The effects of cash holdings on R&D smoothing: evidence from Korea[1]

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ABSTRACT

This study provides evidence that the young firms use more cash holdings to smooth R&D investment than the mature ones in the existence of financial constraints. The firms use more cash holdings to smooth R&D investment during a bear market than a bull market. They build cash holdings during the bull market when internal finance and stock issues are plentiful and then draw them down during the bear market when equity issues are less available. The firms also use more cash holdings to fund asset-counted R&D investment than the cost-counted R&D investment, because the intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value. These findings suggest policy implications that financial constraints and market timing of stock market have important effects on the R&D smoothing of the firms.

Keywords: cash holdings, R&D smoothing, financial constraints, market timing

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INTRODUCTION

R&D investment plays an important role as the innovative driver that increases the firm's future growth opportunities and profitability, and has positive and persistent effects on the firm value. However, when firms try to fund R&D investment from external capital market, they are more prone to the moral hazard and adverse selection problems due to the asymmetric information. Arrow (1962) argues that moral hazard and adverse selection problems due to the asymmetric information hinder external finance for innovation activities such R&D investment. Stiglitz and Weiss (1981) and Myers and Majluf (1984) develop the formal models of moral hazard and adverse selection in debt and stock markets which apply particularly well to R&D investment. Bernanke and Gertler (1989), Calomiris and Hubbard (1990), and Hubbard and Kashyap (1990) state that R&D investment may lead to moral hazard and adverse selection problems because it cannot secure collateral value compared to the fixed asset investment. In particular, since firms hold most of their value in growth opportunities and scientific knowledge, R&D investment is likely to have little or no collateral value. Himmelberg and Petersen (1994) argue the used car market is less convincing than the stock market for the innovative firms.

Firms hardly ever rely on the external finance to fund R&D investment in the existence of the asymmetric information. Brown et al. (2009) argue that neither debt finance nor internal finance appears to be the sources to smooth R&D investment. Brown and Petersen (2010) argue that firms use preferentially cash holdings to smooth R&D investment, because internal finance to fund R&D investment is very volatile.

The adjustment cost for R&D investment is very higher than physical investment such as fixed asset and inventory asset investment. Himmelberg and Petersen (1994) argue that adjustment costs could bias R&D investment because a firm's R&D investment is predominantly a payment to highly trained scientists, engineers and other R&D workers. Twiss (1986) argues that the temporary R&D adjustment is avoided because of high adjustment costs.

Financial constraints also increase adjustment costs for R&D investment. Therefore, the financial constrained firms have strong incentives to build and manage a buffer stock of cash holdings to smooth R&D investment. Brown and Petersen (2010) extend Himmelberg and Petersen's (1994) explanation that firms can use the cash holdings to smooth R&D investment in the existence of the asymmetric information, and they argue that firms can use the cash holdings to smooth R&D investment in the existence of the financial constraints.

This paper examines the effects of cash holdings on R&D smoothing of firms listed on the Korean Exchange (http://www.krx.co.kr). Financial constraints are measured by proxy variables such as firm age and market timing of stock market. First, according to the methods of Hadlock and Pierce (2010) and Brown and Petersen (2010), sample firms are classified into young firms and mature ones by firm age to examine whether young firms use more cash holdings to smooth R&D investment than mature ones. Young firms are more prone to financial constraints than mature firms. Second, according to the methods of Bradley et al. (2008), sample periods are classified into bear market and bull market by market timing of stock market to examine whether firms use more cash holdings to smooth R&D investment in bear market than bull one. Brown and Petersen (2010) argue that young firms use more cash holdings to smooth R&D investment in both of the bear and bull market than mature firms. Third, R&D investment is classified into asset-counted R&D investment and cost-counted R&D investment to examine whether firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment. Asset-counted R&D investment is counted as the intangible assets in the balance sheet, but cost-counted R&D investment is counted as the current expenses in the income statement. The intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value than the tangible assets. This paper expects that young firms use more cash holdings to smooth R&D investment than mature ones, and that firms use more cash holdings to smooth R&D investment in bear market than bull market, and also that firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment. On the ground of these results, this paper presents the implications for R&D investment policy and cash management of firms.

The remainder of this paper proceeds as follows. Section 2 reviews the literature in this field and develops the hypothesis, section 3 provides details on the research design, section 4 shows the empirical results, and section 5 contains conclusion and the limitations of this study.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Literature Review

When firms try to fund R&D investment from external capital market, they are more prone to the moral hazard and adverse selection problems due to the asymmetric information. Thus, they use cash holdings to fund R&D investment in the existence of the asymmetric information. Brown and Petersen (2010) argue that firms use cash holdings to smooth R&D investment, because internal finance to fund R&D investment is very volatile. In particular, they suggest that young firms use cash holdings to dampen the volatility in R&D investment by approximately 75% during the 1998~2002 boom and burst periods in stock market. Cash holdings play an important role in buffering R&D investment from transitory financial shocks. Brown et al. (2009) argue that neither debt finance nor internal finance appears to be the sources to smooth R&D investment. Rather, they suggest that young firms to build cash holdings when internal finance and stock issues are plentiful and then draw them down in years when equity issues are less available.

The argument that firms use more cash holdings to fund R&D investment is usually based on the asymmetric information between firms and capital market. The innovative firms are exposed easily on the asymmetric information. The nature of R&D investment precludes outsiders from making accurate appraisals of value. In addition, even when firms can costlessly transmit information to outsiders, strategic considerations may induce firms to actively maintain asymmetric information. Levin et al. (1987) argue that firms in most industries view patents as an ineffective method of appropriating the returns to R&D investment and often prefer secrecy. Myers and Majluf (1984) provide that asymmetric information about R&D investment causes conflicts of interest between existing security holder and provider of new R&D investment fund. So when R&D investment must be financed externally, this can cause the firm to forgo desirable R&D projects. But the conflict of interest is removed if the firm has access to internal cash holdings. Then, the firm undertakes all R&D projects with a positive net present value.

Myers and Majluf (1984) examine the effect of asymmetric information on the stock market through an extension of Akerlof's (1970) well-known “market for lemons” argument. Akerlof (1970) finds that the used car market is the classic example of a market with asymmetric information and adverse selection problems. But Himmelberg and Petersen (1994) argue the used car market is less convincing than the stock market. A potential buyer of a used car can, at relatively low cost, hire a mechanic to assess the car' true quality. In contrast, a potential investor might have to hire a team of scientist to make an appraisal of the potential value of a firms's R&D projects. Myers and Majluf (1984) explain why firms may be forced to sell equity at a discount (pay a "lemons premium") if they can sell it at all. The adverse selection problems that they describe can be particularly severe for the innovative firms since the range of R&D project quality between "good firms" and "lemons" can be large.

