Effects Of Firm Uncertainty On Association R&D Expenditure And Firm Performance: Evidence From Korea

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ABSTRACT

R&D expenditures not only improve competitiveness but also develop future growth engines. Previous studies have been conducted in relation to the relationships between R&D expenditures and individual corporate characteristics. We examine differences in the effects of firms' R&D expenditures on firm performance (earnings persistence, earnings growth, firm value) among the firms' uncertainty levels. In this study, 9,767 firm-year observations that settle their account end December listed on the Korea Stock Exchange (KSE) from 2002 to 2011 were empirically analyzed. The empirical findings of the study are as follows. First, R&D expenditures of firms with higher uncertainty levels had larger effects on earnings persistence than those of firms with lower uncertainty levels. Second, R&D expenditures of firms with higher uncertainty levels had larger effects on earnings growth than those of firms with lower uncertainty levels. Finally, the R&D expenditures of firms with higher uncertainty levels had larger effects on firm value than those of firms with lower uncertainty levels. Given these results. Both uncertainty and R&D expenditures can be regarded as being determined in the long term. We contribute to existing research in three main respects. First, reflecting firms' uncertainty levels when analyzing the effects of R&D expenditures on firm performance (earnings persistence, earnings growth, firm value) is essential. Second, the characteristics of firms' accounting and financial characteristics should be considered when determining R&D expenditures. Third, the fact that R&D expenditures affect firm performance according to firms' uncertainty levels is helpful when managers make decisions on R&D expenditures.

Keywords: Uncertainty; R&D Expenditure; Earnings Persistence; Earnings Growth; Firm Value

INTRODUCTION

R&D expenditures are important investments that not only facilitate securing competitiveness by improving the quality of products and services but also enable continuous growth by developing future growth engines. Maximization of firms' market value and shareholder value through profit creation are objectives aimed at by R&D expenditures.

Firms invest in R&D to increase the chance of continuous growth and better sustainability. Therefore, increasing sales volumes through R&D expenditures and improving earnings persistence, earnings growth, and profitability should be as much important as R&D itself. Previous studies muddled uncertainty and risk. However, unlike investments in tangible assets, R&D expenditures are much more uncertain. Kay (1988) regarded the characteristics of R&D expenditures as consisting of risks that can be predicted so that countermeasures can be devised and uncertainty that cannot be predicted and cannot be effectively coped with. Park and Kim (2005) examined the relative effects of R&D expenditures and investments in tangible assets on the uncertainty of future economic benefits using firm scales, debt ratios and advertising expense as control variables. The results of the study indicated that R&D expenditures in the relevant year had positive (+) effects on the uncertainty of future economic benefits.

A number of studies have reviewed the effects of R&D expenditures on firm performance. Unsurprisingly, most studies have shown highly positive (+) relationships between R&D expenditures and firm value (Sougiannis, 1994;

Cho and Jung, 2001; Jung et al., 2003), although some study results showed no relationship or significant negative (-) relationships (Lee and Kim, 2002; Gweon and Lee, 2004; Cheong and Park, 2004). Previous studies have also been conducted in relation to the relationships between R&D expenditures and individual firm characteristics. In addition to existing R&D expenditure related studies, this study examines differences in the effects of firms' R&D expenditures on relevant firms' performance (earnings persistence, earnings growth, firm value) among the firms' uncertainty levels[1]. As variables related to firms' uncertainty, standard deviations of ROA (SDROA), standard deviations of CFO (SDCFO), Whited-Wu indexes (WW), market share (MS), and standard deviations of sales (Sales) were analyzed.

Previous studies reported that the levels of importance of firms' R&D investments varied according to business types. Specifically, previous studies have reported that R&D expenditures capitalization levels of high-tech industries were 4-6% and those of non-high-tech industries were 2% arguing that firms in high-tech industries were conducting relatively more R&D investment activities compared to firms in non-high-tech industries (Kim and Kwak, 2010). This result can be regarded to have reflected the situation where firms in high-tech industries experience higher uncertainty. Jung (2003) reported that in the case of information communication firms that make large amounts of R&D expenditures investments not only capitalized development cost information but also ordinary development costs have positive (+) relationships with firm value while in the case of non-information communication firms, only capitalized development cost information has positive (+) relationships with firm value. Eventually, it is assumed that firms with higher uncertainty levels are in need of more R&D investments and their R&D expenditures have larger effects on their value compared to firms with lower uncertainty levels. This relationship holds no matter whether the R&D expenditures are capitalized or not by accounting treatment. Because of their characteristics, if firms with higher uncertainty levels satisfy their consumers' continuous demands for their products, their sales will increase further leading to increases in their firm value compared to firms with lower uncertainty levels. Firms with higher uncertainty levels show higher ratios of R&D expenditures. Therefore, whether R&D is successful or not becomes an important factor for these firms' success or failure.

In this study, 9,767 firm-year observations that settle their account end December listed on the Korea Stock Exchange (KSE) from 2002 to 2011 were empirically analyzed. The empirical findings of the study are as follows. First, R&D expenditures of firms with higher uncertainty levels had larger effects on earnings persistence than those of firms with lower uncertainty levels. Second, R&D expenditures of firms with higher uncertainty levels had larger effects on earnings growth than those of firms with lower uncertainty levels. Given this result, R&D expenditures of firms with higher uncertainty levels can be regarded as a strategy toward growing future profits. Finally, R&D expenditures of firms with higher uncertainty levels had larger effects on firm value than those of firms with lower uncertainty levels.

The results of this study make several contributions. First, reflecting firms' uncertainty levels when analyzing the effects of R&D expenditures on firm performance (earnings persistence, earnings growth, firm value) is essential. Second, the characteristics of firms' accounting and financial characteristics should be considered when determining R&D expenditures. Third, the fact that R&D expenditures affect firm performance according to firms' uncertainty levels is helpful when managers make decisions on R&D expenditures.

The remainder of the paper is organized as follows. Section 2 reviews the related literature and develops the testable hypotheses. Section 3 discusses the research design. Section 4 presents the empirical results of the study. Finally, section 5 concludes the study.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Literature on R&D Expenditures and Firm Performance

R&D expenditures are activities before starting commercial production in the flows of fund expenditures and can be regarded to have flows substituting for capital investments or capital expenditures for commercial production of certain products (Chung and Park, 2014). The range of these R&D expenditures comprises costs directly incurred by

[1] In this study, the concept of R&D intensity (R&D expense/sales volume) is used as the variable R&D expenses. R&D expenses mentioned in this study hereinafter shall mean R&D intensity.

R&D activities and costs that can be distributed by reasonable methods which are separately defined as research costs and development costs under accounting standards. Current R&D expenditures accounting treatment methods include a method that treats all R&D activity related expenditures as costs in the year of incurrence, a method that capitalizes all expenditures, and a method that capitalizes those expenditures that meet certain requirements and treats the remaining expenditures as costs in the year of incurrence[2].

