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Managerial Ability and Financial Outcomes of R&D Spending at Korean High-Technology Firms

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ABSTRACT

This paper examines the effect of managerial ability on the relationship between R&D spending and financial performance at high-technology firms. Since R&D activities are more critical for innovation at high-technology firms than at low-technology firms, high-ability managers at technology firms are expected to manage R&D spending effectively in order to improve firms' financial performance. The analysis of Korean firms' operating income and valuation over the past decade shows that managerial ability strengthens the association between R&D spending and financial performance at high-technology firms but not at low-technology firms. These findings clarify the interplay between managerial qualities and firms' innovation processes at driving firms' performance.

Key words: R&D cost, Financial performance, Managerial ability, High-technology firms

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I. INTRODUCTION

Research and development (hereafter, R&D) activities are the important source of innovation for high-technology firms. Since new knowledge assets generated by R&D activities can create competitive advantage only when they are not easily followed by competitors (Barney, 1991), the importance of R&D in achieving higher performance is considered to be greater for high-technology firms than low-technology firms. That being said, the previous literature that examined the relation between R&D spending and firm performance has found mixed results (e.g., Eberhart et al., 2004; Kim & Kim, 2013; Lin et al., 2006; Park, 2009). Thus, it calls for more research to better understand the meaning of R&D spending for future prospect.

Motivated by the fact, this study examines whether managerial ability plays a role in creating values from R&D efforts among high-technology firms. The literature on managerial ability has been growing under the idea that managerial ability positively affects overall firm performance without specifying the business activities that managers should pay attention (Demerjian et al., 2012). I argue that more competent managers of high-technology firms will manage R&D spending, in particular, more effectively and therefore will positively affect firm performance. This is because high-ability managers know the importance of R&D efforts and are more likely to maintain to R&D spending although expensing R&D spending decreases current earnings (Choi & Yang, 2019). Moreover, high-ability managers process R&D activities into product development with better technical literacy (Chen et al., 2015) and can supply commercialization and marketing suitable for new product introduction (Lin et al., 2006). Therefore, I expect that managerial ability enhances the association of R&D spending and financial performance of a high-technology firm.

To examine the idea, I analyze one-year ahead operating margin and Tobin's Q and compare the effects of R&D spending and managerial ability on those performance measures between high-technology firms and low-technology firms. Using a sample of Korean public firms observed between 2008 and 2018, I document an evidence that managerial ability positively affects financial performance of high-technology firms through R&D efforts. I find that managerial

ability strengthens the association of R&D spending and financial performance of a high-technology firm. In addition, I find that such positive impact of managerial ability on the relationship between R&D spending and financial performance does not appear for low-technology firms. These findings suggest that managers demonstrate their ability in the source of innovation to improve firm performance.

This paper makes several contributions to the literature. First, this study contributes to the existing literature on the relationship between R&D investments and firm performance. As forementioned, several empirical studies have examined the relation between R&D spending and firm performance, and some find a positive relationship while others find no significant relationship (e.g., Eberhart et al., 2004; Kim & Kim, 2013; Lin et al., 2006; Park, 2009). This paper highlights the fact that R&D spending could be a significant performance driver only for high-technology firms and that R&D spending cannot result in a significant increase in financial performance without effective and competent management. Second, this study contributes to the literature on managerial ability. Most accounting studies on managerial ability following Demerjian et al. (2012) has focused on revealing the effects of managerial ability on accounting or information quality (e.g., Baik et al., 2011; Demerjian et al., 2013). By revealing the specific role of management in improving firm performance through R&D activities, this study deepens the understanding of the role of management.

The remainder of the study is organized as follows. Section II reviews related literature and develops the hypotheses. Section III describes the data and sample and discusses the research design. Section IV reports the empirical results. Section V concludes.

II. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

1. The effects of R&D spending on firm performance

R&D activities are probably the most important process to generate innovations which enable a firm to gain competitive advantage. Through R&D activities, firms not only learn about outside technology and knowledge but also generates new information (Cohen & Levinthal, 1989). Those capabilities are firm-specific and

intangible. As a result, firms can develop new products and have technology breakthrough which cannot be easily imitated by the competitors (Lengnick-Hall, 1992). Since such product and technology innovations can create value for customers, firms invest in R&D to attract and maintain customers.

Many researchers have tried to measure the financial outcome of R&D efforts because the output of R&D is new information, which is intangible and difficult to evaluate the efficiency of R&D investments. Previous accounting research on R&D focused on empirically testing whether R&D expenditure leads to a better future financial performance (Cho & Park, 2013). There are studies that find R&D expenditures are positively associated with future profits (Sougiannis, 1994; Pandit et al., 2011) and future stock return (Chan et al., 2001; Eberhart et al., 2004). Those studies support the theoretical explanation that R&D activities generate technological assets and thereby increase firm value. However, some studies point out that not all R&D initiatives are successful and may not have a positive relationship with earnings. For instance, firms tend to reduce R&D spending when it compromises reporting positive earnings (Baber et al., 1991). In addition, Ciftci & Cready (2011) show that the positive impact of R&D intensity on future earnings is weaker in the smaller firms.

