Determinants of Corporate R&D Investment: An Empirical Study Comparing Korea's IT Industry with Its Non-IT Industry

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In our study, we extracted the market, finance, and government factors determining R&D investment of individual firms in the IT industry in Korea. We collected the financial data of 515 individual firms belonging to IT and non-IT industries between 1980 and 1999 from the Korea Investors Service's database and investigated the empirical relationship between the factors using an ordinary regression model, a fixed effects model, and a random effects model. The main findings of our study are as follows: i) The Herfindahl Index variable representing the degree of market concentration is statistically insignificant in explaining R&D expenditures in the IT manufacturing industry. ii) Assets, which is used as a proxy variable for firm size, have a positive and statistically significant coefficient. These two results suggest that the Schumpeterian Hypothesis may be only partially applied to the IT manufacturing industry in Korea. iii) The dividend variable has a negative value and is statistically significant, indicating that a tendency of high dividends can restrict the internal cash flow for R&D investment. iv) The sales variable representing growth potential shows a positive coefficient. v) The subsidy as a proxy variable for governmental R&D promotion policies is positively correlated with R&D expenditure. This suggests that government policy has played a significant role in promoting R&D activities of IT firms in Korea since 1980. vi) Using a dummy variable, we verified that firms reduced their R&D investments to secure sufficient liquidity under the restructuring pressure during Korea's 1998 and 1999 economic crisis.

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I. Introduction

The impressive performance of the US economy and the ongoing rapid diffusion of information and communications technology at a global level throughout the 1990s led a growing number of commentators to conclude that we had entered the era of the "new economy," which represented an overall non-inflationary trend with higher productivity growth. As the knowledge-based economy has become a paradigm for the new economy and as information and telecommunication (IT) technology has become a leading factor in national growth, firms have sought to enhance their competitiveness by upgrading their IT technological potential through augmented research and development (R&D) investment.

However, as we observed in Korea during the economic crisis in 1998 and 1999, called the IMF crisis, the degree of R&D investment is apt to decrease under a national economic crisis. For instance, the total R&D expenditure of Korea was US$8.61 billion in 1998, which was a decrease of 9.0% from US$9.39 billion in 1997, while the GDP declined by 2%, which was the first decline since the annual growth rate of R&D expenditure increased by more than 10% during the 1990s. The proportion of R&D expenditure to GDP also declined from 2.69% in 1997 to 2.52% in 1998.[1] The vulnerability of R&D investment under economic hardship is evident because the short-term effectiveness of R&D is

1) Funds from the private sector constituted 63% of the total amount of R&D expenditure with US$6.85 billion in 1998, while public funds constituted 27% with US$2.53 billion. Even though the private sector expanded more than the public for R&D, the public sector has continuously increased R&D investment while the private sector reduced its investment between 1997 and 1998.

uncertain. However, this trend could weaken both the future competitiveness of a firm and its long-term national productivity during a period of restructuring to overcome the economic crisis. Thus, economic analysis of R&D investment is necessary to allocate R&D resources efficiently and optimally.

Previous research only discussed the relationship between IT investment and productivity improvement, economic growth, and national income increases. Such restricted studies may have fostered an imprudent demand for R&D investment and resulted in excessive and overlapping investment not founded on rational investment decisions. However, verifying R&D determinants can help decision makers understand how funds can be raised for R&D investment and provide valuable information for developing strategies efficiently and allocating limited resources reasonably, all of which will reinforce competitiveness. Especially, the determinants of R&D investment in the IT industry, which possess the idiosyncrasies of high technology intensity and high R&D expenditure and are considered as critical factors for a knowledge-based economy,[2] should be scrutinized to distribute resources efficiently and finally to make the economy a "real knowledge-based economy."

The contributions of this paper are as follows: First, we investigate R&D determinants, including time effects, while previous studies mainly focused on cross section analysis within an industry in a specific year. Consequently, those previous studies just explained inter-firm differences in R&D, which is not sufficient to scrutinize the unexpected environmental factors induced by perturbation over time. This paper analyzes more precisely the individual differences in behavior of R&D investment within a sample period using time series and cross section data.[3] Second, from our analysis, we observed that government policy has played a significant role in promoting R&D activities in the IT industry since 1980.

