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A Study on Research and Development Cost Stickiness: Evidence from Technology Companies
연구개발비의 하방경직성에 관한 연구: 테크놀로지 기업을 중심으로

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The purpose of this study is to examine whether R&D cost stickiness exists and the sticky behavior of R&D expense is pronounced in technology industries. The study entails testing for sticky cost behavior by comparing sales revenue in periods when revenue increases with variations in R&D expenses with revenue in periods when revenue decreases with these variations. The analysis of 109,757 firm-year observations over 41 countries from 2010 to 2019 reveals an absence of R&D expense stickiness across the entire sample; the results show that companies more aggressively reduce their R&D expenses when their sales decline, although there is statistically significant R&D expense stickiness for technology companies; this finding implies that tech managers do not reduce R&D expenditures even with declining revenue. These managers recognize R&D as an essential element for continuous innovation and survival. The findings of this study expand the empirical research on R&D expenditures and cost behavior; they can be used as a practical basis for R&D budgeting and to emphasize the need for continuous investment in R&D activities.

Key Words: cost stickiness; technology industries; R&D intensity

Ⅰ. Introduction

Research and development (R&D) activities are a key driver of sustained growth and, critically, directly affects the survival of companies. Investment in R&D is considered crucial for both short-term corporate growth and long-term progress. Successful R&D is essential because it improves company profitability and significantly affects firm value (Aboody and Lev, 1998; Bulitz and Ettredge, 1989; Hirschey and Weygandt, 1985). In particular, under today's globally competitive circumstances, companies invest in R&D to achieve sustainable improvement and to find new growth engines.

There are a number of studies showing that

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investment in R&D activities provides useful information about companies in the capital market (Bublitz and Ettredge, 1989; Hirschey and Weygandt, 1985; Sougiannis, 1994; Ciftci and Cready, 2011). As such, the importance of R&D investment has long been recognized, and in recent years, researchers have emphasized that R&D activities are essential for not only development of companies but also for the nation's progress.

In a recent work, Govindarajan et al. (2019) argue that R&D is an expense that can be reduced or increased at management discretion. R&D expenditures are significant, and necessary, operating expenses, especially for digital companies such as Facebook, Alphabet, and Netflix, and curtailing them can halt a digital company's operations. Unlike the R&D costs in traditional manufacturing firms, which managers can decrease in response to short-term sales declines, R&D for digital companies is critical, and decreasing R&D investment makes it difficult for companies to achieve corporate innovation; for this reason, it is difficult for digital firms to reduce R&D expenditures proportionally even if their sales decline (Kim, 2019; Moon et al., 2020).

Despite its importance, many accounting researchers and national budget plans still consider R&D a discretionary expense, defined as a cost that is not tied to operations and can be curtailed or even eliminated in the short run without impacting current revenues. For example, tax-imposing government organizations such as the US Internal Revenue Service provide tax credits for R&D investment based on the idea that R&D is a non-essential expenditure that managers might otherwise avoid (Govindarajan et al., 2019). Meanwhile, Sun et al. (2019) found asymmetric cost behavior[1)] in Chinese-listed manufacturing firms and found that such behavior in traditional manufacturing companies decreased those companies' investment ability for the following year; these firms thus reduce their R&D expenses first.

In this context, it is meaningful to examine whether there is an asymmetric R&D expense pattern, particularly stickiness, that the magnitude of the decrease in R&D expense when sales revenue decreases is less than the magnitude of the increase in R&D expense when sales revenue increases. Empirical documentation of R&D cost stickiness can be evidence that firm managers recognize R&D activities as essential for company innovation and therefore that managers cannot easily reduce these expenses even in the face of falling sales revenues. In addition, R&D cost stickiness may be more pronounced in high

1) Asymmetric cost behavior refers to when the magnitude of the increase in costs associated with an increase in volume is different from the magnitude of the decrease in costs associated with an equivalent decrease in volume.

technology because R&D investments are crucial for innovation and the survival of tech firms.

With this study, I expand Anderson et al.'s (2003) cost stickiness model and a test of whether R&D expenditures show stickiness using 41 countries' accounting information from 2010 to 2019 provided by Compustat Global. The asymmetric cost behavior of R&D investments can be verified by comparing the rate of R&D expense reduction in response to sales decrease with the rate of R&D increase in response to sales increase. This process includes analyzing whether technology companies' R&D cost[2)] behavior differs from that of companies in other industries.

Previous researchers have primarily verified whether R&D expenditure data are useful or how to account for R&D expenditures, but empirical studies on R&D cost behavior are not sufficient. This study is an empirical test of R&D cost behavior, and thus it can be used as a basis for conducting relevant empirical research in the future. These findings can also contribute to better understanding the characteristics of R&D expenditures and provide a practical basis for making budgets.

The remainder of this study is organized as follows. Section 2 discusses prior literature on firm's R&D investments and cost stickiness; it also presents the test hypotheses. Section 3 covers the research design including research models, sample selection, and definition of the variable. Sample distributions and details of the test results are explained in Section 4, and the final section summarizes and provides conclusions of the study.