Although R&D might be important to firm success across all industries, its importance is more emphasized in the high-tech firms. This is because high-technology firms pursue innovations based on new technological knowledge in order to create values for customers. On the contrary, low-technology firms are difficult to gain competitive advantages through R&D because new technology developed by R&D is rather simple and mimicable by the competitors. Prior research that recognized the importance of R&D in high-technology firms tried to find out whether R&D spending improves firm performance focusing on those industries and found mixed results. Eberhart et al. (2004) find that the market more positively reacts to R&D investments of high-technology firms than low-technology firms. Meanwhile, Lin et al. (2006) analyze high-technology firms in the United States and find that R&D intensity itself does not significantly affect firm valuation. They suggest that value creation cannot be accomplished by R&D spending alone and additionally requires effective management of commercialization and marketing. Meanwhile, Park (2009) find that R&D intensity increases firm value among Korean high-technology firms. Kim & Kim (2013) examine small and

medium enterprises certified as high-tech firms and find that the impact of R&D intensity on firm performance is insignificant. Therefore, while the theory identifies R&D as one of the major sources of firm success through innovations[1], more empirical research is needed to better understand the effects of R&D spending on firm performance.

2. The impact of managerial ability on financial outcome of R&D spending

Prior research suggests that managerial ability has a positive impact on firm performance. Since managers make strategic choices for their firms, managerial backgrounds and individual characteristics affect decision makings and thereby firm performance (Hambrick & Mason, 1984). Since it is difficult to directly measure managerial ability, extant literature used different proxies for managerial ability such as education, tenure, compensation, etc. (Banker et al., 2013; Bertrand & Schoar, 2003; Milbourn, 2003). However, since these measures are intrinsically related to firm performance, recent studies on managerial ability have adopted the approach of Demerjian et al. (2012). Demerjian et al. (2012) define managerial ability as efficiency in "generating higher revenue for a given level of resources or, conversely, minimizing the resources used for a given level of revenue (i.e., to maximize the efficiency of the resources used)". They demonstrate that managerial ability is positively associated with future stock and accounting returns.

While most recent accounting studies on managerial ability has paid attention to its relationship with accounting quality[2], there are few exceptional studies that examine the specific role of management in improving firm performance, through R&D activities, for instance. Chen et al. (2015) is notable in that sense. They document an evidence that managerial ability is a positive associated with corporate innovative output measured by the number of patents and citations. Moreover, they find that the patents generated by high ability managers affect the market valuation more positively than those generated by low ability managers. However, the previous literature suggests that R&D efforts cannot be measured merely by patent

[1] Another source of firm innovation and success, for example, identified by the previous literature is customer focus (Atuahene-Gima, 1996).

[2] For example, empirical research papers examined the relationship between managerial ability and earnings quality (Demerjian et al., 2013), and disclosure quality (Baik et al., 2011).

filings. Koh & Reeb (2015) find that more than 10 percent of the firms that do not report R&D expenditures file and receive patents, in fact. In addition, only successful R&D can be disclosed by patenting (Glaeser et al., 2020) although firms learn from their failed innovation attempt (Khanna et al., 2016). Thus, to better understand the role of managerial ability in improving firm performance, it is worthy to examine the relationship between R&D spending and firm performance.

I argue that the ability of managers improves the financial outcome of R&D efforts of high-technology firms since competent managers of those firms are more likely to commit to R&D investments and oversee technological activities with better technical literacy. Managers decide on R&D investments and direct R&D activities reflecting their individual characteristics (Bertrand & Schoar, 2003). The previous literature provides the evidence that more able managers understand the value of R&D investments in firm value and thus do not opportunistically interrupt R&D investments. Choi & Yang (2019) show that firms with high-ability managers are less likely to cut R&D spending to manage earnings. Similarly, Oh & Choi (2021) find that R&D spending does not decrease with sales decrease in high-tech firms when the firms are managed by more competent CEOs. Moreover, I contend that more competent managers can utilize and protect knowledge assets gained through R&D better. High-ability managers effectively turn innovative ideas into new product development (Chen et al., 2015) and lead a successful product launch with effective management of commercialization and marketing (Lin et al., 2006). Moreover, management style can reduce the risks of knowledge spillovers, which is detrimental to the value creation of R&D efforts (Belderbos et al., 2021). Therefore, since R&D activities are more critical for the success of high-technology firms than other firms, I expect that managerial ability is an important moderating factor that determines the relationship between R&D spending and financial performance of those firms. In sum, I formulate the following hypothesis:

