stock enhances the total factor productivity.

The purpose of this study is to estimate the knowledge production function both for all industries and for 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 applications.

LITERATURE REVIEW

There are many researches 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), Lanjouw and Schankerman (2004), Beneito (2006), Baudry and Dumont (2006) to name a few.

There are some views in which patents should be considered the intermediate output from R&D because R&D serves to increase the Gross Domestic Product (GDP). Hall *et al*. (1986) estimated a patent production function and found there exists a Constant Returns to Scale (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,

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finally raises the growth rate, regardless of the growth stage. This implies that creation of knowledge and innovative activities is required to achieve economic growth successively. In this respect, it is said that the reason the European Union has a slower economy than the United States results from a deficiency in the innovative components.

Also, there are many studies testing the hypothesis that R&D investment increases patent enrollments for example, Griliches (1990), Kortum (1993), Lanjouw and Schankerman (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 data. Hall *et al*. (1986) showed that there is a time lag between R&D investment and patent enrollment.

TRENDS OF R&D INVESTMENTS AND PATENTS

The raw patent data that we had was classified on the basis of 35 technologies, we reclassified it into 28 industries using technology and industry codes. We created the data set because we don't have the industry specific raw data for patents. Thus, we made a useful data set from the annual data released from Minister of Patents.

We used the patent applications in 28 industries and industry-specific data. The problem was that Korean patent applications differ in industry classification. We tried to match the industry classification of R&D investments to that of patent applications. We analyzed the firm data from 1983-2010. 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 dropped drastically right after the second half of 1997 and the global financial crisis of 2008. It strikingly shows that patents respond to economic fluctuations stronger than R&D investments.

Figure 2 and 3 show the trends of both R&D investments and patent applications for industries 1-12 and 13-27, respectively in Korea. As in Fig. 1, the trends of the two variables dropped drastically right after the second half of 1997 and the global financial crisis of 2008. It shows that patents respond to economic fluctuations more strongly than R&D investment.

ESTIMATION RESULTS OF KNOWLEDGE PRODUCTION FUNCTION

The knowledge production function that we used is based on the R&D-based growth model shown in Eq. 1:

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

We may derive the following estimation in Eq. 2:

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

Where:

PAT = The number of the patent applications
RD = R&D investment
TREND = The time trend
K/L = Capital equipment ratio