Ⅱ. Literature review and hypothesis development

2.1 Literature review

2.1.1 Cost Stickiness

In the traditional model of cost behavior, costs are described as fixed or variable with respect to changes in activity volume (Anderson et al., 2003, p. 47). A total cost that does not change as output changes is a fixed cost, and a variable cost, in contrast, increases in total with an increase in output and decreases in total with a decrease in output (Mowen et al., 2015, p. 68). It is assumed that variable costs change proportionately with changes in the activity driver (Noreen, 1991); this implies that the magnitude of a change in costs depends only on the extent of a change in the

2) Cost refers to the acquisition cost of the assets, and expense is defined as an expired portion of the costs. However, R&D is one of the selling, general and administrative costs, which must be paid in the years in which they occur. As such, R&D cost and R&D expense are used interchangeably in reality, including in this paper.

level of activity, not on the direction of the change (Anderson et al., 2003, p. 48).

However, some investigators find that costs rise more with increases in activity volume than they fall with decreases (Cooper and Kaplan, 1998, p.247; Noreen and Soderstrom 1997; Weiss, 2010; Jang et al., 2015). Anderson et al. (2003) use data from 7,629 companies and find that when sales increase by 1%, selling and general administrative expenses (SG&A) increase by 0.55% on average, while SG&A decreases by only 0.35% when sales decrease by 1%. The authors label this type of asymmetric cost behavior "sticky"; specifically, costs are sticky if the magnitude of the cost increases associated with an increase in volume is greater than the magnitude of the cost decreases associated with an equivalent decrease in volume (Anderson et al., 2003).

This asymmetric cost behavior happens for many reasons but mainly because of managers' perspectives on future sales. When there is uncertainty about future demand and companies must incur adjustment costs[3] to reduce committed resources, managers might purposely delay reductions of committed resources until the permanent decline in demand is more certain. When volume falls, managers must decide whether to maintain committed resources and bear the costs of operating with unused capacity or reduce committed resources and incur the adjustment costs of retrenching. Therefore, stickiness should be stronger when the assessed probability is low that a demand decline is permanent or when the costs of adjusting committed resources are high (Anderson et al., 2003; Prabowo et al., 2018).

The asymmetric cost behavior in Anderson et al.'s (2003) study triggered extensive empirical research about cost behavior. Balakrishnan et al. (2004) utilized data from 1,989 clinic-months from 49 therapy clinics and use the number of therapist hours worked and the salary paid to therapists as dependent variables in testing sticky behavior. They found that clinic managers easily adjusted staffing hours, indicating that current capacity utilization plays an important role in determining the extent of cost stickiness.

There are also extant analyses of the relationship between management performance and the asymmetric behavior of costs. Banker et al. (2006) examine increases and decreases in sales over a two-year period and found that the cost increases when sales had increased for two consecutive years were greater than they were when sales had decreased the previous year and increased in the current year; moreover, costs declined more when sales had

3) Severance pay when employees are dismissed, search and training costs when new employees are hired, and organizational costs such as loss of morale among remaining employees when associates are terminated or erosion of human capital when work teams are disrupted are examples of adjustment costs.

dropped over two consecutive years than when sales had increased the previous year and decreased in the current year. The managers of the companies in this study believed that the probability was fairly low that future sales would increase if sales dropped for two consecutive years, and thus they might have more actively reduced their unutilized resource capacity.

Chen et al. (2008) examine the impact of corporate governance on cost asymmetry. They find that the larger the board of directors and the more outside board members, the lower the agency costs. When the CEO and the board chair are different and when the directors hold a high share value, agency costs are relatively low, thus resulting in relatively lower cost asymmetry.

2.1.2 R&D expenditures

Many studies show that high R&D costs increase the value of companies. Sougiannis (1994) finds that reported accounting earnings that reflect R&D expenditures are positively related to the market value of equity, which reflects the productivity of corporate R&D expenses. Lev and Sougiannis (1996) also show a positive association between firm-specific R&D expenditures and operating income; they provide evidence that an average R&D expenditure of 1USD increases profits by 2USD and future firm value by 5USD and emphasize the importance of R&D investment, which can significantly increase the value.

Many researchers consider R&D expenditure to be the result of significant company value creation efforts, as are other types of intangible assets (Aboody and Lev, 1998; Bublitz and Ettredge, 1989; Hirschey and Weygandt, 1995). Bublitz and Ettredge (1989) analyze the effects of advertising and R&D expenses on stock prices. Specifically, they compare the market reaction to advertising and R&D forecast errors with the reaction to forecast errors for other conventional expenses. In their study, Bublitz and Ettredge use cumulative abnormal stock returns as the dependent variable in regressions with advertising and R&D forecast errors in addition to other control variables. The authors find that advertising forecast errors are significantly negatively related to abnormal returns, whereas R&D forecast errors are positively related, but the result is not statistically significant. This mixed result might have been evidence that the effects of advertising are short lived whereas those of R&D are more long term.

Hirschey and Weygandt (1985) find that advertising and R&D expenditures have positive effects on firms' market value. They regress Tobin's Q on advertising intensity, R&D intensity, changes in sales revenue, and the market risk beta, and they find significant impacts of both advertising and R&D on value. According to, The relationship between R&D

expense and firm value varies across firms (Joos and Plesko 2005). Joos and Plesko (2005) document that investors do not price persistent losses without an R&D component, but when persistent losses contain R&D, the investors value the R&D component separately. Therefore, the authors conclude that investors do not consider losses homogeneously or consider the causes and nature of the losses in order to assess the implications for firm value in the long term.

Meanwhile, Aboody and Lev (1998) establish that the relationships between R&D expenditures and stock returns differ depending on the manner of accounting for the expenditures, whether they are expensed or capitalized. The authors find that changes in capitalized software development costs are positively related to stock returns, unlike changes in expensed software development costs. Chambers et al. (1999) determine that R&D information is more value relevant in stock markets when R&D expenses are amortized over certain time periods after they are capitalized than when they are spent in the year they are incurred in. This suggests that capitalizing R&D investment rather than expensing it is more appropriate financial reporting for R&D expenditures. Overall, investors positively evaluate intangible assets, including R&D expenditures, in the capital market.