Like stock markets, debt markets are also vulnerable to adverse selection problems because of asymmetric information about risk characteristics and default probabilities. Stiglitz and Weiss (1981) argue that banks may ration credit rather than use interest rates to clear the market because increases in interest rates may cause low risk borrowers to exit the application pool. This outcome seems particularly plausible for the innovative firms for which the probability of default may vary widely over a set of equivalent firms.

The issuance of new debt is further complicated by moral hazard problems. Arrow (1962) argues that this problem is especially relevant for R&D projects because the output can never be predicted perfectly from the inputs. Pursuing this line of reasoning, Stiglitz and Weiss (1981) note that as interest rates rise, unmonitored borrowers have an incentive to use loans for projects that are not in the best interest of lenders. In particular, borrowers can invest ex-post in riskier and higher-return projects that increase the probability of bankruptcy but offer no offsetting gain to debt holders if success is achieved. This problem is accentuated as firms become more leveraged. It is for this reason that equity, not debt, is considered the natural financial instrument for R&D investment. Long and Malitz (1985) provide an evidence that financial leverage has a negative effect on R&D investment. Moreover, these problems are compounded by the lack of collateral value for most R&D investments. Bester (1985) argues that in debt market, collateral value can be used as both a signaling device to overcome adverse selection and as an incentive device to overcome moral hazard. However, this options are not likely to be available for the innovative firms, because there is no collateral value to failed R&D investment.

When estimating the effect of cash holdings on R&D investment, it is important to consider the probable existence of adjustment costs for R&D investment. Adjustment costs could bias R&D investment for reasons similar to Griliches and Hausman (1986) who explain the puzzle that within-firm estimates of labor demand functions often yield output elasticities of less than one. They argue that because of adjustment costs, labor is hired in anticipation of permanent output rather than transitory output. Himmelberg and Petersen (1994) argue that the Griliches and Hausman explanation is applicable to R&D investment, because a firm's R&D investment is predominantly a payment to highly trained scientists, engineers and other R&D workers.

Theoretical explanations and empirical evidence of adjustment costs for R&D investment can be found throughout the economics literature. Twiss (1986) argues that the temporary R&D adjustment is avoided because of high adjustment costs. Grabowski (1968) provides a strong evidence that R&D workers, whose salaries constitute a sizable percentage of total R&D investment, are not perfectly elastic in supply and cannot be alternately fired and rehired in accordance with temporary changes in business conditions. There are a number of reasons why temporary hiring and firing of R&D workers is costly. R&D workers require a great deal of firm-specific knowledge, and training new R&D workers is expensive. Perhaps more importantly, fired R&D specialists are able to transmit valuable knowledge and information to competitors who hire them. Pakes and Nitzan (1983) describe optimal labor contracts designed specifically to retain R&D workers to reduce appropriaton problems. Levin et al. (1987) report that hiring a competitor's R&D workers is viewed by many firms as an effective means of procuring technological capital compared to alternative channels of information spillover. Bernstein and Nadiri (1989) present empirical evidence on adjustment costs. They estimate returns for R&D and physical investment as well as the marginal adjustment costs for these inputs for firms. The estimated marginal adjustment costs are higher for R&D investment than physical investment.

Financial constraints also increase adjustment costs for R&D investment. Financial constraints are measured by proxy variables such as dividend payout, firm age and market timing of stock market. Fazzari and Petersen (1993) classify the firms using dividend payout as a proxy variable of financial constraints, and examine the effects of net working capital on the fixed asset investment. Brown and Petersen (2010) argue that financial constraints are higher for young firms than mature ones. In particular, they suggest that young firms use cash holdings to dampen the volatility in R&D investment by approximately 75% during the 1998~2002 boom and burst in stock market. Therefore, the financial constrained firms have strong incentives to build and manage a buffer stock of cash holdings to smooth R&D investment, because the adjustment costs altering the path of R&D investment are very high. Faulkender and Wang (2006) show that the marginal value of cash holdings is higher for firms more likely to face financial constraints, particularly for those financial constrained firms that appear to have R&D investment opportunities but low levels of internal finance. Pinkowitz and Williamson (2007) find that the marginal value of cash holdings is highest in R&D intensive industries such as computer software, pharmaceuticals, computers, and electronic equipment. Denis and Sibilkov (2010) argue that cash holdings are more valuable for financial constrained firms and they provide evidence that more cash holdings permit financial constrained firms to increase R&D investment and that the marginal value of added R&D investment is greater for financial constrained firms than financial unconstrained ones. Brown and Petersen (2010) also provide direct evidence that cash holdings have a positive effect on R&D investment rather than physical investment of financial constrained firms, and suggest a new insight into how cash holdings can be particularly valuable for the innovative firms.

Hypothesis Development

When firms try to fund R&D investment from external capital market, they are more likely to face financial constraints. Financial constraints increase adjustment costs for R&D investment. Therefore, the financial constrained firms have strong incentives to build and manage a buffer stock of cash holdings to smooth R&D investment, because the adjustment costs altering the path of R&D investment are very high. Faulkender and Wang (2006) show that the marginal value of cash holdings is higher for firms more likely to face financial constraints, particularly for those financial constrained firms that appear to have R&D investment opportunities but low levels of internal finance. Pinkowitz and Williamson (2007) find that the marginal value of cash holdings is highest in R&D intensive industries. Denis and Sibilkov (2010) that cash holdings are more valuable for financial constrained firms and they provide an evidence that more cash holdings permit financial constrained firms to increase R&D investment, and that the marginal value of added R&D investment is greater for financial constrained firms than for financial unconstrained ones. Brown and Petersen (2010) argue that firms can use the cash holdings to smooth R&D investment in the existence of the financial constraints. Financial constraints are measured by proxy variables such as firm age and market timing of stock market. Hadlock and Pierce (2010) use firm age as a proxy variable for the presence of quantitatively important financial constraints, and Brown and Petersen (2010) argue that the young firms are more prone to financial constraints than the mature firms. Thus, this paper builds H1 as below to examine whether the young firms use more cash holdings to smooth R&D investment than the mature ones.

H1: The young firms use more cash holdings to smooth R&D investment than the mature ones.

Brown et al. (2009) argue that neither debt finance nor internal finance appears to be the sources to smooth R&D investment. Rather, they suggest that young firms to build cash holdings in bull market when internal finance and stock issues are plentiful and then draw them down in bear market when equity issues are less available. Brown and Petersen (2010) present that young firms use more cash holdings to smooth R&D investment in both of the bear and bull market than mature firms. Thus, this paper builds H2 as below to examine whether firms use more cash holdings to smooth R&D investment in the bear market than the bull market.

