



## Analysis on the Factors Influencing Government's R&D Investment Outcome in the IT Industry

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### Abstract

The purpose of this study is to analyze the effects of government's R&D investment outcome on the IT industry. The analysis of R&D investment outcome developed emphasizing qualitative outcome more than quantitative outcome. However, it is still leaning on technological outcome-centered methods, having relatively little interest in inputs that actually determine the outcome. Thus, this study intends to focus on the qualitative attributes of input resources. The results of the empirical analysis can be summarized as follows. In raising technological outcome and commercialization outcome of R&D investment, more funds per researcher and numbers of researchers and a longer development period had positive effects. However, a higher ratio of doctors had positive effects only on technological outcome (papers and patents), which might be because development period of tasks was over two years on average. On

the contrary, collaboration had negative effects on technological process, which indicates that collaboration between two organizations having conflicting interests would lead to negative effects on the outcome. The results show that the qualitative attributes of input resources have significant effects on R&D investment outcome, and imply that it is necessary to emphasize the qualitative attributes from the input stage to promote governments R&D investment outcome in the future.

**Key Words :** IT Industry, National R&D Project, R&D Performance, Technological Process, Commercialization Process.

## 1 INTRODUCTION

As R&D investment could strengthen corporate competitiveness, develop the industry, and promote economic growth, governments of the world have invested huge resources in corporate R&D. Korean government is also investing lots of resources in R&D every year not to lag behind. According to a report analyzing the ratio of expenditure on R&D to GDP of OECD countries in 2015, Korea (4.23%) took second place following Israel (4.25%). Considering the fact that the average ratio of OECD countries is 2.40%, Korea is investing relatively a larger amount of resources in R&D than competitors.

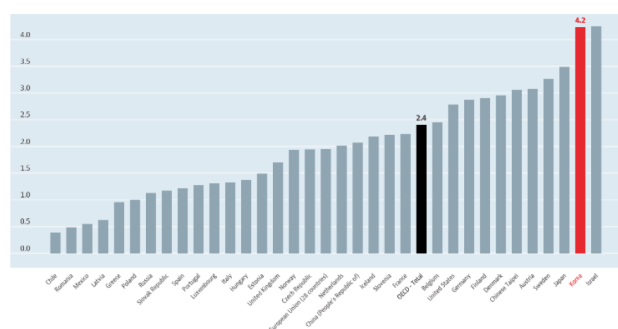


Fig. 1. Gross Domestic Spending on R&D of OECD countries, 2015. Source: OECD Homepage(<https://data.oecd.org/rd/>)

Besides, as even the same amount of capital invested in R&D would result in a high level of outcome for some companies and a low level for others, discussions about the factors influencing the outcome have continued. For the last decade, the analysis on R&D investment outcome has developed immensely. Especially, its focus has moved from quantitative outcome to qualitative outcome. Nevertheless, the analysis is still relying on technological outcome-centered methods. As a result, this analysis focuses on judging qualitative outcome of papers or patents, showing little interest in inputs that actually determine qualitative outcome. That is, it only has highlighted the amount of investment in R&D or numbers of researchers. However, as technological outcome emphasizes qualitative outcome, if qualitative attributes influence the outcome, management of outcome will have to focus on the qualitative attributes from the input stage in the future. Thus, this study intends to focus on the qualitative attributes of input resources, that is, funds per researcher, quality of researchers, collaboration, and so on.

In this sense, this study tries to divide R&D investment outcome into technological outcome (papers and patents) and commercialization outcome (technological process and commercialization process), examine the effects of the qualitative attributes of inputs on the outcome, and derive implications to promote R&D investment outcome.

The remaining parts of this paper are as follows. Chapter II examines preceding studies, and Chapter III introduces samples and methodologies. Chapter IV suggests the main results of the empirical analysis, and Chapter V arranges the conclusion and limitations.