2.2 Hypothesis development

2.2.1 Stickiness of R&D expense

If Sougiannis's (1994) assertion is accurate that current R&D expenditure is related to increase in future firm value, companies that heavily invest in R&D would be more interested in generating future cash flows than current cash flows. Companies that have heavy R&D investment in the current period to generate future cash flows would be less sensitive to sales reductions than those that have no or fewer R&D expenses or expenditures. Following Chambers et al. (1999), if the accounting method that capitalizes R&D expenditure and amortizes it over later periods provides more relevant information than when R&D is expensed right away, then companies would be willing to continue investing in R&D regardless of the increase or decrease in short-term sales revenue. Therefore, asymmetric cost behavior of R&D expense could exist, especially R&D expense “stickiness.”

Anderson et al. (2003) state that cost behavior asymmetry exists because higher tangible asset intensity requires managers to make decisions such as selling or retaining tangible assets they hold depending on future sales prospects. They argue that the higher the asset intensity, the more the committed resources that are determined in advance based on expected demand, resulting in more committed fixed expenses that do not occur in proportion to the level of activity; thus, it can be expected that in the short term it would be difficult to reduce these costs in proportion to the decrease in sales. Therefore, based on the above literature review, I develop the following hypothesis to examine whether stickiness of R&D expense exists:

H1: The relative magnitude of a decrease in R&D expense for a decrease in sales revenue is less than the relative magnitude of an increase in R&D expense for an increase in sales revenue.

If the degree of decrease in R&D expense for a decrease in sales revenue is less than the degree of an increase in R&D expense for an increase in sales revenue, this could be evidence of R&D cost stickiness, which would occur if managers consider R&D activities to be essential to their organizations. Support for H1 would suggest that R&D is an essential cost component that cannot be easily reduced even when sales decrease.

2.2.2 R&D cost stickiness for technology companies

Subramaniam and Watson (2016) verify that R&D cost stickiness varies across industries. They argue that the production environment supplying goods and services, the market situation, and regulations differ by industry, as do different companies' committed resources. Because of these factors, varying adjustment costs might cause the stickiness of R&D costs to vary as well by industry. Mun and Hong (2010) examine an asymmetric cost behavior and document that asymmetric cost behaviors are different among industries

In the global competitive environment, R&D has become a critical element of innovation, and sustainability of organizations is not guaranteed without continuous innovation. Govindarajan et al. (2019) analyze the accounting information of digital firms from 2013 to 2017 and find that R&D expenses are greater and more important to digital companies than to traditional manufacturing firms. In their study, digital companies such as Facebook and Alphabet spent 19% and 15% of their sales on R&D activities in 2017, respectively, and Twitter spent 76% of its sales revenue on R&D in 2013. In contrast, General Motors, one of the traditional manufacturing firms, spent only 2% percent of its revenue, and Walmart reports 0% of R&D intensity.

Examples of technology companies' R&D expenses include salaries of engineers, product managers and IT personnel, as well as large equipment for developing technologically innovative products and services. Therefore, technology companies cannot lay off R&D personnel in the short term and must continue to invest in R&D to achieve technological advances, survive in competitive environments, and meet rapidly changing customer needs. Given that such activity is a critical driver of technological innovation, it requires continuous investments. Owing to these factors, tech firms might reduce their R&D expenditures if their sales revenues decline but not symmetrically: The reduction in expenditures might be less than the rate of the increase in R&D expense for an increase in sales revenue.

However, asymmetric costs may increase a company's risk; it is difficult for companies with asymmetric costs to quickly deal with the risks associated with changing sales revenue due to changes in demand. Because a company with asymmetric cost behavior cannot afford investment activity when it experiences sales decline, it will likely reduce its R&D expenses that are allocated for long-term growth, which will thereby increase the investment risk. Managers at non-technology companies where R&D investments are not yet considered essential may not document the stickiness of R&D expense.

As mentioned above, technology companies' R&D expenditures are essential to their operations, and reducing R&D may threaten their fundamental operations, while traditional manufacturing companies might not consider or recognize R&D costs as essential and thus trust managers to adjust costs at their discretion. Therefore, a difference can be expected between degree of R&D cost asymmetry for technology firms and that for non-technology firms. In other words, the R&D costs of technology firms should have greater cost stickiness than those of non-technology firms, leading to the following hypothesis:

H2: Stickiness of R&D expense is more pronounced for technology companies than for non-technology companies.

The empirical acceptance of H2 would serve as evidence that regardless of the increase or decrease in sales, continuous investment in R&D is inevitable in technology companies.

III. Research Design

3.1 Models

The purpose of this study is to examine whether R&D expense stickiness exists and whether it is more pronounced for technology than non-technology firms. Anderson et al. (2003) produced the most commonly used model for testing cost stickiness. In this study, I apply R&D expense to their model to design equation (1): to reduce heteroscedasticity, the equation takes the natural logarithm of R&D expenses and sales revenues:

$$\log\left[\frac{RND_{i,t}}{RND_{i,t-1}}\right] = \alpha_0 + \alpha_1 \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] + \alpha_2 * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] + \varepsilon_{i,t} \quad \text{(Eq. 1)}$$

where $RND_{i,t}$ denotes firm i's year t R&D expense, $sales_{i,t}$ is total sales revenues of company i at year t, and $DDummy_{i,t}$ is set to 1 if firm i's year t R&D expense is lower than the prior year's t and 0 otherwise.