The results of previous studies that analyzed the effects of R&D expenditures on future management performance and firm value are divergent. One study indicated that R&D expense had positive (+) effects on future management performance and firm value. Sougiannis (1994) argued that investing in intangible assets has more positive effects on firm value than has investing in tangible assets because investments in intangible assets increase tangible assets through indirect effects and because net present values of intangible assets are higher. Paeg (2003) studied the effects of R&D expenditures on stock prices in the case of information communication firms and non-financial manufacturing firms. R&D expenditures and advertising expenses showed significant positive (+) relationships with stock prices in the case of information communication firms but not in the case of non-financial manufacturing firms. In addition, a number of other studies indicated that R&D expenditures had positive (+) effects on future management performance and had effects on firm value. Kim and Kwak (2010) analyzed the relationships between R&D expenditures and firm value and appropriate R&D investment scales by firm in the case of high-tech industries and non-high-tech industries that have different investment propensities in terms of firms' R&D concentration levels and value relevance and reported that R&D expenditures were related with firm value and high-tech industries' R&D expenditures capitalization levels were 4-6% while non-high-tech industries' R&D expenditures capitalization levels were approximately 2%. They suggested that firm in high-tech industries continued relatively more R&D investment activities compared to firms in non-high-tech industries.

Another study indicated that R&D expenditures had negative (-) effects on future management performance and firm value. Kweon and Lee (2004) analyzed the relationship between the ratios of sales to R&D expenditures and TobinQ in 2001-2003 in 106 KOSDAQ firms and the results indicated negative (-) effects. Jung and Park (2004) studied the effects of R&D expenditures on firm value separately for venture firms and general firms among firms listed on KOSDAQ. The results indicated that ordinary R&D expenditures had positive (+) effects on firm value and that the effects were different between venture firms and general firms. Extraordinary R&D expenditures had negative (-) effects on firm value and the effects were not significantly different between venture firms and general firms. Kim (2009) analyzed the value relevance of development costs of KOSDAQ IT firms and the results of the analysis indicated that no matter whether development costs were recognized as costs or assets, the entire development costs had negative (-) effects on stock prices as with other costs[3].

Literature on Accounting Choices of R&D Expenditures

Initial stage studies of R&D expenditures were mainly concerned about accounting choices of R&D expenditures. Daley and Vigeland (1983) reported that firms were making accounting choices of R&D expenditures in line with the debt covenant hypothesis and the political cost hypothesis. Lev and Sougiannis (1996) studied the effects of capitalization of R&D expenditures on current net incomes, stock prices, and stock returns. Capitalized R&D expenditures showed positive (+) relationships with stock prices or stock returns. In addition to studies in the USA where the full amounts of R&D expenditures are treated as costs, studies in the UK (Oswald and Zarowin, 2005) or Japan (Mande et al., 2000) also reported that firms were using accounting choices of R&D expenditures to show favorable firm similarly to studies in South Korea.

Some studies indicated that recognizing the fact that R&D is important for firms' survival and future growth, firms have incentives to effectively create future economic benefits by capitalizing R&D expenditures of discretionary

[2] International Accounting Standards #1038 adopted by South Korea.

[3] Although previous studies on the relationships between R&D expenditures and firm performance were reviewed in many previous studies, a study conducted by Park and Yang (2006) is a representative study that well organized the present situation of previous studies on the relationships between R&D expenses and corporate performance as shown in <Table 1>.

nature. Jung(2003) studied the relationships between R&D expenditures information and firm value by industry and reported that in the case of the information communication industry with large amounts of R&D investments, not only capitalized development cost information but also ordinary development costs treated as costs had positive (+) relationships with firm value while in the case of non-information communication industries, only capitalized development cost information had positive (+) relationships with firm value. Paeg et al. (2004) indicated that the stock price explanatory power of revised net assets and profits was higher in cases where R&D expenditures were capitalized based on future economic benefits by industry than in cases where R&D expenditures were accounting-treated as costs.

Choi and Kim (2011) analyzed differences in the effects of R&D expenditures on future earnings growth between two accounting choices: cases where R&D expenditures were capitalized and cases where R&D expenditures were treated as costs. The results indicated that R&D expenditures had significant negative (-) effects on future earnings growth in cases where R&D expenditures were capitalized. Ha and Cho (2012) compared the effects of capitalized R&D expenditures, R&D expenditures treated as costs, and tangible asset related expenditures on future profit variability with each other. According to the results of analysis, whereas R&D expenditures treated as costs showed the closest relationships with future profit variability, capitalized R&D expenditures and tangible asset related expenditures showed positive (+) relationships with future profit variability but the relationships were not significant. In addition, they reported that, in the case of R&D intensive industries, whereas R&D expenditures treated as costs and tangible asset related expenditures showed positive (+) relationships with future profit variability, capitalized R&D expenditures had no significant relationship with future profit variability.

To summarize previous studies, although most studies indicated that R&D expenditures had positive (+) effects on future management performance and firm value, a few study results indicated that R&D expenditures had negative (-) effects on firm value. In addition, previous studies presented diverse results regarding the effects of capitalized R&D expenditures and R&D expenditures that had been treated as costs. With regard to the inconsistent diverse results of analyses of R&D expenditures and firm value, differences in R&D expenditures and firm performance (earnings persistence, earnings growth, firm value) according to the level of firm uncertainty will be analyzed.

Hypotheses Development

Firm management related uncertainty is defined as states where accurate information on situations to be developed in future cannot be obtained or the possibility for a certain situation to occur cannot be clearly measured. However, the concept of uncertainty has not been clearly distinguished in previous work. Unlike investments in tangible assets, uncertainty of R&D expenditures means that R&D is highly probable to fail and the characteristic of investments in R&D that it is quite unlikely to be recovered economically in cases of failure. Kay (1988) regarded the characteristics of R&D expenditures as consisting of risks that can be predicted so that countermeasures can be devised and uncertainty that cannot be predicted and cannot be effectively coped with. Park and Kim (2005) examined the relative effects of R&D expenditures and investments in tangible assets on the uncertainty of future economic benefits using firm scales, debt ratios and advertising expenses as control variables that can affect the uncertainty of future economic benefits. Their results indicated that R&D expenditures in the relevant year had positive (+) effects on the uncertainty of future economic benefits. As such, R&D expenditures involve high uncertainty.

Firms' R&D expenditures affect firms' internal aspects which are synergistic effects of proactive investments of firms for value creation and the ability to apply technologies already developed and the contents of R&D. In addition, outcomes from the results of R&D generate ripple effects within the industry and between different industries due to the excludability for firms belong to the relevant industry and firms belonging to other industries. That is, the outcomes of R&D expenditures generate ripple effects on not only the firm that developed the outcomes but also other firms belonging to the same industry and those belonging to other industries.