Hypothesis: *Managerial ability strengthens the association of R&D spending and financial performance of a high-technology firm.*

III. RESEARCH DESIGN

1. Model specification

This paper examines whether managerial ability positively affects the association between R&D spending and financial performance among high-technology firms. To explain the effects of R&D spending and managerial ability on firm performance, I estimate the following regression model:

$$\begin{aligned} PERFORMANCE_{i,t+1} = {} & \beta_0 + \beta_1 RD_{i,t} + \beta_2 CEOABILITY_{i,t} + \beta_3 RD \times CEOABILITY_{i,t} \\ & + \beta_4 lnSALE_{i,t} + \beta_5 ROA_{i,t} + \beta_6 SG_{i,t} + \beta_7 LEV_{i,t} + \beta_6 PPE_{i,t} \\ & + \text{Year FE} + \varepsilon_{i,t} \end{aligned} \quad (1)$$

where:

$PERFORMANCE_{i,t+1}$	:	firm performance measured by operating margin (*OM*) and Tobin's Q (*Tobin Q*) for firm *i* in year *t+1*;
OM	=	operating income divided by net sales revenues
Tobin Q	=	sum of market value of common stocks, book value of preferred stocks, and book value of total liability, divided by book value of total asset;
$RD_{i,t}$[3]	=	research and development (R&D) expenditures scaled by net sales revenues for firm *i* in year *t*;
$CEOABILITY_{i,t}$	=	managerial ability as measured by Demerjian et al. (2012);
$lnSALE_{i,t}$	=	log-transformed sales revenue;
$ROA_{i,t}$	=	net income divided by total assets;
$SG_{i,t}$	=	log-change in sales revenue;
$LEV_{i,t}$	=	total liabilities divided by total assets;
$PPE_{i,t}$	=	property, plant, and equipment divided by total assets;
Year FE	=	year dummies.

[3] Alternatively, I measured R&D efforts using total R&D costs provided in footnote disclosures when the information is available. I find that about 55 percent of the final sample has capitalized R&D and thus disclosed such information in the footnote disclosure as required by Financial Supervisory Service. The results are robust to this alternative measure.

To measure firm performance, I use one-year ahead values of operating margin and Tobin's Q as the dependent variable. Operating margin is more appropriate to evaluate the effects of R&D spending on firm performance than other profit measures using net incomes like return on assets since R&D efforts are closely related more with operating performance through product innovation (Kwon et al., 2018).[4] Tobin's Q is calculated as firm value based on market value compared to book value and represent firm performance in terms of growth opportunities (Chung & Pruitt, 1994). Although R&D spending can contribute to performance in the long run, I focus on its impact on the next year to avoid the autoregressive pattern of R&D costs over multiple years that confuse the interpretation of the results (Cho & Park, 2013). In addition, if there was a change in the management team, the R&D initiatives set up by the outgoing manager can be dismissed. Examining the performance of the next year can mitigate those concerns.

To examine whether managerial ability strengthens the effects of R&D spending on financial performance, I include the interaction term between managerial ability (*CEOABILITY*) and R&D intensity (*RD*) since Shin et al. (2009) suggest that managerial ability moderates the relationship between R&D spending and firm performance. Since I expect that more able managers will increase firm performance through R&D efforts, I predict the sign of the coefficient of this variable to be positive for high-technology firms. Although I do not make a formal prediction for low-technology firms, I expect that the moderating effects of managerial ability will be weaker for those firms than high-technology firms because R&D activities are more critical for innovations of high-technology firms.

I control for the variables that are used in the previous literature as the factors of financial performance of firms. Firm size is proxied by the logarithm of sales revenues ($lnSALE_i$) to capture the scale effects on firm performance. Return on assets (*ROA*) is the net income divided by total assets and is predicted to be positively associated with future performance. Sales growth (*SG*) captures firm growth and is expected to affect positively future performance since scale economies improve productivity. Since leverage (*LEV*), which is calculated as total liabilities divided by total assets, provides the information on fund availability from

[4] I follow Eberhart et al. (2004), which do not adjust operating income by adding back R&D expenditures, advertising costs, and depreciation. I find that the results are robust to the use of the adjusted operating income in the calculation of operating margin.

debt financing, it has both positive and negative meanings for future performance. The ratio of property, plant, and equipment (*PPE*) to total assets captures firms' investments in facilities and is predicted to be positively associated with firm performance. Additionally, I include year fixed effects and adjust the estimated standard errors with clustering by firms.