## 2 LITERATURE REVIEW

As active R&D investment is the driving force to lead economic growth, governments over the globe are inputting a great deal of resources into corporate R&D. Especially Korea has recently been tending to expand government-led national R&D projects. If the average R&D investment of OECD countries in 2007 is considered to be 100, R&D investment of Korean government in 2015 was 181.4, greatly exceeding that of OECD countries on average

(115.1), that of 28 EU countries on average (112.4), that of Germany (135.5), that of Taiwan (104.7), and that of Japan (103.6). The total amount of Korean governments investment in national R&D projects in 2015 was 18 trillion 874.7 billion KRW, which increased by 7.0% compared to the previous year. In addition, the amount of Korean government's investment in national R&D projects annually grew by 6.2% on average for the last five years (2011-2015), which is 1.2 times higher than the annual average growth rate of the integrated financial size (5.3%)(Sul, 2017).

Promising futuristic technologies so-called 6Ts (IT, BT, NT, ST, ET, and CT) account for the largest proportion of national R&D projects, with IT being the highest. Korean government invested 3 trillion 336.8 billion KRW in the IT area in 2015, which accounted for 19.0% of the total amount of investment in promising futuristic technologies, 17 trillion 519.9 billion KRW(KISTEP).

As national R&D projects are important political projects spending a huge amount of budget, it is also important to verify if the projects were successful enough to achieve original goals. There are many domestic and foreign studies verifying government's R&D investment outcome as below.

Hsu & Hsueh (2009) proceeded with the assessment of outcomes of 110 R&D projects supported by the government in three stages (First stage: DEA, Second stage: Tobit regression analysis controlling external variables, Third stage: Comparison of R&D projects using 'adjusted data'), and contended that when the government would give a subsidy to a company, there should be an appropriate ceiling. Yoon (2013) aimed for 1,171 corporations, universities and research laboratories that completed the national R&D project from 2006 to 2011, analyzing the factors that would affect the use and spread of the outcome of national R&D field of energy. According to final multiple regression analysis, publication of treatise (non-SCI) and activity about patent (registered patent) had effects on technical commercialization, and both factors had positive effects on it. Kim, Yoo & Ryu (2013) conducted GLS regression analysis on 92,128 R&D programs supported by the Korea national government in the period of four years from 2006 to 2009. They also presented that the relationships between cooperative factors and first & second R&D performance could be moderated by the characteristics of R&D projects such as numbers of researchers and

R&D stage. Lee, Lee & Park (2015) found that government R&D support would positively influence the SMEs' technological performance. However, the level of financial support did not significantly influence the technological uniqueness. As such, it could be expected that the effects from the increase in quantity of government R&D support would be limited. Choi & Kang (2016) aimed to analyze the factors that would influence the technological performance of national R&D programs. In conclusion, different factors influenced the technological performances of the national R&D programs in the chemical and machinery technology R&D. This could imply that it would be necessary to consider the characteristics of industry-specific technology upon making science and technology policies for the national R&D programs. Choi, Oh, & Lee (2016) aimed to analyze the 212 R&D projects with 144 ones for marine and 68 for fisheries performed for 5 years, from 2010 to 2014. Based on the results, this study suggests the policy implications for the success of national R&D program, diversifying the main performing body, operating the system for sharing research infrastructures among researchers, 3introducing the adaptable R&D program management, expending the portion of grants without detailed requests for proposal. Carboni (2017) investigated the effects of seven European governments' support for investment and R&D expenditure. The paper found that grants would trigger the use of long-term credit, suggesting that public policies might help firms facing financial constraints and foster their growth.

Although the outcome of corporate R&D investment could be divided into technological outcome (papers, patents) and commercialization outcome (technological process, commercialization process), most preceding studies consider the outcome of corporate R&D investment to be technological outcome. In addition, although most preceding studies emphasize the qualitative attributes of technological outcome, there are few studies examining the qualitative attributes of input resources.