Previous studies reported that the levels of importance of firms' R&D investments varied with the natures of business types. Concretely, previous studies reported that R&D expenditures capitalization levels of high-tech industries were 4-6% and those of non-high-tech industries were 2%. This demonstrated that firms in high-tech industries were conducting relatively more R&D investment activities compared to firms in non-high-tech industries (Kim and Kwak,

2010). This result can be regarded to have reflected the situation where firms in high-tech industries experience high uncertainty. Jung (2003) reported that in the case of information communication firms that make large amounts of R&D investments, not only capitalized development cost information but also ordinary development costs have positive (+) relationships with firm value. In contrast, for non-information communication firms, only capitalized development cost information has positive (+) relationship with firm value.

Therefore, we assume that firms with higher uncertainty levels are in need of more R&D investments, and their R&D expenditures have larger effects on their value compared to firms with lower uncertainty levels. This relationship holds true no matter whether the R&D expenditures are capitalized or not by the accounting treatment. Because of their characteristics, if firms with higher uncertainty levels satisfy their consumers' continuous demands for their products, their sales will increase further leading to increases in their firm value compared to firms with lower uncertainty levels. Firms with higher uncertainty levels show higher ratios of R&D expenditures and whether R&D is successful or not becomes an important factor for these firms' success or failure. In addition, since firms with high uncertainty levels will spend large parts of their profits as R&D expenditures for continuous growth of the firms in future, their R&D expenditure ratios should be higher. This create the possibility for their R&D to succeed and further increase so that the firms can achieve continuous growth. Therefore, R&D expenditures can be expected to have more positive (+) effects on firm performance (earnings persistence, earnings growth, firm value) in the case of firms with high uncertainty levels than in the case of firms with low uncertainty levels. Based on the foregoing, the following hypotheses were tested:

H_1 : The effect of R&D expenditures on earnings persistence should vary with firms' uncertainty levels.

H_2 : The effect of R&D expenditures on earnings growth should vary with firms' uncertainty levels.

H_3 : The effect of R&D expenditures on firm value should vary with firms' uncertainty levels.

RESEARCH DESIGN

Empirical Models

The Effect of R&D on Earnings Persistence

In this study, the following analysis models were used to analyze the effects of R&D expenditures on earnings persistence according to firms' uncertainty levels and model (1) was set up to verify hypotheses 1. The aspects in which systematic and continuous investments in R&D expenditures are necessary separately from environmental factors faced by firms can be analyzed through the effects of R&D expenditures on earnings persistence according to firms' uncertainty levels.

$$ROA_{t+1} = \begin{array}{l} \beta_0 + \beta_1 ROA_t + \beta_2 RNDRATIO_t + \beta_3 ROA_t \times RNDRATIO_t + \beta_4 Uncert + \alpha_5 Uncert \times \\ ROA_t + \beta_6 Uncert \times RNDRATIO_t + \beta_7 Uncert \times ROA_t \times RNDRATIO_t + \beta_8 SIZE_t + \\ \beta_9 LEV_t + \beta_{10} InvestPPE_t + \beta_{11} Cash_t + \sum YD + \varepsilon_t \end{array} \quad (1)$$

Where,

ROA_t	=	*the return on assets calculated as pretax income divided by lagged total assets;*
$RNDRATIO_t$	=	*the R&D intensity calculated as the sum of R&D expenditures divided by lagged total sales;*
Uncert	=	*an indicator variable that indicates firms with high uncertainty levels, 1 if the firm that fall under top 25% under individual classification criteria (ROA, CFO, sales, Whited-Wu Index, market share), and 0 otherwise ;*
$SIZE_t$	=	*the natural log of total assets;*
LEV_t	=	*the leverage calculated as the sum of current and long-term debt divided by lagged total assets;*

$InvestPPE_t$	=	*the ratio of facility assets calculated as facility assets divided by lagged total assets;*
$Cash_t$	=	*the ratio of cash and cashable assets calculated as cash and cashable assets divided by lagged total assets;*
YD	=	*year dummy*

To verify the effects of R&D expenditures on firms' earnings persistence according to firms' uncertainty levels, the earnings persistence model presented by Dechow and Dichev (2002) was used after some modifications. Where, β_1 which is the parameter of earnings persistence is expected to appear as a positive (+) value and the continuity of profits ranging period t to period t+1 can be said to appear.

The dependent variable in equation (1) is the *ROA* in period t+1 and explanatory variables are $RNDRATIO_t$, *Uncer*t, ROA_t and interactions between ROA_t, $RNDRATIO_t$ and *Uncer*t in period t. The variable *Uncer*t that indicates firms' uncertainty levels was classified using ROA standard deviations (standard deviations for 5 years by firm), CFO standard deviations (standard deviations for 5 years by firm), sales standard deviations (standard deviations for 5 years by firm), Whited-Wu Index (financial constraints), and MS (market share). If differences in earnings persistence occur between firms with high uncertainty levels and other firms, the regression coefficient of $Ucert \times ROA_t \times RNDRATIO_t$ should have a significant value.

The control variables of the earnings persistence model are as follows. As for the variable $SIZE_t$, the natural logarithm values of firms' total assets were taken to control size effects. Future profitability is known to be low when LEV_t is high in cases where other conditions are the same. Therefore, the variable LEV_t was used as a control variable. The variable $InvestPPE_t$ was included to control the effects of previous investments among R&D expenditures and values obtained by dividing the amount of investments in facility assets by total assets at the beginning of the period were used. The variable $Cash_t$ is a variable related to firms' liquidity constraints and values obtained by dividing the cash and cashable assets held by the firm by total assets at the beginning of the period were used. Finally, *YD* were included in the model equation to control year effects.

The Effect of R&D on Earnings Growth

In this study, the following analysis models were used to analyze the effects of R&D expenditures on earnings growth according to firms' uncertainty levels and model (2) was set up to verify hypotheses 2. Since earnings growth reflects profits' qualitative characteristics, it should provide the justifiability of R&D expenditures in situations where firms' uncertainty levels are high and changes in earnings growth according to uncertainty levels suggest the necessity of analysis of the issue of time differences in the results of R&D expenditure as well as the necessity of appropriate R&D expenditures.

$$EarningsGrowth_{t+1\sim t+3} = \begin{aligned} &\beta_0 + \beta_1 ROA_t + \beta_2 RNDRATIO_t + \beta_3 Uncert + \alpha_4 Uncert \times ROA_t \\ &+ \beta_5 Uncert \times RNDRATIO_t + \beta_6 SIZE_t + \beta_7 LEV_t \\ &+ \beta_8 InvestPPE_t \ + \beta_9 Cash_t + \sum YD + \varepsilon_t \end{aligned} \quad (2)$$

Lev and Nissim (2004)'s earnings growth model was used to verify the effects of R&D expenditures on firms' earnings growth according to firms' uncertainty levels. The dependent variable of equation (2) is the *EarningsGrowth* that is a firm-specific indicator of subsequent earnings growth, measured alternatively as: next-year earnings minus current earnings *(*$EarningsGorwth_{t+1}$), average earnings in the subsequent three years minus current earnings ($EarningsGrowth_{t+2}$), and average earnings in the subsequent four years minus current earnings ($EarningsGrowth_{t+3}$). In equation (2), the variable *Uncert* that indicates firms' uncertainty levels represents firms with high uncertainty levels. Its value is 1 for firms that fall under top 25% under individual classification criteria and 0 for other firms. Similarly to the earnings persistence analysis model, the explanatory variable is $Ucert \times RNDRATIO_t$. If differences in earnings growth occur between firms with high uncertainty levels and other firms, the regression coefficient of $Ucert \times RNDRATIO_t$ should have a significant value.