In equation (1), α_1 represents the increasing rate (%) in R&D expense relative to the sales increase, defined as the R&D elasticity for sales increase. If sales revenue decreases compared with previous years, $DDummy_{i,t}$ is set to 1, and $(\alpha_1 + \alpha_2)$ is the R&D elasticity for sales decrease showing the decrease rates of R&D when sales decrease. If the R&D behaves symmetrically in the direction of the changes in activity levels, then its elasticity for sales increase (α_1) is equal to its decreasing elasticity for sales decrease $(\alpha_1 + \alpha_2)$. On the contrary, if α_1 is greater than $(\alpha_1 + \alpha_2)$, in other words negative, then the R&D expense stickiness exists. Therefore, the predicted signs for α_1 and α_2 are positive (+) and negative (-), respectively. To examine H2 for this study, equation (1) is expanded to develop research equation (2) as follows:

$$\begin{aligned}\log\left[\frac{RND_{i,t}}{RND_{i,t-1}}\right] &= \beta_0 + \beta_1 \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] \\ &+ \beta_2 * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] \\ &+ \beta_3 * HT_{i,t} * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] \\ &+ \beta_4 LEV + \beta_5 MTB + \beta_6 ROA + \beta_7 PPE \\ &+ \beta_8 SIZE + \sum AS + \sum Year \\ &+ \sum Country + \varepsilon_{i,t} \quad \text{(Eq. 2)}\end{aligned}$$

where $RND_{i,t}$ is R&D expense of firm i at year t. $sales_{i,t}$ denotes company i's year t total sales revenues and $DDummy_{i,t}$ is set to 1 if firm i's year t R&D expense is lower than the prior year's and 0 otherwise. *HT* is an indicator variable for a high-technology company.[4)]

LEV, *MTB*, *ROA*, *PPE*, *SIZE*, and *AS* are included as control variables in the model.[5)] *LEV* and *MTB* are added because prior studies find that a company's financing condition and growth prospects can affect R&D investment (Fazzari et al., 1988; Gertler, 1988; Kamien and Schwartz 1978). When a company with high leverage experiences a sharp decline in sales, the managers' discretionary decision-making authority is limited. Moreover, the managers are more likely to make decisions that reduce resources and expenses during the period to maintain the status quo for

4) Technology companies are defined in Section 3.3.
5) Detailed explanation of variables is also provided in the Appendix.

uncertain future demand. Therefore, there should be less stickiness of R&D cost when a company has higher leverage.

Sloan (1996) states that the tendency is for currently profitable firms' profits to persist in the future; companies with high net profit or high persistence of net profit will be able to maintain their unused resources even if sales drop. In this case, the R&D cost is stickier so that the cost asymmetry will be greater. To control this, *ROA* (return on assets) is calculated by dividing net profit by total assets and adding the result to the research model.

Following on prior findings that the size of the tangible assets (PPE) and the scale of a company (SIZE) can affect R&D investment and cost behavior, I add *PPE* and *SIZE* into the model. R&D accounting methods vary depending on the accounting standards, so I include *AS*. Finally, to control year and country fixed effects, *Year* and *Country* dummies are included in the model.

In Equation (2) above, the indicator variables of interest are β_2 and β_3. First, β_2 less than 0 means a non-technology firm has R&D cost stickiness, which can indicate that even non-technology companies do not reduce their R&D expenditures even when sales decrease as much as they increase their R&D when sales increase. On the contrary, if β_2 is greater than 0, this asymmetric R&D cost behavior means that non-tech firms more aggressively reduce their R&D costs when their sales revenue decreases. Meanwhile, β_3 indicates the R&D cost stickiness of tech firms; if β_3 is statistically and significantly negative, the stickiness is pervasive, which is potential evidence that for technology firms, continuous investment in R&D are necessary for leading innovation.

3.2 Sample selection

This study is to examine whether there is a difference in sticky behavior of R&D expense between tech and non-tech firms. To do this, I collect 2010 to 2019 data from all countries and companies provided by Compustat Global and Compustat North America. Specifically, the sample consists of companies with a fiscal year end of December 31, no impairment of capital, and financial data available in Compustat. I also winsorize the top and bottom 1% of each variable to mitigate the problems that may be caused by outliers. This results in a sample of 109,757 firm-year observations during 2010 to 2019 covering 41 countries. I exclude from the final sample countries whose sample size is too small to provide meaningful implications (fewer than 100 firm-year observations). Table 1 reports the sample distribution by country, year, industry, and accounting standards used.

〈Table 1〉 Sample distribution

This table presents sample selection. Panel A reports the sample distribution of total firm-year observations of 109,757 by country (n = 41). Panels B, C, and D present the sample distribution by year, by Global Industry Classification Standard (GICS) sector, and by accounting standard, respectively.