H2: The firms use more cash holdings to smooth R&D investment in the bear market than the bull market.

Blundell et al. (1992) use R&D investment as an input factor for technological innovation. R&D investment as proxy variable for technological innovation is composed of asset-counted R&D investment and cost-counted R&D investment. Asset-counted R&D investment is counted as the intangible assets in the balance sheet, but cost-counted R&D investment is counted as the current expenses in the income statement. The intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value than the tangible assets. Thus, this paper builds H3 as below to examine whether firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment.

H3: The firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment.

REASEARCH DESIGN

Data

The sample firms are collected as the firms listed on Korea Exchange from 1999 to 2009 in the KIS Value Library database, according to the criterion as follows: (1) firms need to have complete financial reports from 1999 to 2009 since certain variables are lagged for a period of one fiscal year; (2) firms in financial industries (i.e., bank, securities, insurance, financial holding companies) are excluded due to their being subject to special financial regulations; (3) also excluded are M&A firms because of the continuity problems of financial data.

The total number of firm-year of the sample firms that satisfies the above criteria from 1999 to 2009 is 11,396. The sample firms are classified into the young firms and the mature ones on the basis of firm age according to the method of Hadlock and Pierce (2010). The young firms are defined as the firms that have shorter age than median age of sample firms, but the mature ones are defined as the firms that have longer age than median age of sample firms. The number of firm-year of the young firms is 5,500, and that of the mature ones is 5,896. However, data structure is an unbalanced panel data, because there is no requirement that the firm-year observations data are all available for each firms during the entire periods from the KIS Value Library database.

Next, the sample periods are classified into the bear market and the bull market, on the basis of market timing of stock market. According to the method of Bradley et al. (2008), the bear market is defined as the periods that the Korea Composite Stock Price Index (hereinafter KOSPI) at the end of the year is lower than the beginning of the year, and the bull market is defined as the periods that KOSPI at the end of the year is higher than the beginning of the year. The number of firm-year of firms belong to the bear market is 4,144, and that belong to the bull market is 7,252.

Model and Variable

This paper builds the target R&D investment model as equation (1) according to the method of Himmelberg and Petersen (1994) and Brown and Petersen (2010).

$$\mathrm{TRD_t} = \alpha_0 + \sum_{k=1}^{M} \alpha_k \mathrm{X_{k,t}} \tag{1}$$

where $\mathrm{TRD_t}$ represents the target R&D investment ratio in year t; and $\mathrm{X_{k,t}}$ denote the number of firm characteristic variables in year t. That is, equation (1) represents that the target R&D investment ratio is determined by the firm characteristic variables.

On the assumption that firms adjust the actual R&D investment ratio partially when the actual R&D investment ratio deviates from the target one, Brown and Petersen (2010) suggest partial adjustment model as equation (2).

$$\mathrm{RD_t} - \mathrm{RD_{t-1}} = \theta(\mathrm{TRD_t} - \mathrm{RD_{t-1}}) \tag{2}$$

where $\mathrm{RD_t}$ represents the actual R&D investment ratio in year t; and θ denotes the R&D adjustment speed. Therefore, equation (2) means that the change of actual R&D investment ratio ($\Delta\mathrm{RD_t} = \mathrm{RD_t} - \mathrm{RD_{t-1}}$) is the same as the change of target R&D investment ratio ($\mathrm{TRD_t} - \mathrm{RD_{t-1}}$) times R&D adjustment speed (θ).
Equation (2) can be rewritten as equation (2a).

$$\mathrm{RD_t} = (1-\theta)\mathrm{RD_{t-1}} + \theta\mathrm{TRD_t} \tag{2a}$$

And substituting $\mathrm{TRD_t}$ of equation (1) for $\mathrm{TRD_t}$ of equation (2a), it can be rewritten as equation (3).

$$\mathrm{RD_t} = (1-\theta)\mathrm{RD_{t-1}} + \theta\mathrm{TRD_t} = (1-\theta)\mathrm{RD_{t-1}} + \theta(\alpha_0 + \sum_{k=1}^{M} \alpha_k \mathrm{X_{k,t}}) \tag{3}$$

In order to estimate equation (3), this paper applies fixed effect model such as equation (4) after statistical tests such as the Lagrange multiplier test and the Hausman test. Chamberlain and Griliches (1984) state that existing relations between the omitted variables and the independent variables in the fixed effects regression model, there is the advantage that biases do not arise in the estimate results. This paper identifies firm-specific effects (μ) and time-specific effects (λ_t), according to Lagrange multiplier test which Breusch and Pagan(1980) suggest, and also verifies whether fixed effect model is more adequate than random effect model on the ground of Hausman test. Firm-specific effects (μ) are unobservable but have a significant effect on R&D investment. They differ across firms, but are fixed for a given firm over time. In contrast, time-specific effects (λ_t) vary over time, but are the same for all firms in a given year, capturing mainly economy wide factors that are outside the firm's control.

$$\mathrm{RD}_t = \beta_0 + \beta_1 \mathrm{RD}_{t-1} + \gamma(\Delta\mathrm{CH})_t + \sum_{2}^{6} \gamma_k X_{k,t} + \mu + \lambda_t + \epsilon_t \qquad (4)$$

where $(\Delta\mathrm{CH})_t$ represents the cash holdings change ratio in year t; and $X_{k,t}$ denote the firm characteristic variables in year t such as Tobin-q (Q_t), sales growth rate (GROW_t), free cash flow (FCF_t), equity change ratio ($(\Delta\mathrm{E})_t$), and debt change ratio ($(\Delta\mathrm{D})_t$); μ denotes firm-specific effects; λ_t denotes time-specific effects, and ϵ_t stands for error term, respectively.

The dependent variable in equation (4) is R&D investment ratio (RD_t), which is measured as [(year t R&D investment)/(year t capital stock)], which play an important role as the innovative driver that create the value of intangible assets. The 「Statement of Korea Accounting Standards」 No. 3 (Intangible Assets) regulates that the expenditures generated during the research stage must be cost-counted according to the principle that the expenditures generated during the development stage can be capitalized only if they satisfy the asset measurement requirements, and that they must be cost-counted if they do not satisfy the asset measurement requirements. Based on this regulation, all R&D investment is classified into two groups such as 'asset-counted R&D investment' which is counted as intangible assets in the balance sheet and 'cost-counted R&D investment' which is counted as costs in the income statement. Therefore, the R&D investment ratio [RD_t] is measured as [(year t asset-counted R&D investment + year t cost-counted R&D investment)/(year t capital stock)], and the capital stock is the same as (year t total liabilities + year t total equity capital) in the balance sheet.