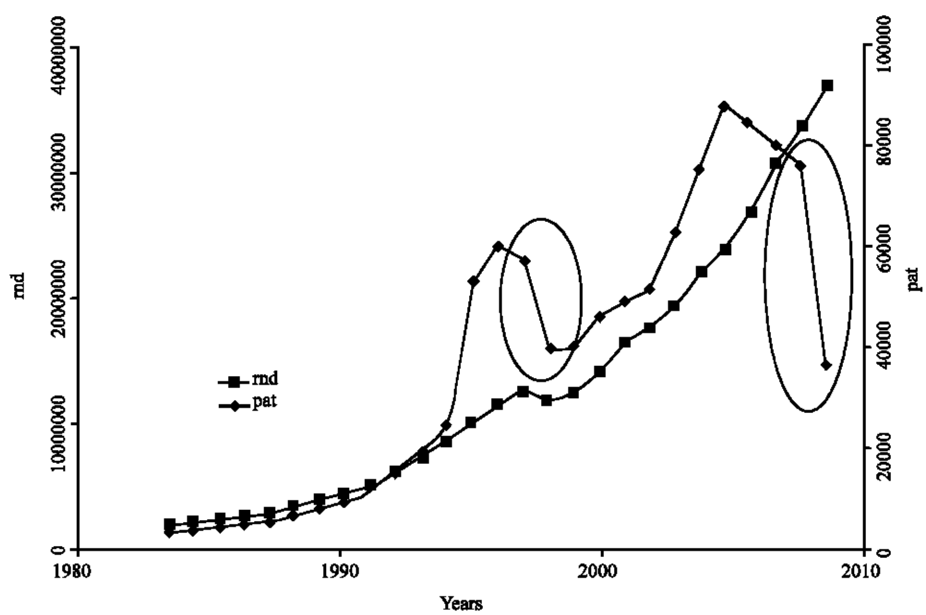

Fig. 1: Trends of total R&D investments and patent applications

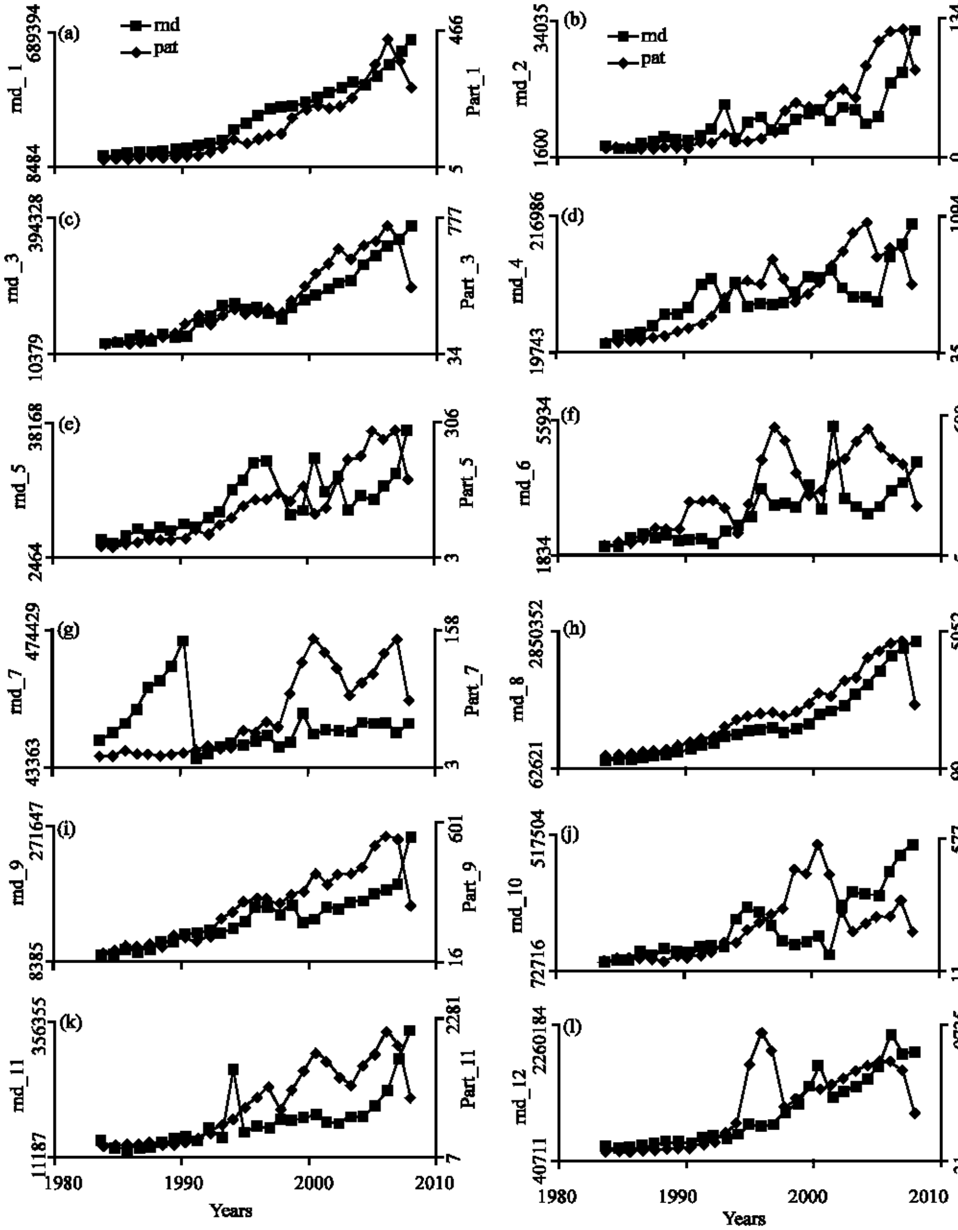

Fig. 2: a-l) Trends of total R&D investments and patent applications for industry 1 through industry 12: 1983-2009

The estimation result for whole sample is shown in Table 1. The first column shows the estimation results for OLS (Ordinary Least Squares), the second column shows the ones for the fixed effect model and the third column shows the ones for the random effect model. By the Hausman test, the fixed effect model is the best one with a 1% significance level.

The coefficient of the R&D investment variable is 0.672, implying that an R&D investment increase of 1% increases patent applications by 0.67%. When we compare our elasticities with the previous ones, ours is a little bit higher than 0.37~0.52 by Hausman *et al*. (1984) 60.208 by Abdih and Joutz (2005) 1 and 0.1~0.6 in Kortum 7.

The fact that R&D investment productivity is <1 means that R&D investment shows DRTS and that attribute of R&D investment is due to an imitativeness.

The coefficient of the capital Labor ratio per (K/L) has a positive value with a high statistical significance. It