The Effect of R&D on Firm Value

In this study, the following analysis models were used to analyze the effects of R&D expenditures on firm value according to firms' uncertainty levels and model (3) was set up to verify hypotheses 3. Since analysis of firm value reflects evaluation scales in the market unlike that of earnings persistence or earnings growth, it should be a tool to analyze investors' market responses to R&D expenditures.

$$Tobin\ Q_{t\sim t+1} = \beta_0 + \beta_1 ROA_t + \beta_2 RNDRATIO_t + \beta_3 Uncert + \beta_4 Uncert \times RNDRATIO_t + \beta_5 SIZE_t + \beta_6 LEV_t + \beta_7 InvestPPE_t + \beta_8 Cash_t + \sum YD + \varepsilon_t \quad (3)$$

Tobin Q was estimated using Morck et al. (1988)'s method to verify the effects of R&D expenditures on firms' firm value according to firms' uncertainty levels. *Tobin Q* is defined as the ratio of the firm's market value to the replacement cost for the assets of the firm. That is, *Tobin Q* = total market value of firm / total assets value of firm. *Tobin Q* is used as a dependent variable to measure firm value. The firm values following R&D expenditures were separately measured for the current period and the next year that corresponds to the future. In equation (3), the variable *Uncert* that indicates firms' uncertainty levels represents firms with high uncertainty levels. Its value is 1 for firms that fall under top 25% under individual classification criteria and 0 for other firms. Similarly to the earnings growth analysis model, a variable of interest here is $Ucert \times RNDRATIO_t$. If differences in firm values occur between firms with high uncertainty levels and other firms, the regression coefficient of $Ucert \times RNDRATIO_t$ should have a significant value.

Measurement of Variables

Proxy for Uncertainty

Variability, risks, and uncertainty are mainly used to indicate firms. Uncertainty is a comprehensive concept referring to things that cannot be measured or quantified. The uncertainty used in this study is an indicator of changes in base prices of uncertainty measuring factors during a certain past period and is shown as the value of the standard deviation calculated using data during period n. The proxies that indicated firms' uncertainty levels were ROA standard deviation (SDROA), CFO standard deviation (SDCFO), Sales standard deviation (Sales), market share (MS), and Whited-Wu Index (WW) and uncertainty levels were identified by the sizes of these proxies. Firms with 25% or higher standard deviations of ROA, CFO, Sales, and Whited-Wu Index and 25% or lower MS were classified into firms with high uncertainty levels.

ROA standard deviations indicate the degree of changes in firm ROA and high variability levels mean that firms' management risks increased due to external competition, etc. The causes of increases in firms' variability can be found from intensifying competition and expansion of differences in outcomes following the introduction of new technologies such as IT. Standard deviations of individual firms' ROA over the last five years were obtained and firms that corresponded to top 25% (firms that fell under top 1/4 of entire firms) in each year were classified into firms with high uncertainty levels.

The Whited-Wu Index is an uncertainty factor developed by Whited and Wu (2006) corresponding to financial constraints, which is measured by the following formula; –0.091 × CF (cash flow) - 0.062 × DIVPOS (dividend) + 0.021 × TLTD (long-term liabilities/total assets) - 0.044 × LNTA (LN total assets) + 0.102 × ISG (sales growth rate of the entire industry) - 0.035 × SG (sales growth rate). Higher values of this index mean stronger financial constraints, that is, high uncertainty levels of individual firms. The averages of individual firms' Whited-Wu Index values were calculated to classify firms with a Whited-Wu Index value that fell under top 25% of Whited-Wu Index values of all firms into firms with high uncertainty levels. As for CFO standard deviations, the averages of individual firms' CFO standard deviations over the last five years were obtained to classify firms with a CFO standard deviation that fell under top 25% of CFO's standard deviations of all firms into firms with high uncertainty levels.

As for MS, individual firms' market shares were calculated to classify firms with a market share that fell under bottom 25% of the market shares of all firms into firms with high uncertainty levels. In firms' sales structures, net profits before tax are calculated by deducting sales costs, selling expenses, and general administrative costs from sales volumes. The reason why standard deviations of sales are considered important in relation to firms' uncertainty is as follows. Sales costs are affected by inflation rates such as material cost increases and costs that fall under selling expenses and general administrative costs such as employee salaries, advertising costs, rents, and vehicle related costs increase continuously. Therefore, profits cannot but decrease continuously if the same sales volumes are recorded without increases. In addition, although returns on assets and cash flows can be controlled to some extent from the standpoint of managers, sales are affected more by industrial business and less controllable. From this viewpoint, standard deviations of sales which are the variability are appropriate as an uncertainty measuring variable.

Sample Selection

In this study, samples that satisfy sample selection criteria during the period 2002-2011 among firms listed on the Korea Stock Exchange (KSE) that run non-banking business are selected. We obtain financial data from TS 2000 database of Korea Listed Firms Association, which provides the financial statements of all listed firms. For comparability, we exclude firms with non-December fiscal year-ends and all firms in which total liabilities are larger than the total assets. Table 1 shows the sample selection criteria and the number of excluded firms to arrive at our final sample. This screening procedure yielded a total of 9,767 firm-year observations. The financial data of the samples for analysis were winsorized at extreme value 1% before being used[4].

Table 1. Sample Selection

Sample Selection Criteria	N
Firm-years with December fiscal year-ends and listed on the KSE during the period 2002-2011	17,581
(Less) Firm-year observations without the R&D expense data	(6,651)
(Less) Firm-year observations without for which financial data are not available	(535)
(Less) Firm-year observations which total liabilities are larger than the total assets	(45)
(Less) Firm-year observations without the stock price data	(583)
Total number of firm-year observations in the final sample	9,767

EMPRICAL RESULTS

Descriptive Statistics and Correlation Analysis

The descriptive statistics of variables used to analyze whether there were differences in the effects of R&D expenditures on corporate performance (earnings persistence, earnings growth, firm value) among different uncertainty levels of firms were reported in Table 2. According to the results of descriptive statistics analysis, generally good standard deviations were shown and the means and the medians of most variables were not much different indicating that they did not deviate much from normal distributions. To review descriptive statistics, the means of *Tobin Q* of 9,767 firm-year observations in period t and t+1 were 1.56 and 1.69 respectively. This means that the market values of common stocks of the sample firms are higher than their book values on average. The means of ROA in periods t and t+1 were 0.04 and 0.03 indicating that the average ratios of net profits before tax to total assets of listed companies were approximately 3%~4%. An *RNDRATIO* which is R&D intensity means the ratio of the total amount of R&D expenditures to the sales of a firm and indicates the degree to which the relevant firm invested in R&D expenses compared to its scale. The mean of R&D intensity was 0.03 and the median was 0.01. Given that the R&D intensity of firms corresponding to upper 90% is 0.08, some firms should concentrate relatively more capabilities on R&D expenses. The mean and median of *SIZE* which are log values of assets were18.744 and 18.429 on average. The mean of *LEV* which are debt ratios was 0.423 indicating that approximately 42% of assets was liabilities. The mean of *InvestPPE* which are the ratio of facility assets was 0.441 indicating that approximately 44% of assets was investments in facility assets.