2. Measurement of managerial ability

I follow the approach of Demerjian et al. (2012) to measure managerial ability. The approach has gained popularity among broad researchers in finance, accounting, and management because of its superior validity compared to traditional proxies used to capture managerial ability. To be specific, Demerjian et al. (2012) calculate managerial ability using the two-stage application of Data Envelopment Analysis methodology. The two-stage model allows to separate out managerial attributes from firm characteristics affecting firm performance, making the managerial ability measure less noisy than other proxies for managerial ability such as education, tenure, compensation, etc. (Banker et al., 2013; Bertrand & Schoar, 2003; Milbourn, 2003).

In the first stage of the model, firm efficiency scores are estimated for each industry using the production frontier estimation method based on DEA. Consistent with Demerjian et al. (2012), I define sales revenue as the output of firms. I use cost of goods sold, SG&A (selling, general and administrative) expenses, net PP&E (property, plant, and equipment), and intangible assets as the inputs of firms following the application of Demerjian et al. (2012) to Korean data conducted by Park et al. (2016).[5] I denote the linear program used to estimate firm efficiency scores as follows[6]:

[5] Park et al. (2016) measure managerial ability of Korean listed firms. They suggest to modify the input variables due to the data availability for the Korean data compared to the ones used in Demerjian et al. (2012). Demerjian et al. (2012) use the cost of inventory, general and administrative expenses, research and development expenditures, tangible assets including operating leases, and intangible assets as input variables.

[6] Variable definitions: *Sales* = sales revenue; *COGS* = cost of goods sold; *SG&A* = selling, general and administrative; *PPE* = tangible assets (tangible assets – land – construction in progress); *Intang* = intangible assets.

$$\max \theta = \frac{Sales}{v_1 COGS + v_2 SG\&A + v_3 PPE + v_4 Intang} \quad (2)$$

In the second stage, I regress the firm efficiency score (θ^*), on the firm characteristics that affect firm efficiency as in the Equation (3). Since the unexplained portion of the total firm efficiency are attributable to managerial ability in efficiently utilizing firm resources, the regression residuals are used as the managerial ability score.

$$FIRM\ EFFICIENCY_{i,t} = \gamma_0 + \gamma_1 SIZE_{i,t} + \gamma_2 MSHARE_{i,t} + \gamma_3 FCF_{i,t} + \gamma_4 FIRMAGE_{i,t} + \gamma_5 BIZSEG_{i,t} + \gamma_6 FOREIGN_{i,t} + \text{Year FE} + \varepsilon_{i,t} \quad (3)$$

Following the previous literature (Park et al., 2016), I use firm size (*SIZE*), market share (*MSHARE)*, free cash flow indicator (*FCF*), firm age (*FIRMAGE*), business segmentation (*BIZSEG*), and foreign currency translation accounts (*FOREIGN*), and year fixed effects as the independent variables.[7] I estimate the regression model using Tobit since the firm efficiency scores vary between 0 and 1. I denote the residuals as *CEOABILITY*.[8]

[7] Variable definitions: firm size = the natural logarithm of total assets at the end of year t; market share = the percentage of revenues earned by the firm within its two-digit KSIC in year t; free cash flow indicator = 1 if free cash flow (net income before depreciation – change in operating capital – capital expenditure) > 0 , = 0 otherwise; firm age = the natural logarithm of the number of years the firm has been listed on Korean Stock Exchange; business segmentation = the number of product sales ratio that exceeds 10%; foreign currency translation accounts = the absolute magnitude of foreign currency translation accounts (foreign currency gain, foreign currency transactions, loss on foreign currency transactions) divided by total sales revenue.

[8] Although the measure of managerial ability can be attributed to management team, I refer this measure as *CEOABILITY* because CEO represents the team and makes final corporate decisions (Fee & Hadlock, 2003; Demerjian et al., 2012).

IV. SAMPLE STATISTICS AND EMPIRICAL RESULTS

1. Sample selection

I used *TS2000* to obtain annual financial information data of Korean firms listed on the KOSPI and KOSDAQ. The sample period spans from 2008 to 2018.[9] I restrict the sample to be non-financial firms since financial service firms have highly different business model to be used to evaluate managerial ability together with the others (Demerjian et al., 2012). I drop the observations with missing values on R&D expenditures and other financial information including the variables required to calculate managerial ability. After this sample selection procedure, the final sample consists of 4,852 firm-year observations.

I identify high-technology firms based on industry classification code following the methodology of the Bureau of Labor Statistics and the states of the United States since it is a widely accepted definition in compiling statistics (Walcott, 2000[10]). I applied the defined Standardized Industry Classification (SIC) code using the matched Korean SIC code, similar to the approach of Kim & Sohn (2011), which matched the US industry code to Korean data. In the final sample, about 48% (2,314 firm-years) is classified as high-technology firms and the remaining 52% (2,538 firm-years) is low-technology tech firms.[11] I winsorized all continuous variables at the top and the bottom 1 percent.