### 3 RESEARCH METHODS

#### *A. Samples and Research Methodologies*

This study intended to examine the factors influencing R&D investment outcome in the IT industry accounting for the largest proportion of Korean government's national R&D projects. Therefore, the object of the empirical analysis was IT project supported by the government R&D budget from 2009 to 2013. Data was obtained from National IT Industry Promotion Agency (NIPA), and 670 tasks containing intact data were selected as samples. <Table I> shows descriptions of the final samples. The research was conducted using regression analysis with Stata 12.

TABLE I  
OUTLINE OF SAMPLES

| Year  | Information<br>communication<br>& media | IT<br>convergence<br>technology | Total |
|-------|-----------------------------------------|---------------------------------|-------|
| 2009  | 77                                      | 124                             | 201   |
| 2010  | 38                                      | 119                             | 157   |
| 2011  | 35                                      | 95                              | 130   |
| 2012  | 25                                      | 60                              | 85    |
| 2013  | 33                                      | 64                              | 97    |
| Total | 208                                     | 462                             | 670   |

#### *B. Definition of Variables*

In order to examine the inputs influencing R&D outcome, this study used technological outcome (papers and patents) and commercialization outcome (technological process and commercialization process) as dependent variables. Funds per researcher, development period, numbers of researchers, ratio of doctors, and collaborative research reflecting the qualitative attributes of input resources were used as independent variables. In addition, local infrastructure, technology life cycle, R&D stage, and main research agent were used as control variable. <Table II> shows more detailed explanations about dependent and independent variables.

TABLE II  
DESCRIPTION OF VARIABLES

| CL.                   | Variables                 | Description on Variables                                                        | Expected Sign |
|-----------------------|---------------------------|---------------------------------------------------------------------------------|---------------|
| Dependent Variables   | Papers                    | Numbers of publication in SCI and non-SCI journals                              |               |
|                       | Patents                   | Numbers of application and registration                                         |               |
|                       | Technological process     | Numbers of technicalization process                                             |               |
|                       | Commercialization process | Numbers of commercialization process                                            |               |
|                       | Funds per researcher      | Ln (Funds / Numbers of researchers)                                             | +             |
| Independent Variables | Development period        | Numbers of months from beginning month and ending month of task                 | +             |
|                       | Numbers of researchers    | Numbers of researchers participating in task                                    | +             |
|                       | Ratio of doctors          | (Numbers of Researchers / Numbers of Doctors) * 100                             | +             |
|                       | Collaborative research    | Collaboration research=1, Non-collaboration research=0                          | +             |
|                       | Local infrastructure      | Capital area (Seoul, Gyeonggi, Incheon) and Daejeon =1, Others=0                | +             |
| Controlled Variables  | Technology life cycle     | Initial stage=1, Growing stage=2, Maturing stage=3, Declining stage=4, Others=5 | +             |
|                       | R&D stage                 | Basic research=1, Application research=2, Development research=3                | +             |
|                       | Main research agent       | Companies=1, Institutions, Universities, Government ministries or Others=0      | +             |

As more funds per researcher could lead to more resources that researchers could use, resulting in more papers and patents and better commercialization process, it appears to be positive (+). As a longer development period could lead to more time to spend in R&D, resulting in better outcome, it is expected to be positive (+). As more numbers of researchers could lead to more active participations in related activities, it is expected to positively influence the outcome. In addition, as a higher ratio of doctors having a larger amount of knowledge could lead to better outcome, it is expected

to have positive effects. As collaborative research could bring about synergy effects by combining internal and external knowledge, it is expected to have positive effects on the outcome. For local infrastructure, a dummy variable, because local infrastructure is more solid in the capital area and Daejeon, it is expected to have positive effects on better R&D outcome. For technology life cycle, it is highly likely that technological outcome will lead to commercialization process as the cycle moves from the introductory stage to the maturing stage, so technology life cycle appears to be positive (+). For R&D stage, as application research and development research would require more technological outcome than basic research, R&D stage is expected to have positive effects on the outcome. For main research agent, although government branches, laboratories, or universities could lean towards technological outcome (papers and patents), companies would focus on making the outcome as commercialization process through technological outcome is more important for them, and thereby main research agent is expected to have positive (+) effects.