[4] The results of analysis after removing extreme value 1% of the data showed similar values to those of the winsorized empirical results.

Table 2. Descriptive Statistics

Variable	Mean	Std.	Min	Q1	Median	Q3	Max
ROA_t	0.037	0.142	-0.099	0.004	0.047	0.103	0.171
ROA_{t+1}	0.035	0.119	-0.094	0.002	0.042	0.095	0.159
$EarningsGrowth_{t+1}$	-0.015	0.072	-0.331	-0.131	-0.004	0.099	0.166
$EarningsGrowth_{t+2}$	-0.013	0.070	-0.276	-0.116	-0.003	0.104	0.174
$EarningsGrowth_{t+3}$	-0.010	0.071	-0.313	-0.124	-0.001	0.112	0.184
$Tobin\ Q_t$	1.568	1.762	0.054	0.201	0.704	2.276	8.631
$Tobin\ Q_{t+1}$	1.694	1.856	0.064	0.234	0.797	2.598	9.798
$RNDRATIO_t$	0.035	0.063	0.001	0.004	0.014	0.037	0.084
$SIZE_t$	18.744	1.473	17.195	17.735	18.429	19.418	20.833
LEV_t	0.423	0.203	0.151	0.265	0.423	0.568	0.684
$InvestPPE_t$	0.441	0.399	0.095	0.223	0.38	0.57	0.769
$Cash_t$	0.076	0.088	0.006	0.018	0.048	0.101	0.183

Note: This table presents the descriptive statistics for the variables used in the sample (9,767 firm-year observations) including the listed firms on the Korea Stock Exchange (KSE) over the period 2002 to 2011. See the Appendix for variable definitions.

Table 3 reports correlation coefficients between variables used in analysis. The left part below the diagonal line shows Pearson correlation coefficients and the right part above the diagonal line shows Spearman correlation coefficients. The correlation coefficients between *ROA* in period t and *ROA* in period t+1 that correspond to the dependent variable was approximately 0.63 indicating that approximately 63% of *ROA* variations in the next period was explained by *ROA* in the current period. Correlations of approximately –10% appeared between *ROA* in period t and firm value *(Tobin Q)* in period t and t+1. It can be seen that R&D expense intensity *(RNDRATIO)* showed negative (-) correlations with *ROA* in periods t and t+1 while showing positive (+) correlations with firm value (*Tobin Q*) in periods t and t+1. Firm scale (*SIZE*), facility asset investments *(InvestPPE)*, and cashable assets *(Cash)* used as control variables showed positive (+) correlations with *ROA* in periods t and t+1. On the other hand, among control variables, debt ratios (*LEV*) were shown to have negative (-) correlations with *ROA* in period t and t+1. It can be seen that firm values (*Tobin Q*) showed negative (-) correlations with firm scale (*SIZE*) and facility asset investments (*InvestPPE*) while showing positive (+) correlations with cashable assets (*Cash*).

Table 3. Correlations among the Variables

	ROA_t	ROA_{t+1}	$Tobin\ Q_t$	$Tobin\ Q_{t+1}$	$RNDRATIO_t$	$SIZE_t$	LEV_t	$InvestPPE_t$	$Cash_t$
ROA_t		0.631	-0.102	-0.101	-0.061	0.169	-0.224	0.032	0.242
ROA_{t+1}	0.630		-0.075	-0.073	-0.056	0.141	-0.191	0.018	0.186
$Tobin\ Q_t$	-0.117	-0.088		0.942	0.077	-0.494	-0.082	-0.167	0.034
$Tobin\ Q_{t+1}$	-0.107	-0.076	0.932		0.079	-0.507	-0.088	-0.173	0.041
$RNDRATIO_t$	-0.170	-0.176	0.047	0.040		-0.308	-0.267	-0.220	0.163
$SIZE_t$	0.197	0.177	-0.162	-0.165	-0.189		0.239	0.358	-0.154
LEV_t	-0.155	-0.161	0.010	0.006	-0.222	0.233		0.211	-0.237
$InvestPPE_t$	0.048	0.044	-0.042	-0.039	-0.103	0.281	0.106		-0.272
$Cash_t$	0.135	0.115	0.022	0.028	0.078	-0.152	-0.179	-0.168	

Note: This table reports pairwise correlations the diagonal for variables. Coefficients shown in bold are significant at $p < 0.05$ (two-tailed test). See the Appendix for all variable definitions

Multivariate Results

The Effect of R&D on Earnings Persistence

Table 4 shows the results of regression analysis conducted using the model under equation (1) to test study hypothesis 1. In the case of (1) SDROA, the regression coefficient and t value of $Ucert \times ROA_t \times RNDRATIO_t$ were estimated as 0.732 and 2.41 respectively. This can be regarded as meaning that R&D expenditures have larger effects on earnings persistence in firms with high uncertainty levels than in other firms. In addition, in the case of (2) SDCFO, (3) WW Index, and (4) MS, the regression coefficients (0.408, 0.594, 0.614) of $Ucert \times ROA_t \times RNDRATIO_t$ were shown to be significant positive (+) values indicating that R&D expenditures improved earnings persistence more in firms with high uncertainty levels than in other firms. This indicates that firms with high uncertainty levels maintain profits more

through continuous R&D activities. On the other hand, in the case of (5) Sales, the regression coefficient of $Ucert \times ROA_t \times RNDRATIO_t$ were not shown to be a significant value. The regression coefficients of the control variables indicated that larger firms showed better future management performance and firms with higher debt ratios showed poorer future profitability. As predicted by hypothesis 1, the abovementioned results indicated that R&D expenditures improved earnings persistence more in firms with high uncertainty levels than in other firms thereby supporting the hypothesis.