Panel A: Sample by country

Country Code	Country	Obs.	%
AUS	Australia	2,432	2.22
AUT	Austria, Republic of	352	0.32
BEL	Belgium, Kingdom of	424	0.39
BGD	Bangladesh	183	0.17
BMU	Bermuda	933	0.85
BRA	Brazil	502	0.46
CHE	Switzerland	909	0.83
CHN	China, People's Republic of	13,938	12.70
CYM	Cayman Islands	2,970	2.71
DEU	Germany, Federal Republic of	2,469	2.25
DNK	Denmark, Kingdom of	447	0.41
ESP	Spain	455	0.41
FIN	Finland, Republic of	786	0.72
FRA	France	2,102	1.92
GBR	United Kingdom	3,822	3.48
GRC	Greece	389	0.35
HKG	Hong Kong	373	0.34
IDN	Indonesia	289	0.26
IND	India	5,408	4.93
IRL	Ireland	127	0.12
ISR	Israel, State of	1,094	1.00
ITA	Italy	751	0.68
JPN	Japan	17,281	15.74
KOR	Korea, Republic of	7,400	6.74
LKA	Sri Lanka, Republic of	115	0.10
LUX	Luxembourg	109	0.10
MYS	Malaysia	1,379	1.26
NLD	Netherlands, Kingdom of the	408	0.37
NOR	Norway	446	0.41
NZL	New Zealand	336	0.31
PAK	Pakistan	253	0.23
PHL	Philippines	270	0.25
POL	Poland	702	0.64
RUS	Russian Federation	194	0.18
SGP	Singapore	645	0.59
SWE	Sweden	1,405	1.28
THA	Thailand	154	0.14
TUR	Turkey	1,022	0.93
TWN	Taiwan	12,661	11.54
USA	United States of America	23,426	21.34
ZAF	South Africa	396	0.36

〈Table 1〉 Sample distribution (continue)

Panel B. Sample by year

Year	Obs.	%
2010	8,641	7.87
2011	8,830	8.05
2012	9,027	8.22
2013	9,366	8.53
2014	9,934	8.05
2015	12,036	10.97
2016	12,559	11.44
2017	13,194	12.02
2018	13,537	12.33
2019	12,633	11.51

Panel C. Sample by GIC sectors

GICS	Sector	Obs.	%
10	Energy	1,951	1.78
15	Materials	13,245	12.07
20	Industrials	22,608	20.60
25	Consumer Discretionary	13,814	12.59
30	Consumer Staples	6,749	6.15
35	Health Care	15,614	14.23
40	Financials	415	0.38
45	Information Technology	29,943	27.29
50	Communication Services	3,921	3.57
55	Utilities	1,257	1.15
60	Real Estate	240	0.22

Panel D. Sample by accounting standards

	Accounting Standards	Obs.	%
DI	Domestic standards generally in accordance with or fully compliant with International Financial Reporting Standards	50,009	45.57
DS	Domestic standards	56,527	51.50
DU	Domestic standards generally in accordance with United States GAAP	2,575	2.35
MU	Modified United States standards	203	0.18
ND	Not Determined	28	0.02
US	United States standards	415	0.38

3.3 Definition and measurement for hi-tech firms

Anderson et al. (2003) use increase and decrease rate of SG&A costs as dependent variables and increase and decrease rate of sales as independent variables to see if there is SG&A cost stickiness. With this study I expand Anderson et al.'s (2003) model to examine whether there is R&D cost stickiness and whether the stickiness is more pronounced in technology companies. I add to the model a cost stickiness variable and an interaction term to indicate a technology firm.

There are a number of working definitions of a technology firm. Loschky (2010) proposes R&D intensity as an indicator of a technology firm; he explains that R&D intensity differs between different sectors but is higher within the high-tech sector, characterized by the highest R&D intensity, than it is among low-tech intensity sectors such as food production and steel and textile manufacturing.

Information technology is one active high-tech sector. IT is the use of computers, storage, networking, and other physical devices to create, process, store, retrieve, and transmit all forms of electronic data (Dainitith, 2009). Especially because of the emergence of the Fourth Industrial Revolution, today's IT encompasses the Internet of Things, cloud computing, and online security among many other facets. Generally, the term is commonly used as a synonym for computers and computer networks, but IT also encompasses other information distribution technologies. Multiple products and services are associated with information technology, including computer hardware, software, electronics, semiconductors, internet, telecom equipment, and e-commerce (Chandler and Munday, 2011).

On the one hand, according to Govindarajan et al. (2019), companies engaged with networks and platforms such as Facebook, Alphabet, and Netflix are digital firms that use high technology. On the other hand, Watanabe et al. (2002) note that the pharmaceutical industry has among the highest R&D intensity. For this study, my interest is technology firms, whose R&D costs are essential for their survival, but it can be challenging to clearly define these companies. Therefore, based on the prior literature and using Global Industry Classification Standards (GICS) codes provided by WRDS Compustat, I identify firms with the following GICS codes as high-technology firms: 35 (health care), 45 (information technology), and 50 (communication services).[6] For this study, *HT* is 1 if a company belongs to one of these GICS codes and

6) Firms under GICS code 35 are in health care equipment & services, pharmaceuticals, biotechnology & life sciences. Code 45 industries are software & services, technology hardware & equipment, semiconductors & semiconductors equipment, and Code 50 encompasses telecommunication services, media, & entertainment.

0 otherwise.

Ⅳ. Results

4.1 Descriptive statistics

From the 2010 - 2019 financial information provided by Compustat, I examine the stickiness of R&D expense with 109,757 firm-year observations over 41 countries. The descriptive statistics for the sample are shown in Table 2. The natural logarithm of the dependent variable, *logRND*, shows a mean of 0.021 (SD = 0.3188, median = 0.0249). Mean *logsales*, representing sales increase and decrease rate, is 0.0192 (SD = 0.2450).