[9] The initial sample starts from year 2007 and ends to 2019. This is because the calculation of sales growth requires the one-year lagged value of sales and the one-year leading values of financial performance such as operating margins and Tobin's Q are used as the dependent variables.

[10] This paper provides the list of high-technology industry in Standardized Industry Classification (SIC) code and discusses the rationale for the choice on high-technology industry in details. Firms having SIC greater than 27 are generally classified as high-technology firms with few exceptions.

[11] The definition of high technology used in this paper is advantageous in that it is inclusive of various definitions used for different perspectives (e.g., Eberhart et al., 2004; Lin et al., 2006; Kim & Sohn, 2011; Park, 2009). From an empirical standpoint, this definition approximately bisects the sample, making it relatively easy to interpret each sample as high-technology and low-technology, respectively.

2. Descriptive statistics

<Table 1> reports the summary statistics of the variables used in the regression analysis for the full sample that has 4,852 firm-year observations. The average operating margin for the sample period is 3.9 percent and the median of operating margin is 4.3 percent. These indicate that financial performance is positive during the sample period, on average. The fact that the average sales growth is 4.5 percent is also supportive of the healthy economic condition over the sample period in general. Meanwhile, the mean value of Tobin's Q is 1.072 and the median value is 0.914, suggesting that some firms have significantly high market value compared to liquidity value. The average (median) value of R&D intensity (*RD*) is 0.008 (0.001). The mean value of the managerial ability measure (*CEOABILITY*) is 0.001, very close to the theoretical mean which is zero.[12] This indicates that the variable does not suffer from survivorship bias due to the sample selection procedures.

<Table 1> Summary Statistics

Variable	N	Mean	Std.Dev	P25	P50	P75
OM	4,852	0.039	0.093	0.015	0.043	0.075
Tobin Q	4,852	1.072	0.628	0.766	0.914	1.135
RD	4,852	0.008	0.019	0.000	0.001	0.007
CEOABILITY	4,852	0.001	0.117	-0.056	-0.002	0.058
lnSALE	4,852	20.320	1.631	19.180	20.145	21.310
ROA	4,852	0.018	0.082	0.002	0.026	0.054
SG	4,852	0.045	0.235	-0.039	0.043	0.136
LEV	4,852	0.495	0.196	0.345	0.511	0.636
PPE	4,852	0.302	0.179	0.175	0.308	0.419

This table presents the descriptive statistics of the variables used in the analyses. The definition of variables are as follows: *OM* is operating income divided by net sales revenues. *Tobin Q* is the sum of market value of common stocks, book value of preferred stocks, and book value of total liability, divided by book value of total asset. *RD* indicates R&D intensity measured by research and development (R&D) expenditures scaled by net sales revenues. *CEOABILITY* is the measure of managerial ability as developed in Demerjian et al. (2012). *lnSALE* is log-transformed sales revenue. *ROA* is net income divided by total assets. *SG* is sales growth measured by log-change in sales revenue. *LEV* is total liabilities divided by total assets. *PPE* is property, plant, and equipment divided by total assets.

[12] *CEOABILITY* is the regression residuals of Equation (3).

<Table 2> reports the univariate tests for high-technology versus log-technology firms for the variables used in the analyses. High-technology firms does not have higher ratio of R&D potentially due to the firms reporting zero R&D expenditure (Koh & Reeb, 2015). High-technology firms also have lower managerial ability scores on average. In addition, the firm size (*lnSALE)*, capital structure (*LEV*), and fixed asset captured by *PPE* are also significantly differ by the subsamples. Thus, in order to mitigate the potential unobserved influence of industry differences on firm performance, I conduct the regression estimation of the model in Equation (1) separately for each subsample.

<Table 2> Mean Comparison: Low-tech vs. High-tech firms

	LOW_TECH		***HIGH_TECH***				
Variable	**N**	**Mean**	**N**	**Mean**	**Diff**		**|t-stat|**
OM	2,538	0.037	2,314	0.042	-0.005	*	1.82
Tobin Q	2,538	1.069	2,314	1.075	-0.006		0.35
RD	2,538	0.009	2,314	0.007	0.002	***	3.08
CEOABILITY	2,538	0.006	2,314	-0.005	0.011	***	3.22
lnSALE	2,538	20.102	2,314	20.560	-0.458	***	9.86
ROA	2,538	0.016	2,314	0.020	-0.004		1.55
SG	2,538	0.049	2,314	0.042	0.007		1.02
LEV	2,538	0.471	2,314	0.521	-0.050	***	-8.81
PPE	2,538	0.325	2,314	0.276	0.049	***	9.75

This table presents the univariate comparison of means of test variables between high tech and low-tech firms. The t-statistic is for a difference of means test from high-tech to low-tech firms. *, **, *** indicated significance at the 10%, 5%, and 1% level, respectively (two-tailed test). Variable definitions are presented in the footnote of Table 1.