Table 4. The Effect of R&D on Earnings Persistence

Dependent Variable = ROAt+1 (n=9,767)										
Variable	**(1) SDROA**		**(2) SDCFO**		**(3) WW**		**(4) MS**		**(5) Sales**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Intercept	-0.087***	-6.65	-0.087***	-6.67	-0.006	-0.4	-0.074***	-5.3	-0.087***	-6.62
ROAt	0.428***	50.14	0.431***	50.24	0.383***	39.09	0.405***	44.87	0.425***	49.44
RNDRATIOt	-0.142***	-7.92	-0.125***	-6.98	-0.094***	-3.75	-0.123***	-5.71	-0.132***	-7.37
ROAt× RNDRATIOt	0.746***	9.85	0.664***	8.83	0.511***	5.13	0.527***	6.34	0.736***	9.76
Uncert	-0.008**	-2.32	-0.002	-0.71	-0.035***	-11.51	-0.017***	-5.67	-0.006**	-2.06
Uncert×ROAt	0.115***	4.04	0.072***	2.74	0.159***	6.46	0.181***	7.91	0.119***	4.32
Uncert× RNDRATIOt	0.118***	3.1	0.024	0.61	0.063*	1.83	0.078***	2.38	0.055	1.49
Uncert×ROA× RNDRATIO	0.732***	2.41	0.408*	1.94	0.594***	2.95	0.614***	3.15	-0.333	-1.07
SIZEt	0.007***	10.25	0.007***	10.22	0.003***	4.03	0.007***	8.89	0.007***	10.2
LEVt	-0.061***	-12.4	-0.061***	-12.29	-0.053***	-10.71	-0.060***	-12.21	-0.061***	-12.42
IvestPPEt	0.001	0.42	0.001	0.34	0.001	0.47	0.001	0.3	0.001	0.24
Casht	0.055***	5.07	0.055***	5.04	0.067***	6.2	0.055***	5.05	0.056***	5.13
Fixed effects	year		year		year		year		year	
Adj. R2	0.42		0.42		0.42		0.42		0.42	

Note: This table presents the regression estimates of the model that examines the relationship between R&D expenditures and earnings persistence depending on the uncertainty levels. T-statistics are corrected for heteroscedasticity. *, **, *** indicate significance at the 10 percent, 5 percent, and 1 percent levels respectively, based on two-tailed test. See the Appendix for variable definitions.

The Effect of R&D on Earnings Growth

The effects of R&D expenditures may appear with different time differences among firms. In particular, in cases where the times of appearance of the effects of R&D expenditure vary with firms' uncertainty levels, results one year after R&D expenditures may be considerably distorted. Therefore, in this study, the effects of R&D expenditures were analyzed using earnings growth by two years and three years.

Table 5 shows the results of regression analysis conducted using the model under equation (2) to test study hypothesis 2. In general, R&D expenditures were shown to increase future earnings growth more in firms with high uncertainty levels than in other firms. In the case of (1) SDROA and (2) SDCFO, the regression coefficients (0.175, 0.213) of $Ucert \times RNDRATIO_t$ were shown to be significant positive (+) values indicating that R&D expenditures improved earnings growth more in firms with high uncertainty levels than in other firms. In the case of (3) WW Index and (4) MS, the regression coefficients of the variable of interest were estimated to be positive (+) values that were not significant indicating that the directivity of these variables was identical to that of (1) SDROA and (2) SDCFO. On the other hand, in the case of (5) Sales, the regression coefficient and t value of $Ucert \times RNDRATIO_t$ were estimated as –0.265 and –3.75 respectively. This result can be regarded as meaning that earnings growth is lower in firms with high uncertainty levels compared to other firm. (5) Sales can be attributable to the fact that sales are measured values related to firms' scales because variations in sales can be regarded as variations in firm scales. When firms with large variations in sales spend R&D expenditures, their profits change leading to reduction in earnings growth rather than increases in earnings growth.

In the case of the control variables, it can be seen that *SIZE* has significant positive (+) relationships with future earnings growth and this indicate that larger firms are more likely to grow in future too. On the other hand, *LEV* and

Cash generally have negative (-) relationships with future earnings growth. One thing interesting here is that in the case of *InvestPPE*, as the subject period of analysis was extended from period t+1 to period t+3, positive (+) effects on future earnings growth increased. This can be interpreted as meaning that the effects of *InvestPPE* appear over a long period of time rather than in a short period of time.

Table 5. The Effect of R&D on Earnings Growth until a period t+1

Dependent Variable = EarningsGrowtht+1 (n=9,767)										
Variable	**(1) SDROA**		**(2) SDCFO**		**(3) WW**		**(4) MS**		**(5) Sales**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Intercept	-0.058***	-2.56	-0.055***	-2.44	0.047*	1.87	-0.060***	-2.47	-0.072***	-3.15
ROAt	-0.488***	-37.84	-0.500***	-38.63	-0.557***	-37.59	-0.511***	-37.08	-0.423***	-33.20
RNDRATIOt	-0.150***	-5.13	-0.152***	-5.20	-0.053	-1.24	-0.087***	-2.34	-0.084***	-3.02
Uncert	-0.021***	-3.73	-0.025***	-4.63	-0.045***	-8.70	-0.013***	-2.50	0.000	0.05
Uncert×ROAt	0.289***	7.39	0.371***	9.58	0.333***	9.00	0.284***	8.53	-0.206***	-6.76
Uncert× RNDRATIOt	0.175***	2.68	0.213***	3.27	0.015	0.27	0.003	0.06	-0.265***	-3.75
SIZEt	0.007***	5.71	0.007***	5.66	0.002	1.25	0.007***	5.49	0.007***	6.11
LEVt	-0.089***	-10.49	-0.089***	-10.50	-0.081***	-9.40	-0.088***	-10.39	-0.088***	-10.30
InvestPPEt	0.010***	2.33	0.009**	2.18	0.010***	2.41	0.010***	2.44	0.007	1.58
Casht	-0.052***	-2.75	-0.054***	-2.85	-0.031	-1.64	-0.052***	-2.73	-0.046***	-2.43
Fixed effects	year		year		year		year		year	
Adj. R2	0.14		0.14		0.15		0.14		0.14	

Note: This table presents the regression estimates of the model that examines the relationship between R&D expenditure and earnings growth in period t+1 depending on the uncertainty levels. T-statistics are corrected for heteroscedasticity. *, **, *** indicate significance at the 10 percent, 5 percent, and 1 percent levels respectively, based on two-tailed test. See the Appendix for variable definitions.

On reviewing the effects of R&D expenditures on earnings growth according to uncertainty levels shown in Table 6 and Table 7, it could be seen that R&D expenditures increased earnings growth in periods t+2 and t+3 marginally more in firms with high uncertainty levels than in other firms. In particular, in the case of $Ucert\times\times RNDRATIO_t$ differences in the effects on earnings growth increased further over time as the period was progressing from t+1 to t+3. Given this result, R&D expenditures invested by firms with high uncertainty levels can be regarded to continuously increase future profits.