By the panel regression analysis, regression coefficient (β_1) of past R&D investment ratio (RD_{t-1}) is estimated, then R&D adjustment speed (θ) can be measured as 1 minus regression coefficient (β_1), that is, as $\theta = 1 - \beta_1$. R&D adjustment speed (θ) moves in range of $0 < \theta \leq 1$, where R&D adjustment speed θ=1 means that adjustment of actual R&D investment ratio toward target R&D investment ratio is done immediately, but in case of R&D adjustment speed (θ) is close to 0, it means mostly no adjustment of actual R&D investment ratio is done. These mean that actual R&D investment ratio is partially adjusted toward target R&D investment ratio ($\mathrm{RD}_{t-1} \rightarrow \mathrm{TRD}_t$) as time goes ($t \rightarrow \infty$). But the financial unconstrained firms with high credit scores can do excessive adjustment. That is, the excessive adjustment ($1 < \theta$) beyond necessity can be done by R&D smoothing.

The explanatory variable in equation (4) is the cash holdings change ratio [$(\Delta\mathrm{CH})_t$], which is measured as [(year t cash holdings - year t-1 cash holdings)/(year t capital stock)], and it is expected to have a negative effect on the R&D investment. Cash holdings in year t are measured as (year t cash and cash-equivalents) according to the method of Opler et al. (1999) and Dittmar et al. (2003). Arrow (1962) argues that moral hazard and adverse selection problems due to the asymmetric information hinder external finance for innovation activities such R&D investment. Bernanke and Gertler (1989), Calomiris and Hubbard (1990), and Hubbard and Kashyap (1990) state that R&D investment may lead to moral hazard and adverse selection problems because it cannot secure collateral value compared to fixed asset investment. Brown and Petersen (2010) argue that the financial constrained firms have strong incentives to build and manage a buffer stock of cash holdings to smooth R&D investment, because the adjustment costs altering the path of R&D investment are very high. Denis and Sibilkov (2010) argue that cash holdings are more valuable for financial constrained firms and they provide an evidence that more cash holdings permit financial constrained firms to increase R&D investment and that the marginal value of added R&D investment is greater for financial constrained firms than for financial unconstrained ones. Brown and Petersen (2010) also argue that firms use preferentially cash holdings to smooth R&D investment, because internal finance to fund R&D investment is very volatile. Therefore, the innovative firms are expected to use more cash holdings to smooth R&D investment than the non-innovative ones.

The control variables in equation (4) are composed of firm characteristic variables such as Tobin-q, sales growth rate, free cash flow ratio, equity change ratio, and debt change ratio. Tobin-q ($\mathrm{Q_t}$) is measured as [(year t market capitalization of equity + year t total liabilities)/(year t total asset)], and it is expected to have a positive effect on the R&D investment as ex ante growth opportunities variable. In traditional investment models, it is assumed that Tobin-q as growth opportunities variable have a positive effect on the R&D investment as well as fixed asset investment. Fazzari and Petersen (1993) report that Tobin-q have a positive effect on the fixed asset investment, and Himmelberg and Petersen (1994) report that Tobin-q have a positive effect on the R&D investment. Sales growth rate ($\mathrm{GROW_t}$) is measured as [(year t sales - year t-1 sales)/(year t-1 sales)], and it is expected to have a positive effect on the R&D investment as ex post growth variable. Himmelberg and Petersen (1994) report that sales growth rate have a positive effect on the R&D investment. Free cash flow ratio ($\mathrm{FCF_t}$) is measured as [(year t free cash flow)/(year t capital stock)], and it is expected to have a positive effect on the R&D investment as the internal finance variable. And free cash flow in year t is measured as (year t EBITDA - year t corporate tax cost - year t net investment), and then net investment in year t is measured as (year t working capital + year t tangibility asset - year t other investment). Equity change ratio ($(\Delta \mathrm{E/K})_\mathrm{t}$) is measured as [(year t equity - year t-1 equity) / (year t capital stock)], and debt change ratio ($(\Delta \mathrm{D/K})_\mathrm{t}$) is measured as [(year t long-term liabilities - year t-1 long-term liabilities) / (year t capital stock)]. They are expected to have a positive effect on the R&D investment as the external finance sources to fund R&D investment. Fazzari and Petersen (1993) report that debt change ratio have a positive effect on the fixed asset investment, whereas Brown et al. (2009) report that debt finance does not appear to be the sources to smooth R&D investment.

This paper builds the R&D investment models such as equation (5) and (6) in order to examine the effects of cash holdings on the asset-counted R&D investment and the cost-counted R&D investment, respectively.

$$\mathrm{RDA_t} = \beta_0 + \beta_1 \mathrm{RDA_{t-1}} + \gamma(\Delta\mathrm{CH})_t + \sum_{2}^{6} \gamma_k \mathrm{X_{k,t}} + \mu + \lambda_t + \epsilon_t \tag{5}$$

$$\mathrm{RDC_t} = \beta_0 + \beta_1 \mathrm{RDC_{t-1}} + \gamma(\Delta\mathrm{CH})_t + \sum_{2}^{6} \gamma_k \mathrm{X_{k,t}} + \mu + \lambda_t + \epsilon_t \tag{6}$$

where $\mathrm{RDA_t}$ represents the asset-counted R&D investment ratio in year t; and $\mathrm{RDC_t}$ denotes the cost-counted R&D investment ratio in year t, respectively.

The dependent variables in equation (5) and (6) are the asset-counted R&D investment ratio ($\mathrm{RDA_t}$) and the cost-counted R&D investment ratio ($\mathrm{RDC_t}$), which are measured as [(year t asset-counted R&D investment)/(year t capital stock)] and [(year t cost-counted R&D investment)/(year t capital stock)], respectively. And the explanatory variable is cash holdings change ratio [$(\Delta\mathrm{CH})_t$], and it is expected to have a negative effect on the asset-counted R&D investment and the cost-counted R&D investment, respectively. In the control variables, Tobin-q ($\mathrm{Q_t}$), sales growth rate ($\mathrm{GROW_t}$), free cash flow ratio ($\mathrm{FCF_t}$), equity change ratio ($(\Delta\mathrm{E/K})_t$), and debt change ratio ($(\Delta\mathrm{D/K})_t$) are expected to have a positive effect on the asset-counted R&D investment and the cost-counted R&D investment, respectively.

EMPIRICAL RESULTS

Descriptive Statistics and Bivariate Results

Table 1 shows the descriptive statistics and correlation coefficients among the variables. The mean of R&D investment ratio is higher than its median, implying that RD is skewed to the left. The mean of cash holdings change ratio is higher than its median, implying that $\Delta\mathrm{CH}$ is skewed to the left. The means of Tobin-q, sales growth rate, free cash flow ratio, equity change ratio, and debt change ratio are higher than each of their median. Hence, the distributions of the other control variables such as Q, GROW, FCF, $\Delta\mathrm{E}$, $\Delta\mathrm{D}$ are all skewed to the left.