II. Literature Survey

Grabowski [3] empirically investigated determinants of research expenditure in three industries: drugs, chemicals, and

petroleum refining.[4] Using an ordinary regression model, he showed that research productivity explained by the number of patents in a specified period, output diversification, and internal liquidity are statistically significant in explaining the firm's R&D investment at the 1% significance level. He also tested Schumpeter's hypothesis that large firms in a given sample would be more research-intensive than their smaller competitors.

Fazzari and Athey [4] formulated a hypothesis that financial variables affect capital spending because of asymmetric information in capital markets.[5] The regression results showed that the amount of financing generated internally matters for its plant and equipment spending. In addition, firms with higher interest expenses tend to invest less. With respect to dividends, firms with lower dividend propensity are highly affected by cash flow for R&D expenditure than those with higher dividend propensity.

Bhagat and Welch [5] empirically explored the determinants of corporate R&D investment in five OECD regions.[6] Specifically, a firm's stock returns, operating cash flows, debt structure, and the tax environment are included in the model. The results indicated that, while debt ratios tend to be negatively correlated with R&D investment in the U.S., they are positive predictors in Japan.[7] Two-year lagged stock returns positively predict R&D investment in all countries except Canada. Operating cash flow is not a strong predictor of future R&D investment in any country. This rejects the notion that R&D occurs mostly when firms have more operating cash flow on hand and can thus avoid the costs of external capital markets. Finally, they found that income tax coefficients are mostly negative in the U.S. but positive in Japan. This suggests that in contrast to the U.S. tax code, the Japanese tax code encourages R&D activities.

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4) $\frac{R_{i,t}}{S_{i,t}} = b_0 + b_1 P_i + b_2 D_0 + b_3 \frac{I_{i,t-1}}{S_{i,t}}$ ($R_{i,t}$: level of R&D expenditures of the i-th firm in the t-th period, D_i : index of diversification, $S_{i,t}$: level of sales of i-th firm in the t-th period, P_i : number of patents, $R_{i,t}$: sum of after-tax profits plus depreciation and depletion expenses of i-th firm in the t-1 period)

5) They used annual data for 637 manufacturing firms obtained from the Value Line Data Base from 1975 to 1985 and applied generalized least squares to correct for both serial correlation and heteroscedasticity in the residuals to the following model.

$$I_{jt} = a_1 L[\Delta(S_{jt} / RPC_{jt})] + a_2 L(IFIN_{jt}) + a_3 L(INTR_{jt}) + a_4 DEPR_{jt} + a_5 D_j + a_6 D_t ,$$

where I_{jt} : gross capital expenditures for firm j in year i, RPC_{jt} : relative price of capital services, S_{jt} : sales, $IFIN_{jt}$: internal finance flow(=profit after tax-dividend), $INTR_{jt}$: interest paid less interest income, $DEPR_{jt}$: depreciation allowances, D_j : dummy variable for firm j, D_t : dummy variable for year i, $L( )$: lag function.

6) The United States, Canada, Great Britain, other European countries (Germany, France, Netherlands) and Japan. They [5] analyzed 6,549 firms' R&D data of those countries for 1985-1990.

7) Bhagat and Welch [5] interpreted this as evidence that either U.S. firms have more of a need to 'safeguard' their R&D investment from possible financial distress, or alternatively, that U.S. lenders are less willing to finance R&D projects.

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2) The U.S. Department of Commerce announced that although IT industries still account for a relatively small share of the economy's total output - an estimated 8.3% in 2000 – they contributed nearly a third of real U.S. economic growth between 1995 and 1999. It also announced that declining IT prices and years of sustained economic growth have spurred massive investments not only in computer and communications equipment, but in new software that harnesses and enhances the productive capacity of that equipment. (http://www.esa.doc.gov/de2k814.htm#_EXECUTIVE_SUMMARY)

3) Hugo Kruiniger [2] pointed out, "One of the advantages of panel data over cross-sectional data when estimating regression models is the possibility to allow for so-called 'individual' effects that can capture unobservable, time-invariant effects, which may be correlated with the observable variables."

Reynard [6] analyzed the correlation between R&D investment and profitability. He considered that the appropriateness from the success of R&D investment generally encourages firms to conduct R&D activities, but that excessive R&D expenditure can be a burden to firms because it cuts their profits. Therefore, he argued that the optimal R&D investment be decided from the proportion of net profit to sales. With financial data from 25 chemical firms, he showed that a decrease of net profit is statistically significant with a decrease of R&D investment.