Table 6. The Effect of R&D on Earnings Growth until a period t+2

Dependent Variable = EarningsGrowtht+2 (n=9,767)										
Variable	**(1) SDROA**		**(2) SDCFO**		**(3) WW**		**(4) MS**		**(5) Sales**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Intercept	-0.120***	-5.17	-0.117***	-5.05	0.026	0.99	-0.115***	-4.64	-0.127***	-5.43
ROAt	-0.524***	-39.61	-0.539***	-40.57	-0.631***	-41.68	-0.589***	-41.95	-0.484***	-36.99
RNDRATIOt	-0.126***	-4.20	-0.130***	-4.33	-0.005	-0.11	-0.041	-1.08	-0.047	-1.64
Uncert	-0.016***	-2.76	-0.023***	-4.09	-0.061***	-11.66	-0.023***	-4.52	0.000	0.10
Uncert×ROAt	0.214***	5.34	0.322***	8.10	0.399***	10.58	0.442***	13.02	-0.099***	-3.18
Uncert× RNDRATIOt	0.196***	2.94	0.241***	3.60	0.017	0.31	0.008	0.15	-0.355***	-4.89
SIZEt	0.011***	8.56	0.011***	8.51	0.003***	2.50	0.011***	8.03	0.011***	8.67
LEVt	-0.082***	-9.34	-0.082***	-9.35	-0.069***	-7.87	-0.080***	-9.24	-0.080***	-9.21
InvestPPEt	0.015***	3.40	0.014***	3.29	0.015***	3.59	0.015***	3.58	0.012***	2.73
Casht	-0.041**	-2.13	-0.043**	-2.23	-0.017	-0.87	-0.044**	-2.27	-0.036*	-1.85
Fixed effects	year		year		year		year		year	
Adj. R2	0.16		0.16		0.17		0.16		0.16	

Note: This table presents the regression estimates of the model that examines the relationship between R&D expenditure and earnings growth in period t+2 depending on the uncertainty levels. T-statistics are corrected for heteroscedasticity. *, **, *** indicate significance at the 10 percent, 5 percent, and 1 percent levels respectively, based on two-tailed test. See the Appendix for variable definitions.

Table 7. The Effect of R&D on Earnings Growth until a period t+3

Dependent Variable = EarningsGrowtht+3 (n=9,767)										
Variable	**(1) SDROA**		**(2) SDCFO**		**(3) WW**		**(4) MS**		**(5) Sales**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Intercept	-0.149***	-6.16	-0.148***	-6.16	0.010	0.38	-0.137***	-5.36	-0.161***	-6.66
ROAt	-0.551***	-40.10	-0.561***	-40.62	-0.665***	-42.39	-0.629***	-43.25	-0.515***	-37.99
RNDRATIOt	-0.133***	-4.27	-0.128***	-4.11	-0.012	-0.27	-0.045	-1.15	-0.041	-1.39
Uncertt	-0.013**	-2.19	-0.013**	-2.29	-0.067***	-12.22	-0.028***	-5.22	0.006	1.38
Uncert×ROAt	0.165***	3.96	0.237***	5.74	0.386***	9.87	0.478***	13.56	-0.112***	-3.44
Uncert× RNDRATIOt	0.201***	2.89	0.191***	2.74	0.024	0.42	0.016	0.29	-0.463***	-6.15
SIZEt	0.013***	9.74	0.013***	9.78	0.005***	3.31	0.012***	8.98	0.013***	10.07
LEVt	-0.091***	-10.05	-0.091***	-10.09	-0.077***	-8.47	-0.090***	-9.98	-0.090***	-9.90
InvestPPEt	0.025**	2.05	0.019**	1.97	0.018**	2.27	0.019**	2.22	0.015**	2.23
Casht	-0.006	-0.30	-0.008	-0.40	0.019	0.93	-0.009	-0.46	-0.002	-0.08
Fixed effects	year		year		year		year		year	
Adj. R2	0.16		0.16		0.18		0.17		0.16	

Note: This table presents the regression estimates of the model that examines the relationship between R&D expenditure and earnings growth in period t+3 depending on the uncertainty levels. T-statistics are corrected for heteroscedasticity. *, **, *** indicate significance at the 10 percent, 5 percent, and 1 percent levels respectively, based on two-tailed test. See the Appendix for variable definitions.

The Effect of R&D on Firm Value

Table 8 shows the results of regression analysis conducted using the model under equation (3) to test study hypothesis 3. In general, R&D expenditures were shown to have larger effects on firm values in firms with high uncertainty levels than in other firms. In the case of (1) SDROA, the regression coefficient (13.871) of $Ucert \times RNDRATIO_t$ was shown to be a significant positive (+) effects indicating that R&D expenditures increased firm values more in firms with high uncertainty levels than in other firms. In the case of (2) SDCFO, (3) WW Index, and (4) MS, the regression coefficients of the variable of interest were estimated to be positive (+) effects that were not significant. On the other hand, in the case of (5) Sales, the regression coefficient and t value of $Ucert \times RNDRATIO_t$ were estimated as –012.899 and –2.21 respectively. This result can be regarded as meaning that firm values are lower in firms with high uncertainty levels compared to other firm and this difference between other variables and (5) Sales can be attributable to the fact that sales are measured values related to firms' scales because variations in sales can be regarded as variations in firm scales. When firms with large variations in sales spend R&D expenditures, their profits change leading to reduction in earnings growth rather than increases in earnings growth.

In the case of the control variables, it can be seen that *SIZE* has significant positive (+) relationships with firm values and this indicate that larger firms are more likely to show growth in profits in future too. On the other hand, *LEV* generally has negative (-) relationships with firm values. One thing interesting here is that in the case of *InvestPPE*, as the subject period of analysis was extended from period t to t+1, positive (+) effects on firm values growth increased. This can be interpreted as meaning that the effects of *InvestPPE* appear over a long period of time rather than in a short period of time.

On reviewing the effects of R&D expenditures on firm values according to uncertainty levels shown in Table 9, it could be seen that R&D expenditures increased firm values in period t+1 marginally more in firms with high uncertainty levels than in other firms. In particular, in the case of $Ucert \times RNDRATIO_t$ which is a variable of interest, differences in the effects on firm values increased further over time as the period was progressing to t+1. Given this result, R&D expenditures invested by firms with high uncertainty levels can be regarded to continuously increase future firm values. In summary, the results of analysis indicated that R&D expenditures had larger effects on the current and future firm values in firms with high uncertainty levels than in other firms. Given these results, both uncertainty and R&D expenditures can be regarded to be determined in the long-term.

Table 8. The Effect of R&D on Firm Value

Dependent Variable = Tobin Qt (n=9,767)										
Variable	**(1) SDROA**		**(2) SDCFO**		**(3) WW**		**(4) MS**		**(5) Sales**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Intercept	58.272***	14.96	57.966***	14.95	48.276***	11.13	60.046***	14.37	58.214***	14.95
ROAt	-15.461***	-7.51	-15.636***	-7.59	-13.224***	-6.03	-16.002***	-7.74	-15.621***	-7.59
RNDRATIOt	11.213**	2.23	8.533*	1.70	11.227	1.53	0.841	0.13	4.877	1.02
Uncertt	-2.011***	-2.34	-2.690***	-3.24	3.371***	3.85	-2.131***	-2.62	-2.675***	-3.89
Uncertt× RNDRATIOt	13.871**	2.15	10.524	0.95	12.417	1.35	12.860	1.44	-12.899**	2.21
SIZEt	2.873***	13.80	2.852***	13.75	2.373***	10.34	2.952***	13.35	2.850***	13.72
LEVt	-5.226***	-3.57	-5.319***	-3.64	-4.324***	-2.92	-4.926***	-3.36	-5.012***	-3.43
InvestPPEt	0.185	0.26	0.210	0.29	0.265	0.37	0.296	0.41	0.145	0.20
Casht	6.018*	1.85	6.124*	1.88	4.879	1.50	5.763*	1.77	5.675*	1.74
Fixed effects	year		year		year		year		year	
Adj. R2	0.03		0.03		0.04		0.03		0.03	

Note: This table presents the regression estimates of the model that examines the relationship between R&D expenditure and firm value in period t depending on the uncertainty levels. T-statistics are corrected for heteroscedasticity. *, **, *** indicate significance at the 10 percent, 5 percent, and 1 percent levels respectively, based on two-tailed test. See the Appendix for variable definitions.