<Table 3> provides the Pearson correlation for the regression variables. The correlation between the R&D intensity (*RD*) and one-year ahead operating margin (OM_{t+1}) is 0.038, and the correlation between the R&D intensity (*RD*) and one-year ahead Tobin's Q ($Tobin\ Q_{t+1}$) is 0.272. Both correlation coefficients are statistically significant at 1 percent level. This indicates that R&D spending is positively related to near future performance. Also, managerial ability is positively related to the

performance measures. The correlation between the managerial ability score (*CEOABILITY*) and one-year ahead operating margin (OM_{t+1}) is 0.130, and the correlation between the R&D intensity (*RD*) and Tobin's Q ($Tobin\ Q_{t+1}$) is 0.066, both significant at l percent level. These findings indicate that the proxy of R&D efforts and the proxy of managerial ability well captures their theoretical role in explaining financial performance. Consistent with prior research, the control variables are generally significantly related with the measures of financial performance, except the fact that the correlation between ROA and Tobin's Q is insignificant.

<Table 3> Correlation Matrix

Variable	OM_{t+1}	$Tobin\ Q_{t+1}$	*RD*	*CEO-ABILITY*	*lnSALE*	*ROA*	*SG*	*LEV*	*PPE*
OM_{t+1}	1.000								
$Tobin\ Q_{t+1}$	0.075***	1.000							
RD	0.038***	0.272***	1.000						
CEOABILITY	0.130***	0.066***	-0.109***	1.000					
lnSALE	0.211***	-0.050***	-0.038***	0.024*	1.000				
ROA	0.476***	0.012	-0.004	0.188***	0.201***	1.000			
SG	0.169***	0.063***	-0.007	0.092***	0.120***	0.226***	1.000		
LEV	-0.182***	-0.026*	-0.127***	-0.032**	0.299***	-0.329***	0.013	1.000	
PPE	0.062***	-0.129***	-0.016	-0.109***	0.119***	0.015	0.035**	0.156***	1.000

This table presents Pearson correlation among variables in the test. *, **, *** indicated significance at the 10%, 5%, and 1% level, respectively (two-tailed test). Variable definitions are presented in the footnote of Table 1.

3. Discussion of empirical results

I hypothesize that managerial ability strengthens the association of R&D spending and financial performance of a high-technology firm. While R&D efforts can affect future performance over the long term, I focus on the effects of R&D in the next year since the moderating role of managerial ability does not persist over multiple years when there is a change in management team. Thus, I measure financial performance using one-year ahead operating margin and Tobin's Q and compare the effects of R&D spending on those performance measures between

high-technology firms and low-technology firms. Accordingly, I conducted the regression estimation of Equation (1) using OLS and report the results in Table 4 and Table 5. I winsorized all continuous variables at the top and bottom 1 percent to remove the outliers. To address the serial correlation within firm, I use the robust standard errors clustered by firm for the estimation.

<Table 4> shows the results of the regression of operating margin on R&D spending and managerial ability. I expect that the interaction term between R&D spending and managerial ability (RD * CEOABILITY) to be positive in the subsample of high-technology firms. I do not make directional predictions for the standalone variables, RD and CEOABILITY, because my argument is that managerial ability increases firm performance through effective management on R&D activities. Importantly, although I do not make a formal prediction, I expect that the moderating effects of managerial ability will be weaker for low-technology firms than high-technology firms because R&D activities are more important to high-technology firms. Thus, I provide the results of low-technology firms to compare with that of high-technology firms. In Column (1), I find that the coefficient of RD * CEOABILITY is statistically insignificant among the low-technology subsample. This suggests that managerial ability does not contribute to R&D profitability among the firms in the businesses requiring relatively low technology. On the other hand, in Column (2), I find that the coefficient of RD * CEOABILITY is positive statistically significant at the 5 percent level among the high-technology subsample, consistent with the hypothesis. The results imply that more competent managers can improve accounting performance through the activities that is the source of innovation which is R&D activities in the case of product and technology innovations of high-technology firms.