Kim and Lee [7] applied existing models, such as the Reynard [6] and Wallin and Gilman [8] models, to Korean data with a sample of 152 individual listed firms between 1985 and 1989. They tested empirically which model is more suitable for Korean firms. They found that the significant variables for R&D investment are one-year and three-year lagged R&D investments. In particular, they found that one-year lagged R&D investment strongly affects the current R&D investment. They also suggested that sales and net profit are significant explanatory variables, although the correlation effects differed between industries.

Table 1. Variables and results of previous studies about determinants of R&D investment.

Author (Year)	Variables (Results)
Grabowski (1968)	Fund scale (+), Corporate scale (+), Patents (+), Product differentiation (+)
Fazzari and Athey (1987)	Dividend (+), Cash flow (+)
Bhagat and Welch (1995)	Stock returns (+), Cash flow (+), Debt ratio and corporate tax (differed in countries),
Reynard (1979)	Net profit (+)
Mansfield (1981)	Firm size (+), Market concentration (+)
Kim and Lee (1993)	Three-year and one-year lagged R&D investment (+), Sales (differed in industries), Net profit (differed in industries)
Cho, S., Lee, K. H., Kang, S. W., and Kwon, O. B. (1999)	Firm size (+), Market concentration (x), Debt (x), Dividend (+), Internal fund (x), Fixed asset investment (–)

Note: (+) means positive correlation, (–) means negative correlation, and (x) means statistically insignificant

Cho et al. [9] developed an R&D determinant model for Korea's IT industry. In their model, the explanatory variables were classified mainly into financial variables and ownership structure variables. They implemented an empirical analysis with cross sectional financial data from 1995 to 1996. The

results were i) the firm size and dividend variables were positively correlated with R&D investment in the IT industry, ii) market concentration, internal fund, and long-term debt variables were statistically insignificant, iii) the negative correlation between fixed asset investment and R&D investment was verified, iv) the age of top management was statistically insignificant, while executives with engineering careers showed a more open attitude toward R&D investment, and v) firms whose representative director was a dominant shareholder invested less in R&D activity. Table 1 gives a summary of our literature review.

III. Model

1. Hypotheses

We postulate the following six hypotheses regarding firm size, market structure, internal funds, government policy, and growth potential, which were determined to be important determinants of R&D investment in the literature we surveyed.

H1: The firm size is positively associated with R&D investment.

H2: The more concentrated the market is, the more R&D investment increases.

H3: As net profit increases, R&D investment increases.

H4: Firms with high dividend tendency restrict internal cash flow for R&D investment.

H5: Government subsidy promotes firms' R&D investment.

H6: High growth potential is positively correlated with R&D investment.

The first hypothesis (H1) reflects Schumpeter's assertion [10] that "the large firm operating in a concentrated market was the most powerful engine of progress and ... long-run expansion of total output," which inspired vast empirical studies focused on testing the following two hypotheses: i) innovation increases proportionately with firm size and ii) innovation increases with market concentration. However, empirical results on the Schumpeterian hypotheses are inconclusive, largely because investigators have failed to take systematic account of more fundamental sources of variation in the innovation behavior and performance of firms and industries [11]. Thus, several arguments have been offered to justify the positive effect of firm size on inventive activities (usually explained by R&D investment),[8] while numerous

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8) One claim is that capital market imperfection confers an advantage on large firms in securing finance for risky R&D projects, because size is correlated with availability and stability of internally generated funds. A second argument is that there is an economy of scale in the technology of R&D. The third one is that returns from R&D are higher where the innovator has a large volume of sales which enables him to spread the fixed cost of R&D investment. Finally, R&D is alleged to be more productive in large firms as a result of complementarities between R&D and other non-manufacturing activities (e.g., marketing and financial planning), which seems to be more developed in large firms.

counterarguments to the proposition have been also suggested.[9]

The second hypothesis (H2) on market structure is also closely related to the Schumpeter's discussion.[10] As the market structure becomes more concentrated, firms obtain more appropriation from R&D investment, which can result in the growth of profit. Therefore, firms have an incentive to increase R&D activities to maintain the leading position in the market through innovation of production and technology. The majority of empirical studies examining the relationship between market concentration and R&D activities have found a positive relationship (e.g., Scherer [12], Levin [13], Wahlroos and Backstrom [14], Connolly and Hirschey [15]). However, others have demonstrated, under the assumption of perfect *ex post* appropriation, that a firm's gains from innovation at the margin are larger in an industry that is competitive *ex ante* than under monopolistic conditions [16].