As the Pearson (Spearman) correlation coefficients shows, $\Delta\mathrm{CH}$ has a negative and significant relation with RD at the 1% level. Among the control variables, significant and insignificant coefficients are mixed up. Tobin-q, sales growth rate, and equity change ratio have positive and significant relations with RD at the 1% level, respectively. But free cash flow ratio and debt change ratio is insignificant. Moreover, this paper tests multicollinearity using the variance inflation factors (VIFs) among each variables, and identifies the VIFs distribute in statistic allowance range. The absolute value of the highest correlation coefficient is 0.244(0.272) for Pearson (Spearman) correlations. This is below 0.8 and unlikely to lead to multicollinearity (Kennedy, 1992). Diagnostic tests confirm this conclusion with the highest VIF being 1.11.

Table 2 shows the results of mean difference tests between subsamples. Panel A presents the results of mean difference tests between the young firms and the mature ones. As the results show, R&D investment ratio of the young firms is lower than the mature ones at the 1% level. Cash holdings change ratio of the former is lower than the latter at the 10% level. Tobin-q and sales growth rate of the former are lower than the latter at the 1～10% level, respectively. But free cash flow ratio, equity change ratio, and debt change ratio is insignificant. This explains why the young firms use more cash holdings to smooth R&D investment. Therefore, this means the young firms are different from the mature ones, implying the former is more likely to use cash holdings to fund R&D investment in existence of financial constraints.

Panel B presents the results of mean difference tests between the bear market and the bull market. As the results show, R&D investment ratio of the firms belong to the bear market is lower than the bull market at the 1% level. Cash holdings change ratio of the former is higher than the latter at the 1% level. Tobin-q of the former are lower than the latter at the 1% level, but sales growth rate of the former are higher than the latter at the 1% level. Equity change ratio, equity change ratio, and debt change ratio of the former are lower than the latter at the 1% level, respectively. This explains why the firms use more cash holdings to smooth R&D investment at the bear market of stock market. Therefore, this means the firms belong to the bear market are different from that belong to the bull market, implying the former is more likely to use cash holdings to fund R&D investment in existence of financial constraints.

However, the bivariate tests present a firm's R&D investment is likely a function of not just one factor, but rather multiple factors such as cash holdings change ratio, Tobin-q, sales growth rate, free cash flow, equity change ratio, and debt change ratio. Because these factors may have interdependent effects that are not captured in bivariate tests, this paper takes multivariate framework for full examinations of the determinants of R&D investment in the next section.

Multivariate Results

This section examines the effects of cash holdings on R&D smoothing of the firms listed on the Korean Exchange, controlling for ex ante growth opportunities, ex post growth, internal finance, external equity finance, and external debt finance using a broad variety of multivariate regression models.

Table 3 shows the results for regression models to examine whether the young firms use more cash holdings to smooth R&D investment than the mature ones. Table 3 also ascertain the firm-specific effect and time-specific effect by the Lagrange multiplier test, and check out whether fixed effect model is more adequate than the random effect model by the Hausman test.

As the results show, the cash holdings change ratio has a negative and significant effect on the R&D investment of the young firms at the 1% level, whereas it has a negative and significant effect on the R&D investment of the mature firms at the 10% level. This is consistent with the Faulkender and Wang (2006) and Brown and Petersen (2010). Faulkender and Wang (2006) show that the marginal value of cash holdings is higher for firms more likely to face financial constraints, particularly for those financial constrained firms that appear to have R&D investment opportunities but low levels of internal finance. Brown and Petersen (2010) argue that firms can use the cash holdings to smooth R&D investment in the existence of the financial constraints. Hadlock and Pierce (2010) use firm age as a proxy variable for the presence of quantitatively important financial constraints, and Brown and Petersen (2010) argue that the young firms are more prone to financial constraints than the mature ones. Moreover, the R&D adjustment speed ($\theta = 1 - \beta_1$) for the young firms is 0.717, which is slower than 0.759 for the mature ones. This presents indirect evidence that the young firms use more cash holdings to smooth R&D investment than the mature ones.

Among the control variables, both of Tobin-q as ex ante growth opportunities variable and sales growth rate as ex post growth variable have positive and significant effects on the R&D investment of the young firms and the mature ones at the 5~10% level, respectively. This is consistent with Himmelberg and Petersen (1994) that Tobin-q and sales growth rate have positive effects on the R&D investment. Free cash flow ratio as internal finance source has a positive and significant effect on the R&D investment of the young firms at the 1% level, but it is insignificant on the mature ones. Equity change ratio as external equity finance sources has a positive and significant effect on R&D investment of the young firms and the mature ones at the 1% level, respectively, but debt change ratio as external debt finance sources are insignificant. This is consistent with Brown et al. (2009) that debt finance does not appear to be the sources to smooth R&D investment.

Comparing the cash holdings effects between the young firms and the mature ones classified by firm age, the former has higher effects than the latter. According to the equality tests between the regression coefficients suggested by McDowell (2005), the regression coefficient (γ_1=-0.012) for cash holdings of the young firms is lower than γ_1=-0.006 for the mature ones at the 5% level. Thus, **H1** that the young firms use more cash holdings to smooth R&D investment than the mature ones is proved. This implies the young firms use more cash holdings to smooth R&D investment than the mature ones in the existence of the financial constraints.

Table 4 shows the results for regression models to examine whether firms use more cash holdings to smooth R&D investment in the bear market than the bull market. The bear market is defined as the periods that KOSPI at the end of the year is lower than the beginning of the year, and the bull market is defined as the periods that KOSPI at the end of the year is higher than the beginning of the year.

As the results show, the cash holdings change ratio has a negative and significant effect on the R&D investment during the bear market at the 1% level, whereas it has a negative and significant effect during the bull market at the 10% level. Moreover, during the bear market, the cash holdings change ratio has a negative and significant effect on the R&D investment of the young firms and the mature ones at the 1% and 10%, respectively. But it is insignificant on both of the young firms and the mature ones during the bull market. This is consistent with Brown et al. (2009) and Brown and Petersen (2010). Brown et al. (2009) suggest that young firms to build cash holdings in bull market when internal finance and stock issues are plentiful and then draw them down in bear market when equity issues are less available. Brown and Petersen (2010) present that young firms use more cash holdings to smooth R&D investment in both of the bear and bull market than mature ones.