4.2 Mean difference test results of R&D intensity

I also test the mean difference in R&D intensity between technology and non- technology

〈Table 2〉 Descriptive statistics

This table presents descriptive statistics of the dependent and independent variables used in the regression equations. The sample period is from 2010-2019. All variables are defined in the Appendix.

Variable	Obs.	Mean	Std. Dev.	Median
Dependent variable				
logRND	109,757	0.0210	0.3188	0.0249
Explanatory variable of interest				
logsales	109,757	0.0192	0.2450	0.0234
*D*logsales*	109,757	-0.0445	0.1829	0.0000
*HT*D*logsales*	109,757	-0.0255	0.1474	0.0000
Control variable				
LEV	109,757	0.5670	0.4190	0.4494
MTB	109,757	1.6550	2.2730	1.0667
ROA	109,757	0.0313	0.3756	0.0297
PPE	109,757	0.2299	0.1776	0.1990
SIZE	109,757	3.4463	1.3594	3.4637
Others				
RND	109,757	0.6327	3.5775	0.1213
D	109,757	0.3421	0.4744	0.0000
HT	109,757	0.4508	0.4976	0.0000

〈Table 3〉 T-test results of R&D intensity difference

This table reports the results of mean difference test of R&D intensity. Panel A presents the results of a mean difference test between high technology (HT) and non-high technology (non-HT) firms, and Panel B shows the results between accounting standards DI (domestic standards generally in accordance with or fully compliant with IFRS) and DS (Domestic standards).
***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively. The sample period is from 2010-2019.

Panel A. HT vs. non-HT

Group	Obs.	Mean	t
HT firms	49,478	0.8233	
Non-HT firms	60,279	0.0927	
T			4.18***

Panel B. DI vs. DS (accounting standards)

Group	Obs.	Mean	t
DI adopted firms	50,009	0.5560	
DS adopted firms	56,527	0.2762	
T			1.54

firms; Panel A in Table 3 shows the results. Average *RND* for *HT* firms is 0.8233, and that for non-*HT* firms is 0.0937. The difference between *HT* and non-*HT* firms is statistically significant at 1%.

In addition, I test the mean difference in R&D intensity among the different accounting standards (*AS*) used by the sample companies, a total of five. I first exclude the sample data with ND (accounting standards not determined) and then run an ANOVA for the five *AS* groups[7]; I find no statistical significance in the differences among the *AS* groups (not tabulated). For instance, three accounting standards, DU, MU, and US, are all compliant with US standards, but there are no statistically significant differences between DI and US or between DS and US (not tabulated). The results for the mean difference test between DI and DS, the two most commonly used standards in the sample, are reported in Table 3, Panel B. The average R&D expenditure for the companies using DI is 0.556, and for the companies using DS, the

7) The five AS I use in this study are as follows: DI is domestic standards generally in accordance with or fully compliant with International Financial Reporting Standards. DS is domestic standards. DU is domestic standards generally in accordance with United States' standards. US means United States' standards. They are also reported in Table 1, Panel D.

average is 0.2762. This might imply that the companies that adopt standards that are compliant with International Financial Reporting Standards (IFRS) recognize more R&D expense, but there is no statistical significance.

4.3 Regression results

The regression results of equations (1) and (2) are presented in Table 4. First, in equation (1), *logsales* and *D*logsales* are both statistically and significantly positive at 1%; the positive *logsales* (α_1) indicates that the changing rate of R&D increases when the changing rate of sales revenue increases. The coefficient of *D*logsales* (α_2) is also positive, indicating that all companies in the sample also reduce R&D expenses when sales decrease. The results show that companies more aggressively reduce their R&D expense when their sales decline. I find no stickiness of R&D cost in the entire sample, and therefore H1 is rejected.

Second, for H2 regarding R&D expense stickiness for technology firms to be supported, the coefficient of *logsales* (β_1) in equation (2) needs to be positive and the coefficient of *HT*D*logsales* (β_3) should be negative. In addition, β_1 greater than ($\beta_1 + \beta_3$) implies that the R&D expenses for high-tech companies are stickier than those for non-tech companies.

The results in Table 4 show that the coefficient of *logsales* (β_1) is 0.1740 and statistically significant at 1%; *D*logsales* (β_2) is 0.5474 and significant at 5%. This means that non-tech companies more aggressively reduce their R&D when sales decline compared with the increasing rate in R&D when sales increase, and this is consistent with the result for H1. The coefficient of *HT*D*logsales* (β_3) is -0.2066 and significant at 5%. ($\beta_1 + \beta_3$) is -0.0326, less than β_1 of 0.1740; therefore, H2 is supported: There is greater expense stickiness for technology companies than for non-technology companies. This finding is evidence that tech company managers are well aware of the importance of R&D activities and they do not reduce their firms' R&D investments even if sales drop because R&D expenditures are necessary for technology innovation.

LEV is negative and statistically significant at 10%, meaning there is a negative relationship between increasing rate of R&D expense and the company's leverage. *MTB* indicates a firm's growth, and it shows a positive relationship with *logRND* at 5%. *ROA*, a firm's profitability and has a positive but not statistically significant relationship with *logRND*. There is a negative relationship between *PPE* and *logRND* at 5%, indicating that companies with a high proportion of property, plant, and equipment tend to invest in R&D. Finally, *SIZE* is positively related with *logRND* but there is no statistical significance.

〈Table 4〉 Regression results

This table presents the results of the regression equations (1) and (2). All variables are defined in the Appendix.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
The sample period is from 2010-2019.