The third and fourth hypotheses (H3 and H4) are related to sources of R&D financing. In general, long-term, large-scale financial support is indispensable for conducting R&D activities. However, risk and uncertainty hamper financing from outside the company. Furthermore, firms much prefer internal to external funding for conducting R&D activities because of restrictions caused by asymmetric information. The source of internal funding is closely related to the profitability of a firm.[11] The internal fund theory argues that the financial status of a firm determines the degree of investment.[12] Fazzari and Athey [4] used the dividend as a proxy for internal cash flow and determined that internal cash flow is positively correlated with R&D investment in the firms. However, this has a limitation because the dividend can be interpreted as representing future growth. In the meantime, Cho et al. [9]

showed that the dividend tendency is positively correlated with R&D investment in the IT industry.[13]

The fifth hypothesis (H5) is about government policy to promote R&D investment. Hyun and Kim [17] suggested that a government budget could be highly effective in facilitating the Korea Information Infrastructure program. However, the effect of governmental subsidy on R&D investment appears uncertain. Some assume that the subsidy encourages R&D activities in firms. However, there may be a negative effect: The moral hazard and burden of a result-sharing agreement owing to the subsidy may result in a disincentive to conduct R&D activities. Folster [18] empirically found that governmental subsidy programs requiring cooperation increase the incentive to conduct R&D. In addition, Yoon [19] verified that the government subsidy of the IT industry stimulated corporate R&D activities in Korea.

The sixth and last hypothesis (H6) is about the potential of growth. When a firm has the potential to create more profit than its competitors, it tends to make a greater effort to increase growth by maintaining the competitive advantage. In other words, firms desire to differentiate themselves from rivals to preserve their competitiveness. This generally results in increasing R&D investment. Thus, the potential for future growth is likely to have a positive effect on R&D activities.

2. Estimation

From the determinants of R&D investment that we extracted from the literature review, we postulate an empirical model as follows.

$$\ln R\&D_{it} = \beta_{1it} + \delta_{1it}(Dummy)_{it} + \beta_{2it}\ln X_{1it} + \beta_{3it}\ln X_{2it}$$
$$+ \beta_{4it}\ln X_{3it} + \beta_{5it}\ln X_{4it} + \beta_{6it}\ln X_{5it} + \beta_{7it}\ln X_{6it} + \varepsilon_{it}$$

($Dummy_{it}$: IMF dummy, X_{1it}: asset, X_{2it}: Herfindahl Index, X_{3it}: profit growth rate, X_{4it}: dividend/sales, X_{5it}: subsidy, X_{6it}: sales growth rate)

In this paper, we selected 515 individual firms belonging to 23 manufacturing industries among all the firms listed on the Korea Stock Exchange. For homogeneity of the samples, firms whose fiscal year ended with the calendar year were selected. In analyzing the model, the Picture, Acoustic & Communications Equipment manufacturing industry was regarded as belonging to the IT industry on the basis of the Corporate Yearbook. The data collected from 1980 to 1999 was pooled.

According to the definition of the Korea Corporate

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9) The most prominent argument is that, as firms grow large, efficiency in R&D is undermined through loss of managerial control. Also, as firms grow large, the incentives of individual scientists and entrepreneurs become attenuated because the possibility of capturing the benefits from their efforts diminishes.

10) In this regard, Shumpeter's discussion has two distinct themes. First, Schumpeter recognized that a firm required the expectation of some form of transient market power to create the incentive to invest in R&D. Second, an *ex ante* oligopolistic market structure and the possession of *ex ante* market power also favored innovation. Schumpeter claimed that an oligopolistic market structure made rival behavior more stable and predictable and thereby reduced the uncertainty associated with excessive rivalry that tended to undermine the incentive of R&D investment. He also suggested, implicitly assuming that capital markets are imperfect, that the profits derived from the possession of *ex ante* market power provided firms with the internal financial resources necessary to invest in R&D activity.