## 4 EMPIRICAL ANALYSIS

This study tried to verify the inputs influencing government's R&D investment outcome in the IT industry. <Table III> shows the descriptive statistics quantity of main variables and their correlations. As a result of analyzing their correlations, the coefficient between variables turned out to be below 0.4, which is appropriate.

TABLE III  
DESCRIPTIVE STATISTICS AND CORRELATION ANALYSIS

| Descriptive statistics            | 1.            | 2.            | 3.    | 4.   | 5.  | 6.  | 7.  | 8.  | 9.  |
|-----------------------------------|---------------|---------------|-------|------|-----|-----|-----|-----|-----|
| Mean                              | 609           | 26.2          | 24.9  | 64.5 | 0.5 | 0.9 | 1.4 | 2.4 | 0.3 |
| Standard deviation                | 1.2           | 18.1          | 26.9  | 25.8 | 0.5 | 0.3 | 0.9 | 0.8 | 0.5 |
| Correlation coefficient           |               |               |       |      |     |     |     |     |     |
| 1. Funds per researcher (million) | 1.000         |               |       |      |     |     |     |     |     |
| 2. Development period             | 0.071<br>**   | 1.000         |       |      |     |     |     |     |     |
| 3. Numbers of researchers         | -0.291<br>*** | -0.107<br>*** | 1.000 |      |     |     |     |     |     |

|                           |           |           |          |          |           |         |          |          |       |
|---------------------------|-----------|-----------|----------|----------|-----------|---------|----------|----------|-------|
| 4. Ratio of doctors       | -0.395**  | 0.059     | 0.326*** | 1.000    |           |         |          |          |       |
| 5. Collaborative research | 0.291***  | -0.127*** | -0.048   | -0.135** | 1.000     |         |          |          |       |
| 6. Local infrastructure   | -0.068*   | -0.042    | -0.057   | -0.014   | -0.040    | 1.000   |          |          |       |
| 7. Technology life cycle  | -0.178*** | -0.046    | -0.020   | -0.029   | -0.246*** | 0.067** | 1.000    |          |       |
| 8. R&D stage              | -0.004    | 0.030     | 0.065*   | 0.020    | -0.033    | 0.001   | -0.042   | 1.000    |       |
| 9. Main research agent    | -0.045    | -0.039    | -0.114** | -0.068*  | -0.099    | 0.065** | 0.144*** | 0.295*** | 1.000 |

\*, \*\*, \*\*\* indicate statistical significance at the significance level =10%, 5%, 1%, respectively.

In order to analyze the determinants of government's R&D investment outcome, regression analysis was conducted, and the analysis results are shown in <Table IV>. The model fit turned out to be significant at 1%.

TABLE IV  
SUMMARY OF REGRESSION ANALYSES

| CL.                    | Paper                | Patents              | Technological Process | Commercialization Process |
|------------------------|----------------------|----------------------|-----------------------|---------------------------|
| Funds per researcher   | 0.001***<br>(7.51)   | 0.001***<br>(6.88)   | 0.001*<br>(1.67)      | 0.001***<br>(3.65)        |
| Development period     | 0.048***<br>(3.00)   | 0.051***<br>(4.51)   | 0.002<br>(1.56)       | 0.002*<br>(1.82)          |
| Numbers of researchers | 0.084***<br>(7.48)   | 0.090***<br>(11.39)  | 0.006***<br>(6.43)    | 0.004***<br>(6.46)        |
| Ratio of doctors       | 0.020*<br>(1.66)     | 0.030***<br>(3.52)   | 0.001<br>(0.87)       | 0.001<br>(0.57)           |
| Collaborative research | 0.268<br>(0.44)      | -0.147<br>(-0.34)    | -0.110**<br>(-2.00)   | -0.001<br>(-0.94)         |
| Local Infrastructure   | 1.056<br>(1.25)      | 1.911***<br>(3.22)   | 0.147*<br>(1.95)      | -0.144***<br>(-3.30)      |
| Technology life cycle  | -0.186<br>(-1.58)    | -0.271<br>(-1.20)    | 0.016<br>(0.57)       | -0.021<br>(-1.27)         |
| R&D stage              | -0.843**<br>(-2.25)  | -0.435*<br>(-1.65)   | 0.022<br>(0.67)       | 0.010<br>(0.50)           |
| Main research agent    | -4.192***<br>(-6.43) | -1.829***<br>(-3.98) | -0.152***<br>(-2.61)  | 0.072*<br>(2.17)          |
| _cons                  | 2.706*<br>(1.79)     | -0.563<br>(-0.53)    | -0.261*<br>(-1.93)    | 0.014<br>(0.18)           |
| N                      | 670                  | 670                  | 670                   | 670                       |
| R <sup>2</sup>         | 0.22***              | 0.24***              | 0.09***               | 0.10***                   |
| F                      | 20.261               | 23.716               | 6.934                 | 7.943                     |