Models:

Eq.(1) $$\log\left[\frac{RND_{i,t}}{RND_{i,t-1}}\right] = \alpha_0 + \alpha_1 \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] + \alpha_2 * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] + \varepsilon_{i,t}$$

Eq.(2) $$\begin{aligned}\log\left[\frac{RND_{i,t}}{RND_{i,t-1}}\right] &= \beta_0 + \beta_1 \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] + \beta_2 * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] \\ &+ \beta_3 * HT_{i,t} * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t=1}}\right] + \beta_4 LEV + \beta_5 MTB \\ &+ \beta_6 ROA + \beta_7 PPE + \beta_8 SIZE + \sum AS + \sum Year + \sum Country + \varepsilon_{i,t}\end{aligned}$$

Variables	exp sign	Eq.(1)			Eq.(2)		
		Coeff	t	p	Coeff	t	p
Intercept		0.0378	0.0974	0.543	0.0550	0.1372	0.3222
LogSales		0.1851	0.2177	0.000***	0.1740	0.2876	0.000***
*D*LogSales*	+/-	0.3775	0.2998	0.003***	0.5474	0.2358	0.016**
*HT*D*LogSales*	-				-0.2066	-0.2032	0.048**
LEV	-				-0.0279	-0.0932	0.061*
MTB	+				0.2118	0.0131	0.018**
ROA	+				0.1669	0.0040	0.972
PPE	-				-0.3703	-0.1232	0.029**
SIZE	+				0.0221	0.0049	0.571
AS			Included			Included	
Year			Included			Included	
Country			Included			Included	
Adjusted R^2			0.2235			0.3892	
Obs.			109,757			109,757	

〈Table 5〉 Additional analysis

This table presents the results of additional analysis based on the different country regions to see if there is any difference of R&D expense stickiness among different capital markets. Panel A shows the results for Europe and the United States. Europe includes the following 18 countries: Austria, Belgium, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, and Sweden. Panel B reports the results of two Asian countries, China and Japan. All variables are defined in the Appendix.
***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is from 2010-2019.

Models:

Eq.(2) $$\log\left[\frac{RND_{i,t}}{RND_{i,t=1}}\right] = \beta_0 + \beta_1 \log\left[\frac{sales_{i,t}}{sales_{i,t=1}}\right] + \beta_2 * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t=1}}\right] + \beta_3 * HT_{i,t} * DDummy_{i,t} * \log\left[\frac{sales_{i,t}}{sales_{i,t-1}}\right] + \beta_4 LEV + \beta_5 MTB + \beta_6 ROA + \beta_7 PPE + \beta_8 SIZE + \sum AS + \sum Year + \sum Country + \varepsilon_{i,t}$$

Panel A. Europe and United States

Variables	Exp. sign	Europe			US		
		Coeff.	t	p	Coeff.	t	p
Intercept		0.0353	2.14	0.032**	0.1208	2.73	0.001***
LogSales	+	0.5242	3.79	0.001***	0.0452	5.29	0.000***
*D*LogSales*	+/-	0.1799	2.81	0.043**	0.6734	4.94	0.000***
*HT*D*LogSales*	-	-0.0401	-0.59	0.553	-0.2316	-3.20	0.000***
LEV	-	-0.0378	-2.28	0.050**	-0.0019	-1.67	0.067*
MTB	+	0.0405	0.58	0.528	0.1218	5.96	0.000***
ROA	+	0.0133	0.73	0.467	0.0169	1.54	0.084*
PPE	-	-0.0180	-1.17	0.249	-0.1386	-2.21	0.029**
SIZE	+	0.0265	4.54	0.000***	0.0180	2.06	0.044**
AS		Included			Included		
Year		Included			Included		
Country		Included			Included		
Adjusted R^2		0.2021			0.4329		
Obs.		16,103			23,426		

〈Table 5〉 Additional analysis (continue)

Panel B. China and Japan

Variables	Exp. sign	China			Japan		
		Coeff.	t	p	Coeff.	t	p
Intercept		0.0358	5.66	0.000***	0.0376	3.82	0.001***
LogSales	+	0.1475	7.79	0.000***	0.2864	5.85	0.000***
*D*LogSales*	+/-	0.1841	5.59	0.000***	0.1381	2.14	0.032**
*HT*D*LogSales*	-	-0.2351	-6.89	0.000***	-0.3195	-4.75	0.000***
LEV	-	-0.0216	-4.11	0.000***	-0.0105	-1.31	0.191
MTB	+	0.0091	0.35	0.728	0.0047	1.55	0.120
ROA	+	0.0233	3.86	0.000***	0.0151	1.11	0.268
PPE	-	-0.0440	-3.27	0.001***	-0.0026	-0.27	0.787
SIZE	+	0.0033	1.55	0.120	0.0099	4.93	0.000***
AS		Included			Included		
Year		Included			Included		
Country		Included			Included		
Adjusted R^2		0.2765			0.2529		
Obs.		13,938			17,281		

4.4. Additional tests

I also run additional tests to examine whether the R&D expense stickiness varies by the types of international capital markets. First, I divide total samples by four different regions, Europe,[8] the United States, China, and Japan. These are the four regions with the most frequent firm-year observations in the sample: 14.67%, 21.34%, 12.70%, and 15.74%, respectively. I then run regression equation (2) by regions, and the results are reported in Table 5.