It is not surprising that the coefficient of RD is insignificant in the low-technology subsample since low-technology generated by R&D are relatively easy to mimic and thereby cannot create a competitive advantage (Lengnick-Hall, 1992). Meanwhile, it is interesting that the coefficient of RD is insignificant as well in the high-technology subsample. The results indicate that R&D spending does not always have a positive impact on earnings but increase earnings when it is effectively managed by more able managers. Moreover, the estimated coefficient of CEOABILITY is positive and significant in Column (1). Since low-technology firms pursue innovations from other activities than R&D, the variable of managerial

ability could capture its positive impact on firm performance through other sources of innovations such as customer focus (Atuahene-Gima, 1996). Collectively, these findings corroborate the argument of this paper that managers demonstrate their ability in the source of innovation to improve firm performance.

<Table 4> Regression of Operating Margin on R&D spending and Managerial Ability: Low-tech vs. High-tech firms

		(1) Low-Tech Sample	(2) High-Tech Sample
	Predicted Sign	**OM_{t+1}**	**OM_{t+1}**
RD		0.105	0.253
		(0.47)	(0.80)
CEOABILITY		0.090***	0.009
		(3.49)	(0.42)
RD * CEOABILITY	+	-2.846	3.923**
		(-1.51)	(2.21)
lnSALE		0.009***	0.008***
		(4.73)	(3.53)
ROA		0.474***	0.339***
		(7.45)	(4.93)
SG		0.045***	0.013
		(2.70)	(0.87)
LEV		-0.035*	-0.086***
		(-1.89)	(-4.26)
PPE		0.046**	0.008
		(2.46)	(0.47)
Constant		-0.137***	-0.080*
		(-3.50)	(-1.80)
Year FE		Yes	Yes
Observations		2538	2314
Adjusted R^2		0.313	0.229

This table reports the regression results of the impact of R&D spending and managerial ability on operating margin in year t+1 for low-tech firms versus high-tech firms using Equation (1). Variable definitions are presented in the footnote of Table 1. Continuous variables are winsorized at the top and bottom 1 percent. I used robust standard errors clustered by firm and include year fixed effects. The robust t-statistics are in parentheses. *, **, *** indicated significance at the 10%, 5%, and 1% level, respectively (two-tailed test).

I find that the effects of the control variables are generally consistent with the prediction. lnSALE, and ROA in the current year are positively associated with operating margin in the next year. Sales growth (*SG*) and fixed asset intensity (*PPE*) are positively associated with performance only in the low-technology firms. Meanwhile, leverage is negatively associated with operating margin in both subsamples.

Similarly, I analyze the effects of R&D spending and managerial ability on market valuation captured by Tobin's Q and report the results in <Table 5>. I expect that the interaction term between R&D spending and managerial ability (RD * CEOABILITY) to be positive only for high-technology firms since R&D activities are less critical for the success of low-technology firms. In Column (1), consistent with the prediction, I find that the coefficient of RD * CEOABILITY is statistically insignificant among the low-technology subsample. This suggests that the equity market investors do not think managerial ability plays a significant role in turning R&D efforts into firm value when the firm runs a low-technology business. On the other hand, in Column (2), I find that the coefficient of RD * CEOABILITY is positive statistically significant among the high-technology subsample (p-value = 0.067), consistent with the hypothesis. The results imply that the market value of a high-technology firm increases with a more competent manager who effectively execute R&D spending.

In the regression of Tobin's Q shown in <Table 5>, I additionally find the estimated coefficient of CEOABILITY is positive and significant in the low-technology sample but insignificant in the high-technology sample. This result is similar to the result of the regression of operating margin shown in <Table 4>. It is possible that the coefficient of CEOABILITY estimated for the low-technology sample capture the effects of managerial ability on firm performance through other activities than R&D. In the meantime, the coefficients of RD are significant in both subsamples. The results imply that the market perceives R&D spending as positive for firm value generation overall and value it more positively when R&D in high-technology firms is managed by more able managers.

I find that the effects of the control variables are generally consistent with those

reported in the previous literature (e.g., Kwon et al., 2018). Sales growth (*SG*) is strongly associated with firm value in both subsamples and has a positive impact as predicted. As a contrast to the results of operating margins, PPE is negatively associated with Tobin's Q in both subsamples.

<Table 5> Regression of Tobin's Q on R&D spending and Managerial Ability: Low-tech vs. High-tech firms

		(1) Low-Tech Sample	(2) High-Tech Sample
	Predicted Sign	***Tobin*** Q_{t+1}	***Tobin*** Q_{t+1}
RD		11.263***	6.806*
		(4.80)	(1.93)
CEOABILITY		0.836***	-0.065
		(3.21)	(-0.32)
RD * CEOABILITY	+	4.067	27.825*
		(0.32)	(1.83)
lnSALE		-0.015	-0.025
		(-0.88)	(-1.31)
ROA		-0.736	1.140*
		(-1.25)	(1.76)
SG		0.220***	0.185***
		(3.13)	(3.00)
LEV		0.113	0.262*
		(0.77)	(1.72)
PPE		-0.295**	-0.475***
		(-2.29)	(-3.44)
Constant		1.177***	1.485***
		(3.83)	(4.00)
Year FE		Yes	Yes
Observations		2538	2314
Adjusted R^2		0.193	0.074