11) As critical determinants for R&D investment, profit plays two important roles. First, profit takes the place of the expectation proxy variable. The growth of profit through realization of large earnings means that the firm is lucrative and successive, so as to encourage executives who expect higher profits from R&D investment to decide to invest more on R&D activities. Second, the large scale or the growth of profit stands for the capacity of internal funding. An increase in profit means that the firm is flexible in utilizing internal funds.

12) Specifically, since internal funds for R&D investment can be more easily raised than external funds and since managers have a tendency to avoid financial liabilities that can constrain business operation, internal funding has greater effect on the decision of investment than an external loan and capitalization increase from additional share-publishing.

13) They [9] suggested that i) the dividend variable in the model may subrogate other explanatory variables whose coefficients are positive, and ii) as dividends and R&D investment are luxury goods, their growth depends on the market conditions.

Accounting Standard, we calculated the R&D investment by aggregation of the current R&D expenditure recorded as a cost in an income statement and deferred R&D expenditure considered as an asset in a cash flow statement. The proxy variables were introduced to represent explanatory variables. First of all, to test the Schumpeterian hypotheses, the firm size was represented by the asset account in the balance sheet and the market concentration was substituted with the Herfindahl Index.[14] To explain the internal fund, we used the net profit growth rate and the dividend collected from the profit surplus disposition statement over sales. In addition, the subsidy in the balance sheet was used as a proxy for the government promotion policy. We used the sales growth rate as the proxy variable for growth potential due to the limitation in collecting data even though numerous recent studies have developed proxies for corporate future growth, such as Market-to-Book Ratio[15] and Tobin's q.[16] Finally, a dummy variable was introduced to analyze the effects of the Korean economic crisis because firms reduced their investments to secure liquidity under restructuring pressures imposed as a solution to the crisis.

We divided the original data from the financial statements of firms by GDP deflators to obtain their real value. We transformed all variables into natural logarithms[17] and when the minimum value of a variable was non-positive, we added the absolute number of the minimum value of the corresponding variable and one.[18]

After identifying the necessary variables, we estimated the coefficient of each variable using an ordinary regression model, a fixed effects model, and a random effects model.[19] We

performed certain diagnostic tests to check the reliability of the estimates. Specifically, given the longitudinal nature of the data in this paper, we tested if panel regressions (fixed effects or random effects models) were more efficient than ordinary regression on the pooled data. We performed an F-test on the restriction of equal intercepts at the group level and rejected this restriction for all specifications,[20] because the result suggested that it is appropriate to use either the fixed or random effects model instead of the ordinary regression model. We also conducted Breusch and Pagan's [22] Lagrange multiplier test. The result showed a high value, which verified that the null hypothesis of non-random individual effects can be rejected.[21] This result suggested that the use of the random effects model is appropriate. It is, however, possible that the unobserved firm specific effects were correlated with the explanatory variables, in which case the generalized least squares estimate of the coefficient vector in the random effects model was biased and inconsistent. Finally, we conducted Hausman and Taylor's [22] specification test to see which of two panel regressions (fixed effects or random effects) should be used, and we found that the fixed effects model was more suitable.[22]

IV. Results

1. Descriptive Analysis

Until 1994, the R&D intensity in the IT manufacturing industry was almost the same as that in non-IT manufacturing industries; after 1994, the figure for the IT industry almost doubled.[23] For instance, in 1998, the R&D intensity was 3.98% for the IT manufacturing industry while it was 2.01% for non-IT manufacturing industries. After the Korean economic crisis, even though the R&D intensity of all industries decreased, the IT manufacturing industry showed the relatively high figure of 1.96% compared to the non-IT manufacturing industries' figure of about 1%. This phenomenon seems to be reasonable since R&D competence in the IT industry is considered a key factor for a firm's competitiveness[24] (Fig. 1).

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14) The Herfindahl index is obtained by summing squares of each firms' market share, so that the Herfindahl Index ranges from 10,000 (in the case of a pure monopoly) to a number approaching zero (in the case of an atomistic market). Although it is desirable to include all firms in the calculation, the lack of information about small firms is not critical because such firms do not affect the Herfindahl Index significantly.