Comparing the cash holdings effects between the bear market and the bull market classified by market timing of stock market, the former has higher effects than the latter. According to the equality tests between the regression coefficients, the regression coefficient (γ_1=-0.013) for cash holdings during the bear market is lower than γ_1=-0.001 during the bull market at the 1% level. Thus, H2 that the firms use more cash holdings to smooth R&D investment in the bear market than the bull market is proved. This implies the firms use more cash holdings to smooth R&D investment in the bear market than the bull market in the existence of the financial constraints. Moreover, during the bear market, the regression coefficient (γ_1=-0.021) for cash holdings of the young firms is lower than γ_1=-0.009 for the mature ones at the 5% level. But cash holdings are insignificant during the bear market. Thus, H1 that the young firms use more cash holdings to smooth R&D investment than the mature ones during the bear market is reproved.

Table 5 shows the results for regression models to examine whether the firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment.

Asset-counted R&D investment is counted as the intangible assets in the balance sheet, but cost-counted R&D investment is counted as the current expenses in the income statement. Hence, the intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value than the tangible assets.

As the results show, the cash holdings change ratio has a negative and significant effect on the asset-counted R&D investment at the 5% level, and it is significant on the cost-counted R&D investment at the 10% level. Moreover, the adjustment speed ($\theta = 1 - \beta_2$) for the asset-counted R&D investment is 0.757, which is faster than $\theta = 0.696$ for the cost-counted R&D investment. This presents indirect evidence that the firms use more cash holdings to smooth the asset-counted R&D investment than the cost-counted R&D investment.

Comparing the cash holdings effects between asset-counted R&D investment and cost-counted R&D investment, the former has almost higher effects than the latter. According to the equality tests between the regression coefficients, the regression coefficient (γ_1=-0.003) for the asset-counted R&D investment is lower than γ_1=-0.002 for the cost-counted R&D investment at the 10% level. Thus, **H3** that the firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment is proved. This implies the firms use more cash holdings to smooth asset-counted R&D investment than the cost-counted R&D investment, because the intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value than the tangible assets.

CONCLUSIONS

This paper examines the relations between cash holdings and R&D investment of the firms listed on the Korea Exchange. First, the sample firms are classified into the young firms and the mature ones by firm age. Second, sample periods are classified into bear market and bull market by market timing of stock market. Third, R&D investment is classified into asset-counted R&D investment and cost-counted R&D investment.

The main result shows evidence that the young firms use more cash holdings to smooth R&D investment than the mature ones. This means that the young firms can use the cash holdings to smooth R&D investment in the existence of the financial constraints. Firms use more cash holdings to smooth R&D investment during the bear market than the bull market, and the young firms use more cash holdings to smooth R&D investment than the mature ones during the bear market. This means that the young firms to build cash holdings in bull market when internal finance and stock issues are plentiful and then draw them down in bear market when equity issues are less available. Moreover, the firms use more cash holdings to smooth asset-counted R&D investment than cost-counted R&D investment. The former is counted as the intangible assets in the balance sheet, but the latter is counted as the current expenses in the income statement. In particular, the intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value than the tangible assets.

In conclusion, these results support the evidence that the young firms use more cash holdings to fund R&D investment in the existence of the financial constraints. The firms use more cash holdings to smooth R&D investment during the bear market than the bull market, and the young firms use more cash holdings to smooth R&D investment than the mature ones during the bear market. The firms also use more cash holdings to fund asset-counted R&D investment than the cost-counted R&D investment, because the intangible assets created by asset-counted R&D investment may act as an innovative driver that can have a greater multiplier effect on the firm value. These findings suggest policy implications that financial constraints and market timing of stock market have important effects on the R&D smoothing of the firms.

This paper has a few limitations because it is the only early study about the relations between cash holdings and R&D investment. Specifically, this paper does not adequately capture all of the subtle features for the R&D investment. Thus, it is necessary to expand sample firms and control variables, and use more elaborate analytic methods in the future studies.

REFERENCES

Akerlof, G. A. 1970, "The market for lemons: Quality and uncertainty and the market mechanism," *Quarterly Journal of Economics,* 84(3): 488-500.

Arrow, K. J. 1962, "Economic welfare and the allocation of resources for invention," in R. R. Nelson(ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*(Princeton: Princeton University Press): 609-625.

Bernanke, B. and M. Gertler, 1989, "Agency costs, net worth and business fluctuations," *American Economic Review,* 79(1): 14-31.

Bester, H. 1985, "Screening vs. rationing in credit markets with imperfect information," *American Economic Review*, 75(4): 850-855.

Betnstein, J. I. and M. I. Nadiri, 1989, "Rates of return on physical and R&D capital and structure of the production process: Cross section and time series evidence", in B. Raj(ed.), Advances in Econometrics and Modelling(Dordrecht: Kluwer Academic Publishing): 169-185.

Blundell, R., S. Bond., M. Devereux., and F. Schiantarelli, 1992, "Investment and tobin q," *Journal of Econometrics,* 51(1): 233-257.

Bradley, D. J., B. D. Jordan, and J. R. Ritter, 2008, "Analyst behavior following IPOs: The bubble period evidence," *Review of Financial Studies,* 21(1): pp. 101-133.

Breusch, T. S. and A. R. Pagan, 1980, "The Lagrange multiplier test and its applications to model specification in econometrics," *Review of Economic Studies*, 47(1): 239-253.

Brown, J. R., S. M. Fazzari, and B. C. Petersen, 2009, "Financing innovation and growth: Cash flow, external equity and the 1990s R&D boom," *Journal of Finance*, 64(1): 151-185.

Brown, J. R. and B. C. Petersen, 2010, "Cash holdings and R&D smoothing," *Forthcoming , Journal of Corporate Finance.*

Calomiris, C. W., and R. G. Hubbard, 1990, "Firm heterogeneity, internal finance, and credit rationing," *Economic Journal,* 100(399): 90-104.

Chamberlain, G. and Z. Griliches, 1984, *Panel Data*, in Z. Griliches, and M. Intrilligator, eds. Handbook of Econometrics, 2.

Denis, D. J. and V. Sibilkov, 2010, "Financial constraints, investment and the value of cash holdings," *Review of Financial Studies,* 23(1): 247-269.

Dittmar, A., J. Mahrt-Smith, and H. Servaes, 2003, "International corporate governance and corporate cash holdings," *Journal of Financial and Quantitative Analysis*, 38(1): 111-133.

Faulkender, M. and R. Wang, 2006, "Corporate financial policy and the value of cash," *Journal of Finance*, 61(2), pp. 931-962.