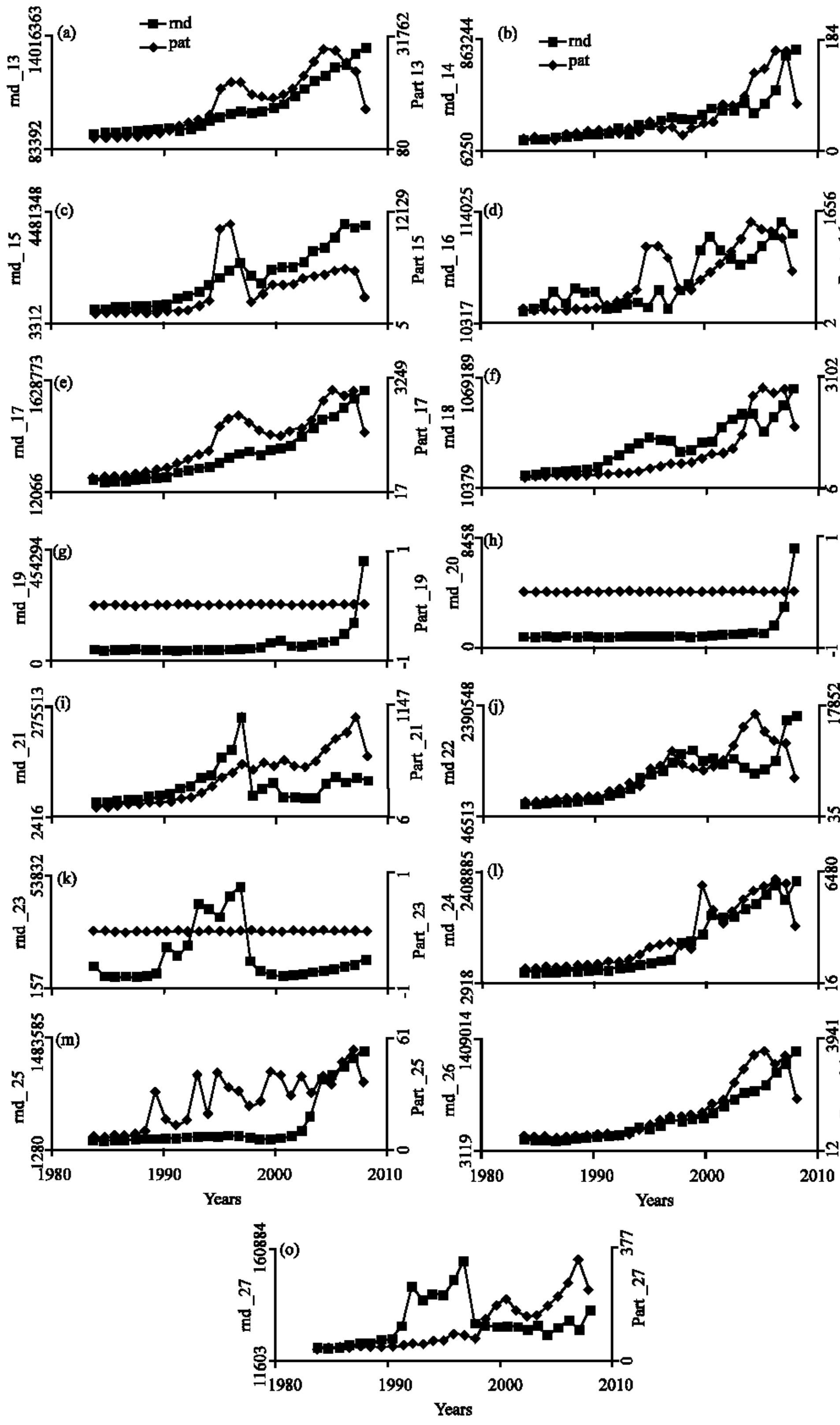

Fig. 3: a-o) Trends of total R&D investments and patent applications for industry 13 through industry 27: 1983-2009

Table 1: Estimation results of knowledge production function: all industries

Parameters	Dependent variable: log PAT Pooled	FE	RE
log RD	0.871868*** (26.085)	0.672171*** (20.319)	0.693975*** (21.232)
log 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

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

Table 2: Bank of Korea 28 Industry classifications resort to 8 industry groups

Industry groups	Bank of Korea 28 industry classifications
1	Agriculture, forestry and fishing, mining and quarrying, food beverages and tobacco products
2	Textile and apparel, wood and paper products, printing and reproduction of recorded media
3	Petroleum and coal products, chemicals, drugs and medicines, non-metallic mineral products
4	Basic metal products, fabricated metal products except machinery and furniture, general machinery and equipment, transportation equipment
5	Electronic and electrical equipment, precision instruments, furniture and other manufactured products
6	Electricity, gas, steam and water supply, construction
7	Transportation, communications and broadcasting
8	Real estate and business services, public administration and defense, education, health and social work, other services, dummy sectors

implies that other things being equal, the higher the capital equipment ratio, the greater the number of patents and the higher the productivity of R&D investment.

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

Table 2 shows the estimation results for eight industrial groups. The optimal model varies in industry in Table 2. In Table 2, the coefficient of variable log RD 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 8. The reason the elasticity is bigger than the other sectors might be that the R&D sector belongs to one of these industries.

The second highest elasticity is 0.869 for industry group 7. The third highest elasticity is 0.846 for industry group 5. The fourth highest elasticity is 0.738 for industry group 6. The least elasticity of patent applications with respect to R&D investment belongs to industry group 1.

CONCLUSION

Findings from knowledge production function estimations are as follows. It turns out that the R&D investments have played a very important role in increasing patent applications. The elasticity of patent applications with respect to R&D investment is 0.672, implying that a 1% increase in R&D investments will increase patent applications by 0.672%. Our estimate of the elasticity of patent applications 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 applications with respect to R&D investments for eight industrial groups considering the panel data characteristics.

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