15) The Kallapur and Trombley [20] document, based on an analysis of annual samples comprising all Compustat firms from 1978 through 1991, stated that the Market-to-Book Ratio (MBR) is the measure most highly (negatively) correlated with future growth. The MBR is calculated as MBR = {total asset – total book value of common equity + (stock price at the end of period * number of shares)} / total asset.

16) Hoshi [21] used Tobin' q, which is the ratio of the market value of depreciable assets (debt plus equity minus the market value of non-depreciable assets such as land) divided by an estimate of the replacement cost of depreciable capital as the proxy for corporate growth potential.

17) When absolute figures are used, heteroscedasticity is invariably present and scale effects tend to dominate the regression equations. In order to avoid these problems, we use logarithmic transformations in this paper.

18) For example, the net profit variable is calculated as Net Profit = ln (net profit/GDP deflator)+|minimum value|+1.

19) In the ordinary regression model, the intercept terms, which denote non-observable characteristics of individual firms, were assumed to be the same across firms. The other two models, however, allowed the intercept term to vary between firms. In the fixed effects model, the non-observable individual effects were treated as fixed or non-random, while they were treated as random in the random model. That is, in the latter model the error term had two components, the individual firm's specific random effects and the usual residual error.

20) F-values were 109.6605 and 1863.545, respectively, for IT and non-IT manufacturing industries.

21) See Table 2.

22) The Hausman specification test, which is based on the differences between the coefficients estimated from random and fixed effects models, shows that the null hypothesis of zero correlation between the firm specific effects and the explanatory variables in the model can be rejected since the values of the Hausman test were 22.96 in the IT manufacturing industry and 55.25 in non IT manufacturing industries.

23) The rapid increase of the figure between 1993 and 1994 in the IT manufacturing industry can be explained as the result from licensing Personal Communications Services (PCS). To acquire a PCS license, individual companies might have drastically increased investment in 1994 to develop the technology and prepare for the demand of the PCS services.

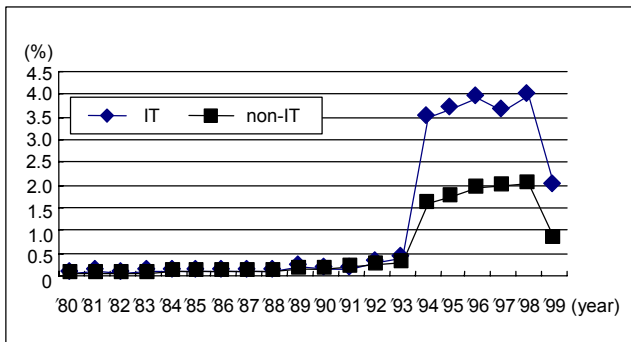24) More detailed information about descriptive analysis can be provided upon request.

Fig. 1. A comparison of the R&D intensity between IT and non-IT manufacturing industries.

2. Regression Analysis

Assets, a proxy variable for firm size, had a positive and statistically significant coefficient, which is consistent with hypothesis 1. The strong and stable significance of the assets variable emphasizes the importance of firm size as a fundamental determinant for vigorous R&D investment.[25] However, the Herfindahl Index, representing market concentration, was statistically insignificant with R&D investment in the IT manufacturing industry so that the Schumpeterian hypotheses were applied partially for the IT manufacturing industry in Korea. The effects, however, of market structure on R&D investment in each industry were inconsistent since appropriation through R&D investment was different in each industry.[26]

The variables representing internal funds, such as net profit growth and dividends, had different estimated results. The dividend variable had the expected negative sign (–) and was statistically significant at the 1% level or higher. This shows that a high dividend tendency seemed to restrict the internal cash flow for R&D investment for the IT manufacturing industry. The net profit growth variable was statistically insignificant in both industries. One possible explanation for this is that short-term profit was not a fundamental determinant for R&D investment since R&D activities needed a long-term plan. In other words, as R&D investment was determined according to long-term discernment, there might be time lags between R&D investment and its determinants.

In Korea, government policy has played a significant role in promoting R&D activities in the IT manufacturing industry

Table 2. Estimates of R&D determinants in the fixed effects model.