Fazzari, S. M. and B. C. Petersen, 1993, "Working capital and fixed investment: New evidence on financing constaints," *The RAND Journal of Economics,* 24(3): 328-342.
Grabowski, H. G. 1968, "The determinants of industrial research and development: A study of the chemical drug and petroleum industries," *Journal of Political Economy,* 76(2): 292-306.
Griliches, Z. and J. A. Hausman, 1986, "Errors in variables in panel data," *Journal of Econometrics,* 31(1): 93-118.
Hadlock, C. J. and J. R. Pierce, 2010, "New evidence on measuring financial constraints: Moving beyond the KZ index," *Review of Financial Studies,* 23(5): 1909-1940.
Himmelberg, C. and B. Petersen, 1994, "R&D and internal finance: a panel study of small firms in high-tech industries," *Review of Economics and Statistics,* 76(1): 38-51.
Hubbard, R. G. and A. Kashyap, 1990, "Internal net worth and the investment process: An application to U.S. agriculture," *Journal of Political Economy,* 100(3): 506-534.
Kennedy, P.1992, *A Guide to Econometrics,* 3rd ed., (Basil Blackwell, Oxford, UK).
Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter, 1987, "Appropriating the returns from industrial research and development," *Brookings Papers on Economic Activity,* 18(3): 783-831.
Long, M. and I. Malitz, 1985, "Investment patterns and financial leverage," in B. M. Friedman(ed.), Corporate Capital Structure in the U.S.(Chicago: University of Chicago Press): 325-351.
McDowell, A. 2005, "Testing the equality of regression coefficients across independent areas," www.stata.com.
Myers, S. C. and N. S. Majluf, 1984, "Corporate financing and investment decisions when firms have information that investors do not," *Journal of Financial Economics,* 13(2): 187-221.
Opler, T., L. Pinkowitz, R. Stulz, and R. Williamson, 1999, "The determinants and implications of corporate cash holdings," *Journal of Financial Economics*, 52(1): 3-46.
Pakes, A. and S. Nitzan, 1983, "Optimum contracts for research personnel, research employment, and the establishment of rival enterprises," *Journal of Labor Economics,* 1(4): 345-365.
Pinkowitz, L. and R. Williamson, 2007, "What is the market value of a dollar of corporate cash?," *Journal of Applied Corporate Finance*, 19(3), pp. 74-81.
Stiglitz, J. E. and A. Weiss, 1981, "Credit rationing in markets with imperfect information," *American Economic Review,* 71(3): 393-410.
Twiss, B. 1986, *Managing Technological Innovation*, (New York: Longman).

Table 1: Descriptive Statistics, Correlation Coefficients, and Variance Inflation Factors

Variable	Mean	Standard Deviation	Median	RD	ΔCH	Q	GROW	FCF	ΔE	ΔD	VIF
RD	0.0128	0.0262	0.0124	1	-0.022**	0.183**	0.114**	-0.032**	0.122**	0.016	
ΔCH	0.0060	0.0797	0.0041	-0.045**	1	-0.007	0.087**	-0.245**	0.134**	0.057**	1.05
Q	0.7749	0.4111	0.7720	0.046**	-0.007	1	-0.025	-0.009**	0.056**	0.009	1.01
GROW	0.1258	0.3486	0.0944	0.108**	0.105***	-0.007	1	-0.070**	0.285**	0.064**	1.07
FCF	0.0479	0.1063	0.0397	-0.003	-0.165**	-0.024**	-0.058**	1	-0.053**	-0.190**	1.06
ΔE	0.1146	0.3211	0.0828	0.062**	0.166**	-0.017*	0.244**	-0.147**	1	0.053**	1.11
ΔD	0.0158	0.3925	0.0076	0.015	0.038**	0.008	0.065**	-0.111**	0.089**	1	1.02

Notes: RD is the R&D investment ratio. ΔCH is the cash holdings change ratio. Q, GROW, FCF, ΔE, and ΔD are Tobin-q, sales growth rate, free cash flow ratio, equity change ratio, and debt change ratio, respectively. Pearson (Spearman) correlation coefficients are reported below (above) the diagonal. ** and * denote statistical significance at the 1% and 5% levels, respectively, using a two-tailed test. VIF denotes the variance inflation factors to test multicollinearity among each variable.

Table 2: Mean Difference Tests between Subsamples

Panel A: Mean Difference Test between Young Firms and Mature Ones				
Variable	**Young Firms**	**Mature Firms**	**Mean Difference**	**t-test**
RD	0.0106	0.0149	-0.0043	-8.995***
ΔCH	0.0047	0.0073	-0.0026	-1.748*
Q	0.7677	0.7816	-0.0139	-1.786*
GROW	0.1140	0.1368	-0.0228	-3.506***
FCF	0.0327	0.0425	-0.0098	-0.954
ΔE	0.1134	0.1157	-0.0023	-0.390
ΔD	0.0209	0.0113	0.0096	1.250
Panel B: Mean Difference Test between Bear Market and Bull Market				
Variable	**Bear market**	**Bull market**	**Mean Difference**	**t-test**
RD	0.0122	0.0132	-0.0010	-2.0297**
ΔCH	0.0099	0.0038	0.0061	3.8627***
Q	0.7240	0.8040	-0.0800	-10.5357***
GROW	0.1498	0.1120	0.0378	5.5063***
FCF	0.0000	0.0000	0.0000	-4.6228***
ΔE	0.0926	0.1272	-0.0346	-5.3909***
ΔD	-0.0074	0.0286	-0.0361	-4.5216***

Notes: Variable definitions are the same as described in Table 1. ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively, using a two-tailed test.

Table 3: The Effects of Cash Holdings on R&D Smoothing

Variable Name	Coefficient	Young Firms	Mature Firms
Constant	β_0	0.008*** (14.98)	0.014*** (19.08)
$\mathbf{RD_{t-1}}$	β_1	0.283*** (21.64)	0.241*** (19.51)
$(\Delta CH)_t$	γ_1	-0.012*** (-3.94)	-0.006* (-1.69)
Q_t	γ_2	0.002** (2.04)	0.001* (1.71)
$GROW_t$	γ_3	0.001* (1.72)	0.002** (2.46)
FCF_t	γ_4	6.961*** (9.80)	0.595 (0.64)
$(\Delta E)_t$	γ_5	0.002*** (3.15)	0.002*** (2.58)
$(\Delta D)_t$	γ_6	0.001 (0.99)	0.001 (0.62)
Adjustment Speed (θ)	$1-\beta_1$	0.717	0.759
Number of Observations (n)		5,500	5,896
Number of Firms (g)		485	535
R^2 **– Within**		0.1165	0.1746
R^2 **– Between**		0.9568	0.9735
R^2 **– Overall**		0.5310	0.4763
Lagrange Multiplier Test		67.04***	80.35***
Hausman Test		2784.93***	3088.62***
F – value		82.38***	58.62***
Regression Coefficients Equality Test (t – value)		H_0: Young firms(γ_1)-Mature firms(γ_1)=0 : -0.006(-2.18)**	

Notes: In the regression models, dependent variable is RD_t, and explanatory variable is $(\Delta CH)_t$. The control variables are composed of firm characteristic variables such as Q_t, $GROW_t$, FCF_t, $(\Delta E)_t$, and $(\Delta D)_t$ which stand for Tobin-q, sales growth rate, free cash flow ratio, equity change ratio, and debt change ratio in year t, respectively. The White corrected t-statistics for the t-test are reported in parentheses. ***,**,* denote statistical significance at the 1%, 5% and 10% levels, respectively, using a two-tailed test.