\*, \*\*, \*\*\* indicate statistical significance at the significance level =10%, 5%, 1%, respectively.

Looking at the analysis results, more funds per researcher had positive effects on the outcome as expected. This result indicates that more funds per researcher would lead to more focus on R&D, resulting in better outcome. Although a longer development period had positive effects on papers, patents, and commercialization process, it had no effects on technological process. As a result of confirmation, an average development period was 26.2 months, and due to the short period, only 28 and 21 tasks went through technological process and commercialization process, respectively. This result came out because R&D investment should take a fairly large amount of time to lead to success of commercialization process. More numbers of researchers had positive effects on the outcome, which implies that more available manpower for creation of the outcome would result in better outcome. A higher ratio of doctors turned out to have positive (+) effects on papers and patents. As only approx. two years passed for most tasks, it seems that a higher ratio of doctors has not influenced commercialization outcome yet. Unexpectedly, collaborative research had negative effects only on technological process, which indicates that collaboration has more negative effects than synergy effects on technological process. As a result of confirmation, collaboration took approx. 52%, and it was found most at educational-industrial organizations. As universities emphasize technological outcome (papers and patents) much more, they have different interests from companies that focus on commercialization process. Although more solid local infrastructure had positive effects on patents and technological process, it had negative effects on commercialization process, which indicates that commercialization process was performed less in the capital area and Daejeon. R&D stage turned out to have negative effects on papers and patents in the early stage, which shows that application research and development research require more papers and patents than basic research. Although main research agent, a corporate dummy variable, had negative effects on papers, patents, and technological process, it had positive effects on commercialization process. This result implies that companies emphasize commercialization process more than papers, patents, or technological process outcome.

## 5 CONCLUSION

Korean government is inputting a large amount of budget into national development projects every year, especially the IT field. Investment is important, but optimizing R&D investment outcome is even more fundamental. Thus, in order to grasp the qualitative inputs influencing governments R&D investment outcome in the IT industry, this study analyzed 670 IT tasks performed by government R&D budget.

If preceding studies focused on the qualitative assessment of technological outcome, this paper tried to highlight the qualitative attributes of input resources to examine their effects on the outcome. The results of the empirical analysis were as follows. In raising technological outcome and commercialization outcome of R&D investment, more funds and numbers of researchers and a longer development period had positive effects. However, as the average task development period was a little over two years, a higher ratio of doctors had positive effects only on technological outcome (papers and patents). This result implies that phased management is necessary to raise the outcome because R&D investment should take much time to result in success of commercialization process. On the contrary, collaboration had negative effects on technological process, which means that collaboration between two organizations having conflicting interests could negatively influence the outcome.

The results above show that the qualitative attributes of input resources have significant effects on R&D investment outcome. In other words, among input resources, especially funds per researcher, development period, numbers of researchers, and ratio of doctors have positive effects on technological outcome and commercialization outcome, which implies that it is important to emphasize the qualitative attributes from the input stage to promote government's R&D investment outcome in the future.

This study has a limitation that the average task development period is short. A follow-up study will be conducted later to overcome this limitation through reanalysis.

## 6 ACKNOWLEDGMENT

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