Explanatory variables	Industries	
	IT manufacturing industry	non-IT manufacturing industry
IMF dummy	–0.8092[b] (–2.8631)	–0.3217[b] (–3.4045)
Asset	2.6559[b] (23.9030)	1.7097[b] (22.6514)
Herfindahl Index	0.0005 (0.4032)	–0.5775[b] (–9.8472)
Net profits	–0.3662 (–0.9384)	0.0536 (1.4275)
Dividends	–51.5231[b] (–4.3146)	–0.0023 (–0.2599)
Subsidy	0.0850[b] (2.6061)	0.0289 (0.8719)
Sales	0.4006[a] (2.1046)	0.7775[b] (9.6971)
Adjusted R^2	0.6766	0.6205
Observations	946	8809
Test of significance of fixed effects	109.6605 Prob.>F=0.000	1863.545 Prob.>F=0.000
Breusch and Pagan LM-test for random effects	LM=866.56 Prob.>F=0.000	LM=14239.08 Prob.>F=0.000
Hausman specification test	Hausman=26.88 Prob.>F=0.0062	Hausman=55.25 Prob.>F=0.000

Note : i) Logarithmic values for both dependent and independent variables
ii) The numbers in parentheses are *t*-values
iii) Prob. refers to the probability that the test statistic takes a value greater than the computed value
a. indicates a result that is significant at the .05 level
b. indicates a result that is significant at the .01 level

since 1980.[27] The subsidy variable representing government promotion policy had a positive effect on R&D investment showing a statistical significance at the 0.01 level. This shows that direct policy by means of reducing corporate tax stimulates R&D activities in the IT manufacturing industry, while there was no correlation in non-IT manufacturing industries.

As a proxy variable for growth potential, the sales growth variable had a positive and statistically significant coefficient, showing that firms have an incentive to conduct R&D activities lest they compromise their current competitive advantage.

Lastly, as predicted, the IMF dummy variable had negative

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25) The estimated coefficients represent elasticity owing to a logarithmic transformation. For instance, the value of the estimated coefficient for assets was 2.6559 for the IT-manufacturing industry, which means that an increase in assets by 1% led to more than 2.6% increase in R&D investment *ceteris paribus*.

26) Intuitively, appropriation is considered to be low in Clothes & Fur and Leather, Bags, and Harnessry & Shoes manufacturing industries because firms maintaining a high level of market share in those industries do not have incentives to conduct R&D activities to increase sales due to a high possibility of imitation.

27) Due to the World Trade Organization (WTO) 1996 agreement, direct governmental aid was prohibited except for an indirect supporting R&D policy. Thus, all data about subsidies in this paper are for before 1996.

effects on R&D expenditures in both IT and non-IT manufacturing industries. This led us to accept the hypothesis that firms reduced R&D investment to secure liquidity under restructuring pressure after the Korean economic crisis. Table 2 summarizes the empirical results of our investigation.

V. Concluding Remarks

1. Limitation

In this study, we extracted the financial factors determining R&D investment of individual firms through literature reviews and tested those factors empirically. Even though our study comprehensively dealt with the determinants of R&D investment in the IT industry using panel data analysis, it has some limitations. First, since the regression results were deduced from the financial data of listed firms on the Korea Stock Exchange, the listed firms in KOSDAQ[28] and non-listed firms were excluded. Second, we mainly focused on the financial factors and market structure determining R&D investment at the firm level. Strategies for investment, however, are also decided by the internal and external environments of firms, such as the behavior of managers and shareholders, technology capability, consumer characteristics, market conditions, and so on.

2. Future Research Opportunities

The empirical study in this paper suggests the following future research opportunities. First, since each industry has its own specific features, the empirical framework is limited. As we have shown, the fitness explained by adjusted-R^2 is different from one industry to another. Therefore, we need a theoretical approach that can establish a general model for the determinants of R&D investment. Second, information about R&D investment of a firm plays an important role in determining the firm's value due to its close relationship to future growth and profitability. Hence, it is worthwhile to investigate how the effects of information on R&D investment in an individual firm are related to the firm's value. Third, due to the 1996 WTO agreement, the government has not been allowed to give direct financial aid to individual firms except through support of technology development activities. As a result, the government has only two alternatives to support development activities, the direct way and indirect way. The direct way involves directly giving subsidies for technology development. The indirect way involves developing technology through government-run research institutes and making the results available for common use. Thus, a study on

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28) Korea Securities Dealers Automated Quotations (KOSDAQ) trading began in 1996 so its data was unavailable for the period of analysis in this paper.

which path is more effective and efficient is necessary to help the government decide how to allocate its limited resources to maximize the social benefit.