Table 4: The Effects of Cash Holdings on R&D Smoothing between the Bear Market and the Bull Market

Variable		**Bear Market**			**Bull market**		
Variable Name	**Coefficient**	**Total**	**Young Firms**	**Mature Firms**	**Total**	**Young Firms**	**Mature Firms**
Constant	β_0	0.011*** (10.96)	0.007*** (5.73)	0.014*** (9.27)	0.012*** (21.34)	0.009*** (14.40)	0.014*** (16.12)
$\mathbf{RD_{t-1}}$	β_1	0.191*** (11.53)	0.277*** (10.66)	0.160*** (7.33)	0.216*** (18.51)	0.257*** (15.87)	0.196*** (12.05)
$(\Delta CH)_t$	γ_1	-0.013*** (-3.41)	-0.021*** (-3.71)	-0.009* (-1.67)	-0.001* (-1.76)	-0.004 (-1.41)	-0.003 (-0.70)
Q_t	γ_2	0.001* (1.76)	0.002* (1.70)	0.002 (1.21)	-0.001 (-1.33)	-0.001 (-0.60)	-0.001 (-1.33)
$GROW_t$	γ_3	0.003*** (2.75)	0.003** (2.18)	0.003** (2.11)	0.001* (1.73)	0.001* (1.69)	0.001 (0.52)
FCF_t	γ_4	2.580** (2.46)	1.989** (2.37)	2.321 (0.91)	3.633*** (5.59)	7.850*** (10.19)	0.124 (0.12)
$(\Delta E)_t$	γ_5	0.001** (2.36)	0.001** (2.31)	0.001* (1.67)	0.003*** (4.45)	0.003*** (3.24)	0.003*** (3.17)
$(\Delta D)_t$	γ_6	0.001 (0.41)	0.001 (0.04)	0.001 (0.57)	0.001 (0.33)	0.001 (0.72)	0.001 (0.20)
Adjustment Speed (θ)	$1-\beta_1$	0.809	0.723	0.840	0.784	0.743	0.804
Number of Observations (n)		4,144	2,000	2,144	7,252	3,500	3,752
Number of Firms (g)		1,007	472	535	1020	485	535
R^2 **– Within**		0.1523	0.1891	0.1468	0.1639	0.1227	0.1471
R^2 **– Between**		0.8547	0.8869	0.8057	0.9293	0.8891	0.9345
R^2 **– Overall**		0.4342	0.5353	0.3749	0.5179	0.5131	0.5185
Lagrange Multiplier Test		36.98***	21.04***	24.84***	40.22***	50.55***	11.64***
Hausman Test		2134.95***	537.30***	843.30***	3749.75***	2078.98***	1858.35***
F – value		21.81***	17.41***	10.62***	56.22***	52.90***	21.95***
Regression Coefficients Equality Test (t – value)		H_0: Young Firms(γ_1)-Mature Firms(γ_1)=0 : -0.012(-2.33)**			H_0: Young Firms(γ_1)-Mature Firms(γ_1)=0 : -0.001(-0.63)		
		H_0: Bear Market(γ_1)-Bull market(γ_1)=0 : -0.014(-3.48)***					

Notes: In the regression models, dependent variable is RD_t, and explanatory variable is $(\Delta CH)_t$. The control variables are composed of firm characteristic variables such as Q_t, $GROW_t$, FCF_t, $(\Delta E)_t$, and $(\Delta D)_t$ which stand for Tobin-q, sales growth rate, free cash flow ratio, equity change ratio, and debt change ratio in year t, respectively. The White corrected t-statistics for the t-test are reported in parentheses. ***,**,* denote statistical significance at the 1%, 5% and 10% levels, respectively, using a two-tailed test.

Table 5: The Effects of Cash Holdings on the Asset-counted R&D and the Cost-counted R&D Smoothing

Variable		**Asset-counted R&D Investment**	**Cost-counted R&D Investment**
Variable Name	**Coefficient**		
Constant	β_0	0.004*** (11.20)	0.007*** (22.21)
$\mathbf{RDA_{t-1}}$	β_2	0.304*** (25.45)	
$\mathbf{RDC_{t-1}}$	β_3		0.243*** (34.66)
$(\Delta\mathbf{CH})_t$	γ_1	-0.003** (-1.98)	-0.002* (-1.76)
$\mathbf{Q_t}$	γ_2	0.001*** (2.79)	0.001 (0.03)
$\mathbf{GROW_t}$	γ_3	0.002*** (4.75)	0.001 (0.48)
$\mathbf{FCF_t}$	γ_4	1.040** (2.41)	1.651*** (3.92)
$(\Delta\mathbf{E})_t$	γ_5	0.001 (0.97)	0.002*** (4.78)
$(\Delta\mathbf{D})_t$	γ_6	0.001 (0.32)	0.001 (0.27)
Adjustment Speed (θ)	$1-\beta_2$ $1-\beta_3$	0.757	0.696
Number of Observations (n)		11,396	11,396
Number of Firms (g)		1,020	1,020
$\mathbf{R^2}$ **– Within**		0.1668	0.1161
$\mathbf{R^2}$ **– Between**		0.9706	0.9708
$\mathbf{R^2}$ **– Overall**		0.3823	0.5369
Lagrange Multiplier Test		82.93***	159.60***
Hausman Test		5258.46***	5465.39***
F – value		97.64***	179.19***
Regression Coefficients Equality Test (t – value)		H_0: Asset-counted R&D Investment(γ_1)-Cost-counted R&D Investment(γ_1)=0 : -0.001(-1.80)*	

Notes: In the regression models, dependent variable is RD_t, and explanatory variable is $(\Delta CH)_t$. The control variables are composed of firm characteristic variables such as Q_t, $GROW_t$, FCF_t, $(\Delta E)_t$, and $(\Delta D)_t$ which stand for Tobin-q, sales growth rate, free cash flow ratio, equity change ratio, and debt change ratio in year t, respectively. The White corrected t-statistics for the t-test are reported in parentheses. ***,**,* denote statistical significance at the 1%, 5% and 10% levels, respectively, using a two-tailed test.