This table reports the regression results of the impact of R&D spending and managerial ability on operating margin in year t+1 for low-tech firms versus high-tech firms using Equation (1). Variable definitions are presented in the footnote of Table 1. Continuous variables are winsorized at the top and bottom 1 percent. I used robust standard errors clustered by firm and include year fixed effects. The robust t-statistics are in parentheses. *, **, *** indicated significance at the 10%, 5%, and 1% level, respectively (two-tailed test).

<Table 6> Alternative Model Specification of Regression of Future Performance on R&D spending and Managerial Ability: Low-tech vs. High-tech firms

		(1)	(2)
	Predicted Sign	**Full Sample** OM_{t+1}	**Full Sample** $Tobin\ Q_{t+1}$
LOW_TECH * RD		0.050	11.081***
		(0.21)	(4.97)
HIGH_TECH * RD		0.348	7.655**
		(1.23)	(2.36)
LOW_TECH * CEOABILITY		0.098***	0.603**
		(3.98)	(2.11)
HIGH_TECH * CEOABILITY		0.003	0.019
		(0.16)	(0.09)
LOW_TECH * RD* CEOABILITY		-2.994	6.343
		(-1.50)	(0.56)
HIGH_TECH * RD * CEOABILITY	+	3.908**	29.802**
		(2.30)	(2.00)
lnSALE		0.008***	-0.020
		(5.85)	(-1.64)
ROA		0.428***	0.112
		(9.19)	(0.23)
LEV		-0.053***	0.178
		(-4.06)	(1.55)
PPE		0.029**	-0.420***
		(2.35)	(-4.09)
SG		0.025**	0.201***
		(2.28)	(4.26)
Constant		-0.112***	1.369***
		(-3.82)	(5.98)
Year FE		Yes	Yes
Observations		4852	4852
Adjusted R^2		0.268	0.121

This table reports the regression results of the impact of R&D spending and managerial ability on operating margin and Tobin's Q in year t+1 for low-tech firms versus high-tech firms. Variable definitions are presented in the footnote of Table 1. Continuous variables are winsorized at the top and bottom 1 percent. I used robust standard errors clustered by firm and include year fixed effects. The robust t-statistics are in parentheses. *, **, *** indicated significance at the 10%, 5%, and 1% level, respectively (two-tailed test).

Additionally, one might argue that there is no reason to believe that the effects of the control variables differ by the subsamples. To address the possible concern, I estimated an alternative regression model that compares the effects of R&D spending and managerial ability between low-tech and high-tech in the full sample and report the results in <Table 6>. HIGH_TECH is a dummy variable, which equals to 1 if the firm belongs to high-tech industries, and 0 otherwise. LOW_TECH is a dummy variable, which equals to 1 if the firm belongs to low-tech industries, and 0 otherwise. The coefficient of HIGH_TECH * RD * CEOABILITY is positive and significant in the regression of operating margin and Tobin's Q. It supports the hypothesis that managerial ability strengthens the association of R&D spending and financial performance of a high-technology firm. Thus, I conclude that the results are robust to this alternative model specification.

V. CONCLUSION

This paper examines whether managerial ability affects the relationship between R&D efforts and financial performance of high-technology firms. By analyzing Korean high-technology firms in the last decade, I document an evidence that managerial ability enhances the impact of R&D spending on firm performance, consistent with theoretical prediction. To be specific, I find that managerial ability strengthens the association of R&D spending and firm value and profitability of a high-technology firm. On the contrary, I find that the performance of low-technology firms does not increase with R&D spending moderated by managerial ability but increase by managerial ability alone that might captures its positive impact on firm performance through other sources of innovations such as customer focus (Atuahene-Gima, 1996).

The findings of this study provide implications to the researchers who are interested in the effects of R&D investments on firm performance. This paper suggests that R&D spending could be a significant performance driver only for high-technology firms and that R&D spending cannot result in a significant increase in financial performance without effective and competent management. In addition, the findings emphasize that considering managerial ability in evaluating R&D profitability.

While I examined only one-year ahead performance for the R&D spending in the given year, future research may examine how long the effects of R&D spending and managerial ability persist. Although I presume that the effects of managerial ability for the given year does not persist longer than one year because R&D initiatives set up by the outgoing manager can be dismissed if there was a change in the management team, it is possible that intangible assets garnered by R&D efforts are still valuable over the longer time. I expect that a future research address this issue and provide a further understanding of the duration of the relation between R&D efforts and future performance.

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