References

[1] The Korean Ministry of Science and Technology, *The Survey Result of National Science, Technology and R&D Activity in 1999*, www.most.go.kr, 2000.

[2] H. Kruiniger, "On the Estimation of Panel Regression Models with Fixed Effects," *10th Int'l Conf. on Panel Data*, 2002, c6-2.

[3] H. Grabowski, "The Determinants of Industrial Research and Development: A Study of the Chemical, Drug, and Petroleum Industries," *Journal of Political Economy*, vol. 76, 1968, pp. 292-306.

[4] S. Fazzari and M. Athey, "Asymmetric Information, Financing Constraints and Investment," *Review of Economics and Statistics*, 1989, pp. 481-487.

[5] B. Sanjai and I. Welch, "Corporate Research & Development Investment: International Comparison," *Journal of Accounting and Economics*, vol. 19, 1995, pp. 443-470.

[6] E. Reynard, "A Method for Relating Research Spending to Net Profits," *Research Management*, vol. 22, no. 4, 1979, pp. 12-14.

[7] D.-Y. Kim and Y.-S. Lee, "A Study on Corporate R&D Investment Model in Korea," *Economic Study*, vol. 41, no. 1, 1993, pp. 141-159.

[8] C. Wallin and J. Gilman, "Determining the Optimum Level for R&D Spending," *Research Management*, vol. 29, no. 5, Sept.-Oct. 1986, pp. 187-221.

[9] S. Cho, K.H. Lee, S.W. Kang, and O.B. Kwon, "A Study of Rational R&D Policy in IT Industry," *KISDI* 99-01, 1999.

[10] J.A. Schumpeter, "Capitalism, Socialism and Democracy," *Harper*, New York, 1942, p. 106.

[11] W. Cohen and R. Levin, "Empirical Studies of Innovation and Market Structure," *Handbook of Industrial Organization*, North-Holland, 1989, pp. 1074-1078.

[12] F. Scherer, "Research and Development Resource Allocation under Rivalry," *Quarterly Journal of Economics*, vol. 131, 1967, pp. 359-394.

[13] R.C. Levin, "Toward and Empirical Model of Shchumpeterian Competition," *Working Paper Series A*, Yale School of Organization and Management, no. 43, 1981.

[14] B. Wahlroos and M. Backstrom, "R&D Intensity with Endogenous Concentration: Evidence for Finland," *Empirical Economics*, vol. 7, 1982, pp. 13-22.

[15] R.A. Connolly and M. Hirschey, "R&D, Market Structure, and Profits: a Value-based Approach," *Review of Economics and Statistics*, vol. 66, 1984, pp. 682-686.

[16] W. Fellner, "The Influence of Market Structure on Technological Progress," *Quarterly Journal of Economics*, vol. 16, 1951, pp. 70-83.

[17] Tchanghee Hyun and Dong-Hwan Kim, "The Evolution of Korean Information Infrastructure and Its Future Direction: A System Dynamics Model," *ETRI J.*, vol. 20, no. 1, 1998, pp. 1-15.

[18] S. Folster, "Do Subsidies to Cooperative R&D Actually Stimulate R&D Investment and Cooperation?" *Research Policy*, vol. 24, 1995, pp. 403-417.

[19] C.-H Yoon, N.H. Kwon, H.M. Sim, "An Analysis of Spill-over Effects of R&D Activities on National Economy: Focused on IT Industry," *KISDI* 2000-02, 2000.

[20] Kallapur and Trombley, "The Association between Investment Opportunity Set and Realized Growth," *Journal of Business, Finance and Accounting*, vol. 26, 1999, pp. 505-519.

[21] T. Hoshi, A. Kashyap, and D. Scharfstein, "Corporate Structure, Liquidity and Investment: Evidence from Japanese Industrial Groups," *Quarterly Journal of Economics*, vol. 155, 1991, pp. 33-60.

[22] T.S. Breusch and A.R. Pagan, "The Lagrange Multiplier Test and its Application to Model Specification in Econometrics," *Review of Economic Studies*, vol. 47, 1980, pp. 239-253.

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