An Estimation of Knowledge Production Function by Industry in Korea

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Abstract

Background/Objectives: 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.

Methods/Statistical analysis: 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.

**Findings:** 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.

**Improvements/Applications:** The higher the capital-labor ratio, the higher the productivity of R&D investment. These imply that R&D investment increases patent and thus it helps the economy grow in Korea.

**Key Words:** Knowledge Production Function, R&D Investment, Patent, Panel Data Analysis.

1 **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.

2 Literature Survey

There are many works on R&D and patents: Schumpeter 13, Nordhaus 11, Pakes and Griliches 12, Bound and Cummins 4, Hall, Griliches and Hausman 5, Griliches 9, Kortum 7, Lanjouw and Schankerman 8, Beneito 3, Baudry and Dumont 2, 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, Griliches and Hausman 5 estimated a patent production function and found there exists a constant returns to scale (CRST) between R&D investment and the number of patents.

On the contrary, Bound and Cummins 4 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 2 asserted that R&D investment, acting as the driving force for the innovation, 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 9, Kortum 7, Lanjouw and Schankerman 8, and so on. Pakes and Griliches 12 founds a strong correlation between a firm’s R&D investment and a patent enrollment using firm data. Hall, Griliches and Hausman 5 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 reclassified it into 28 industries using technology and industry codes. We don’t have the industry-specific raw data.
for patents, thus we made a useful data set from the annual patent applications released from Minister of Patents.

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 to 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 1: Trends of total R&D investments and patent applications](image)

<Figure 2> and <Figure 3> show the trends of both R&D investments and patent applications for industries 1-12 and 13-27, respectively, in Korea. As in <Figure 1>, the trends of the two variables dropped drastically right after the second half of 1997 and the global financial crisis of 2008. These show that patents respond to economic fluctuations more strongly than R&D investment too.
Figure 2: Trends of total R&D investments and patent applications for industry 1 through industry 12: 1983-2009

Figure 3: Trends of total R&D investments and patent applications for industry 13 through industry 27: 1983-2009
4 Estimation Results of Knowledge Production Function

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

\[ \dot{A} = \delta (R&D)^\lambda A^\phi \]  

(1)

We may derive the following estimation in equation (2)

\[ \log PAT = \alpha + \beta \log RD + \gamma_1 \text{TREND} + \gamma_2 \log \frac{K}{L} + u \]  

(2)

where, PAT equals the number of the patent applications, RD equals R&D investment, TREND equals the time trend, and \( \frac{K}{L} \) equals capital equipment ratio.

The estimation results for whole sample are shown in <Table 1>.

<table>
<thead>
<tr>
<th>Dependent Variable: ( \log PAT )</th>
<th>Pooled</th>
<th>FE</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log RD )</td>
<td>0.871868*** (26.085)</td>
<td>0.672171*** (20.319)</td>
<td>0.693975*** (21.232)</td>
</tr>
<tr>
<td>( \log \frac{K}{L} )</td>
<td>0.178013** (2.698)</td>
<td>1.234811*** (15.823)</td>
<td>1.156222*** (15.120)</td>
</tr>
<tr>
<td>Constant</td>
<td>5.541907*** (55.861)</td>
<td>6.839315*** (67.421)</td>
<td>6.732157*** (25.574)</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.563978 -1.15e-03</td>
<td>0.547426 -7.46e-02</td>
<td>0.747060</td>
</tr>
<tr>
<td>log likelihood</td>
<td>642</td>
<td>642</td>
<td>642</td>
</tr>
</tbody>
</table>

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

The first column shows the estimation results for pooled OLS(Ordinary least squares), the second column shows the ones for the fixed effect (FE) model, and the third column shows the ones for the random effect (RE) 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 in Hausman, Hall and Griliches 6 0.208 in Abdih and Joutz 1, and 0.1~0.6 in Kortum 7.

The fact that R&D investment productivity is less than 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 \( \left( \frac{K}{L} \right) \) has a positive value with a high statistical significance. It 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 3> shows 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 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 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.

<table>
<thead>
<tr>
<th>Industry Group</th>
<th>Bank of Korea 28 Industry classifications</th>
</tr>
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<tbody>
<tr>
<td>Group I</td>
<td>1. Agriculture, forestry and fishing, 2. Mining and quarrying, 3. Food, beverages and tobacco products</td>
</tr>
<tr>
<td>Group II</td>
<td>4. Textile and apparel, 5. Wood and paper products, 6. Printing and reproduction of recorded media</td>
</tr>
<tr>
<td>Group VI</td>
<td>17. Electricity, gas, steam and water supply, 18. Construction</td>
</tr>
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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.

### 5 Conclusion

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### 6 Acknowledgment

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References