Table 9. The Effect of R&D on Firm Value

Dependent Variable = Tobin Qt+1 (n=9,767)										
Variable	**(1) SDROA**		**(2) SDCFO**		**(3) WW**		**(4) MS**		**(5) Sales**	
	Coefficient	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Intercept	67.392***	15.48	66.929***	15.44	54.944***	11.34	68.782***	14.74	67.742***	15.58
ROAt	-15.649***	-6.80	-15.827***	-6.88	-12.588***	-5.14	-16.280***	-7.04	-15.827***	-6.88
RNDRATIOt	7.478	1.33	5.127	0.91	7.818	0.95	1.384	0.19	2.799	0.52
Uncert	-2.277***	-2.37	-2.698***	-2.91	4.331***	4.43	-1.900**	-2.09	-3.453***	-4.49
Uncert× RNDRATIOt	21.908*	1.77	10.532	0.85	13.670	1.33	5.116	0.51	2.088	0.15
SIZEt	3.325***	14.29	3.297***	14.22	2.702***	10.55	3.390***	13.72	3.320***	14.31
LEVt	-5.314***	-3.25	-5.399***	-3.30	-4.144***	-2.50	-5.068***	-3.10	-5.086***	-3.11
InvestPPEt	0.540	0.67	0.565	0.70	0.642	0.80	0.644	0.80	0.566	0.70
Casht	8.260**	2.27	8.333**	2.29	6.923*	1.90	7.979**	2.19	8.001**	2.20
Fixed effects	year		year		year		year		year	
Adj. R2	0.03		0.03		0.03		0.03		0.03	

Note: This table presents the regression estimates of the model that examines the relationship between R&D expenditure and firm value in period t+1 depending on the uncertainty levels. T-statistics are corrected for heteroscedasticity. *, **, *** indicate significance at the 10 percent, 5 percent, and 1 percent levels respectively, based on two-tailed test. See the Appendix for variable definitions.

CONCLUSION

R&D expenditures in firms lead to synergistic effects of proactive investments of firms for value creation and the ability to apply already derived technologies and R&D contents thereby affecting firms' management performance improvement. For firms, R&D expenditures are important investments that not only enable securing competitiveness by improving the quality of products and services but also enable continuous growth by developing future growth engines. The most fundamental reason for manager to invest firm assets in R&D expenditures is firm growth which is creating profits and pursuing the maximization of firms' market values and shareholder values through the profit creation. Therefore, unlike the past, R&D expenditures' roles for firm performance have been continuously increasing and this phenomenon appears particularly frequently in industries with high uncertainty levels. Because of their characteristics, if firms with higher uncertainty levels satisfy their consumers' continuous demands for their products, their sales will increase further leading to increases in their firm value compared to firms with lower uncertainty levels. Firms with higher uncertainty levels show higher ratios of R&D expenditures and whether R&D is successful or not becomes an important factor for these firms' success or failure.

This study demonstrated how R&D expenditures should be spent for maximization of firm values by analyzing the effects of R&D expenditures on firms' management performance (earnings persistence, earnings growth, firm value) according to uncertainty levels by firms instead of the general and notional aspect of R&D expenditures. As variables related to uncertainty levels by firm, standard deviations of return on asset (SDROA), standard deviations of cash flows (SDCFO), WW index which is financial constraints (WW), market shares (MS), and standard deviations of sales (Sales) were analyzed. Since the effects of R&D expenditures may appear with different time differences among firms and may vary according to uncertainty levels. In particular, in the case of earnings growth, management performance two years and three years after R&D expenditures were analyzed as dependent variables.

The empirical findings of the study are as follows. First, R&D expenditures of firms with higher uncertainty levels had larger effects on earnings persistence than those of firms with lower uncertainty levels. Second, R&D expenditures of firms with higher uncertainty levels had larger effects on earnings growth than those of firms with lower uncertainty levels. Given this result, R&D expenditures of firms with higher uncertainty levels can be regarded as strategy toward growing future profits. Finally, R&D expenses of firms with higher uncertainty levels had larger effects on firm value than those of firms with lower uncertainty levels.

The results of this study indicate that R&D expenditures should be continuously invested through accounting and financial environments by firm. In addition, the fact that R&D expenditures discriminately affect firm performance according to firms' uncertainty levels is considered to be very helpful when managers make decisions on R&D expenditures.

Limitations of this study may include the fact that the effects by industry were not analyzed in more practical forms. In addition, there may be a problem of omitted variables that may additionally affect dependent variables. Despite that samples were carefully selected based on previous studies, researcher's will might have been involved in the procedure for selection of samples. Furthermore, ownership structures such as major shareholder share ratios and foreigner share ratios are expected to affect R&D expenditures and studies on such effects can be said to be necessary.

AUTHOR BIOGRAPHIES

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APPENDIX

Variable		Definitions
Dependent Variables		
ROA_{t+1}	=	the return on assets calculated as pretax income in period t+1 divided by lagged total assets in period t+l.
$EarningsGrowth_{t+1-t+3}$	=	a firm-specific indicator of subsequent earnings growth, measured alternatively as: next-year earnings minus current earnings ($EarningsGrowth_{t+1}$), average earnings in the subsequent five years minus current earnings ($EarningsGrowth_{t+2}$), and average earnings over the subsequent four years minus current earnings ($EarningsGrowth_{t+3}$)
Tobin Q_{t-t+1}	=	a dependent variable to measure firm value, the ratio of the firm's market value to the replacement cost for the assets of the firm, Tobin Q = total market value of firm / total assets value of firm.
Explanatory Variables		
RNDRATIO	=	the R&D intensity calculated as the sum of R&D expenditures divided by lagged total sales.
Uncert	=	an indicator variable that indicates firms with high uncertainty levels, 1 if the firm that fall under top 25% under individual classification criteria (ROA, CFO, sales, Whited-Wu Index, market share), and 0 otherwise.
Control variables		
SIZE	=	the natural log of total assets.
LEV	=	the leverage calculated as the sum of current and long-term debt divided by lagged total assets.
InvestPPE		the ratio of facility assets calculated as facility assets divided by lagged total assets.
Cash	= =	the ratio of cash and cashable assets calculated as cash and cashable assets divided by lagged total assets;
YD	=	year dummy.