The results of the additional tests show a similar pattern to the findings for the main regression equation. US and Japanese *HT*D*logsales* (β_3) increases with statistical significance from 5% to 1%, and *D*logsales* (β_2) for the United States increases as well. However, in Europe, *HT*D*logsales* (β_3) shows a negative relationship with *logRND*, but I find no statistical significance. The R&D cost stickiness in the China market is also statistically and significantly positive at 1% for

8) The region of Europe is including the following 18 countries: Austria, Belgium, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, and Sweden.

logsales, *D*logsales*, and *HT*D*logsales*. Finally, the test of equation (2) with 51.925 observations of Asian countries, including China, Japan, Korea, Singapore, and Taiwan, results in significantly positive, positive, and negative relationships with *logRND* for β_1, β_2, and β_3, respectively (not tabulated).

Ⅴ. Conclusion

This study is an investigation of whether R&D expense stickiness exists using 109,757 firm-year observations over 41 countries from 2010 to 2019 provided by Compustat. It tests for sticky cost behavior by comparing the variation in R&D expenses with sales revenue in periods when revenue increases with the variation *of R&D* expenses with sales revenue in periods when revenue decreases. In brief, I cannot find sticky R&D cost behavior for all sample companies: Companies increase their R&D expenditures when sales increase, and they decrease their R&D expense even more when sales decrease. However, when I add the interaction term for dummy variables indicating high-tech firms and sales decreases, the model does find statistically significant R&D cost stickiness for technology companies. This result implies that the managers in high-tech companies do recognize their R&D as critical to firm survival and do not reduce R&D expenditures even when their sales revenue are lower than those for the case of non-tech companies. Because the level of resources a company spends is the result of management's discretion, managers who are aware that R&D is essential to the firm decrease R&D costs less when sales fall than the costs increase when sales rise by an equivalent amount.

The findings of this study can contribute in many ways. First, it can academically contribute to expanding the empirical research on R&D expenditures and cost behavior of R&D. The result is meaningful because it empirically documents that asymmetric cost behavior of R&D varies by industry and that managers in high technology companies recognize the importance of R&D for leading innovation. Despite the importance of R&D investment, empirical research on this issue is relatively insufficient. Under this circumstance, this study is meaningful in expanding the scope of R&D research to asymmetric cost behavior by empirically investigating the R&D cost stickiness. This study is expected to contribute to further research on R&D costs and cost behavior.

Second, the current study has an implication for policy perspectives. The finding of the R&D cost stickiness suggests that managers should not reduce R&D expenditures because they expect sales to decrease, and this can be used as a basis for R&D budgeting. In the global competitive environment, the importance of R&D activities is increasing, because R&D leads innovation that determines the survival of a company. The sticky behavior of R&D expense can be used on a practical basis to emphasize the need for continuous investment in R&D activities.

Third, the results of this study can be used as an evidence for supporting the necessity of new or various systems that can more properly measure, value, and report R&D expenditures. In particular, it can provide an opportunity to reconsider the way to account for R&D expenditures that are currently required to be treated as expenses, and can contribute to the potential acceptance of an accounting method that allows a broader recognition of R&D as value-creating assets.

Despite the above contributions, this study has some limitations. First, there may be a sample selection bias. Many companies were eliminated during the sample selection procedure because of the criterion that all data should be available for inclusion in the sample. Therefore, sample selection bias may exist. Second, R&D cost behavior is affected by various internal and external factors; therefore, there may be an omitted-variables problem.

With this study, I analyze R&D cost stickiness using R&D expense data reported on income statements. So far, many companies do not report their R&D-related expenditures either in the financial position statements or in the notes and disclosure of financial statements. Under the IFRS, expenditures incurred during the research phase are recognized as expenses and expensed in the year they occur because of the uncertainty of future economic benefits.

However, if the expenditure incurred at the development stage meets the requirements for capitalization, it is recognized as an asset and treated as an account of development costs, and if the requirements for capitalization are not met, it is treated as an account for ordinary development expense. Therefore, not only the R&D expenses in the income statement but also development costs classified as intangible assets can be considered R&D investments. Although there will be limitations such as having to manually collect the data from each individual company's financial statements, examining the R&D cost stickiness in a comprehensive manner, including development cost information provided in the notes section in financial statements will be a valuable topic for future research.

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〈Appendix〉 Variable definitions

Variable	Source	Definition
Dependent variables		
logRND	Anderson et al. (2003)	Natural logarithm of current year R&D expense divided by prior year R&D expense
Variables of interest		
logSales	Anderson et al. (2003)	Natural logarithm of current year sales revenue divided by prior year sales revenue
*D*logSales*	Anderson et al. (2003)	Interaction variable of sales decrease dummy and *logRND* as defined above
*HT*D*logSales*	Anderson et al. (2003)	Interaction term of IT company indicator variable, sales decrease dummy, and *logSales* as defined above
Control variables		
LEV	Compustat	Total liability divided by total asset
MTB	Compustat	Market value divided by net assets
ROA	Compustat	Income before extraordinary items divided by total assets
PPE	Compustat	Property, plant, and equipment – net deflated by total assets
SIZE	Compustat	Natural logarithm of total assets
Other variables		
RND	Lev and Sougiannis (1996)	R&D intensity: R&D expense divided by total sales revenues
DDummy	Anderson et al. (2003)	Sales decrease dummy variable, which equals 1 if current year total sales revenue decreased compared to previous year total sales revenue, and 0 otherwise
HT	Global Classification Standard (GICS)	IT company indicator variable, set to 1 if GICS sectors are 35 (health care), 45 (information technology), or 50 (telecommunication service), and 0 otherwise