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The Effect of Export on R&D Cost Behavior: Evidence from Korea*

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Abstract

Purpose – This research intends to find out whether R&D cost stickiness shows differentiated aspects depending on exports in Korea. A cost behavior that indicates a lower rate of costs decrease when sales decrease than the rate of costs increase when sales increase is called cost stickiness. This sticky cost behavior is caused by considering the adjusting costs. This study aims to empirically verify that R&D cost stickiness is greater in export firms than in non-export firms. We also investigate the effect of exports on R&D cost stickiness is nonlinear.

Design/methodology – We obtain data for the analysis from Kis-Value and TS2000 from 2012 to 2020. This study tests for R&D cost stickiness of exports using the cost stickiness model developed by Anderson et al. (2003) that is used in a lot of prior literature. To explore the nonlinear behavior of R&D cost stickiness we include a quadratic term of exports in our model.

Findings – The results of our analysis are as follows. First, we observed that R&D costs of export firms are more sticky than that of non-export firms. Our result indicated that export firms are less likely to reduce R&D costs in decreasing sales periods in preparation for future sales recovery. Second, our empirical evidence shows that export firms view R&D costs much favorably. However, we hypothesize that the effect of export intensity on R&D costs may not necessarily be linear. Our result shows the effect of exports intensity on R&D stickiness is thus nonlinear, forming a reverse U-shaped curve. When export intensity exceeds a certain threshold, the growth rate of R&D costs appears to be viewed negatively. Firms with relatively high export intensity do not support R&D costs, viewing them as taking away firms' resources from other more productive costs. On the contrary, those with export intensity under the threshold view R&D costs as beneficial and therefore promote further R&D costs when revenue decreases.

Originality/value – The results of this research can contribute academically to the expansion of empirical research on R&D cost stickiness. R&D cost stickiness varies by industry. As a result of our research, the managers of export firms recognize the importance of R&D to lead innovation. We expected that this research contributes to further studies on R&D costs and cost stickiness. Second, this research has implications from a business perspectives. Our findings of export firms' R&D stickiness suggest that export firms' managers should consider keeping the stickiness of R&D when revenue decreases because it is essential for exporting firms to maintain their R&D stickiness to secure long-term competitiveness. R&D stickiness can be used on a practical basis to emphasize the need for continuous investment in exporting firms' R&D activities.

Keywords: Cost stickiness, Export, R&D
JEL Classifications: F14, M10, M41

1. Introduction

In 2021, Korea achieved the highest export performance of 644.5 billion dollars (MoTIE,

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2022). It was found to be the fastest recovery to pre-COVID19 levels among advanced countries. MoTIE [1] announced that it will expand research and development (R&D) expenditures of 10 promising export items to achieve complete normalization beyond the pandemic, and will support a total of 1.2 trillion won. To find new growth engines and to gain a differential competitive advantage over its competitors in today's dynamic global competitive environment, it is very important to promote the technological innovation of exports companies through significant R&D investments.

R&D expenditures are an important factor for companies from survival to sustainability. Many studies showed that R&D is essential to improving firms' profitability and firm value (Aboody and Lev, 1998; Bulitz and Ettredge, 1989; Hirschey and Weygandt, 1985). R&D investments provide useful information in the capital market (Bublitz and Ettredge, 1989; Hirschey and Weygandt, 1985; Sougiannis, 1994; Ciftci and Cready, 2011).

Despite the importance of R&D, many accounting researchers still consider R&D as a discretionary expense. Govindarajan et al.(2019) argue that R&D is an expense that can be reduced or increased at management discretion. Sun et al. (2019) verified asymmetric cost behavior in Chinese-listed traditional manufacturing firms and these firms reduce their R&D expenses first because the company's investment capacity in the following year decreases.

Recently, researchers have emphasized the importance of R&D expenses for the IT industry. R&D is critical for the IT industry. There is statistically significant R&D stickiness for technology companies (Yoon, 2021). It implies that the managers of technology companies do not reduce R&D expenditures proportionally even with declining sales revenue (Kim, 2019; Moon et al., 2020; Yoon, 2021). Decreasing R&D investment makes it difficult for IT companies to achieve corporate innovation. For this reason, even if it is difficult to achieve the purpose of R&D investment in a short term, R&D investment will continue.

In this study, we extend this line of literature by documenting the cost behavior of export firms. We attempted to empirically find out whether R&D cost stickiness shows differentiated aspects depending on exports. We focus on export firms because R&D is one of the most essential investment decisions of exporters to create a competitive advantage. For export firms, R&D cost is a more critical resource for their survival and growth than for any other non-exports firm (Lin and Tang, 2013; Yim, 2019). Therefore, it is important to examine whether there is an asymmetric R&D cost behavior in export firms. Asymmetric R&D cost behavior refers to when the magnitude of the increase in R&D costs associated with an increase in sales revenue is different from the magnitude of the decrease in R&D costs associated with an equivalent decrease in sales revenue (Anderson et al., 2003). Empirical studies of an asymmetric R&D cost behavior can be evidence that managers recognize R&D is crucial for innovation and therefore managers cannot reduce R&D expenses even in decreasing revenues. R&D stickiness may be more pronounced in export firms because R&D investments are essential for innovation and the survival of export firms.

We obtain data for the analysis from Kis-Value and TS2000 from 2012 to 2020. This study investigates the R&D cost stickiness of export companies using the novel methodology based on Anderson et al. (2003) cost stickiness model that is used in a lot of prior literature. The asymmetric cost behavior of R&D expenses can be verified by comparing the rate of R&D expenses reduction in response to the sales revenue decrease with the rate of R&D expenses increase in response to the sales revenue increase. This process includes analyzing whether

[1] MoTIE:Ministry of Trade, Industry and Energy.

export firms' R&D cost behavior differs from that of non-export firms.

The results of our study are expected to contribute to a better understanding of the characteristics of R&D expenditures of export companies. It can contribute academically to the expansion of empirical research on R&D cost stickiness. It is also meant to expand the scope of R&D research by confirming that the managers of export firms managers recognize the importance of R&D to lead innovation. This study will contribute to further studies on R&D costs and cost stickiness. Second, this study implies business perspectives. Under the COVID-19 crisis, R&D stickiness can be used on a practical basis to emphasize the need for continuous investment in exporting firms' R&D activities.

This study consists of the following chapters. Section 1, Introduction provides the background and objectives of our study. In Section 2, a literature review and hypothesis development are established. In Section 3, the research model is presented, along with variable definition and the sample selection process. In Section 4, the empirical results of descriptive statistics, correlations, and hypothesis verification multivariate regression analysis are presented. In Section 5, we summarize the results.

2. Literature Review and Hypothesis Development

2.1. Literature Review

2.1.1. Cost Stickiness

Anderson et al. (2003) find that sales revenue decreases by 1%, selling, general, and administrative costs (SG&A costs) decrease by 0.35%, while SG&A costs increase by 0.55% on average when sales revenue increase by 1%. This type of asymmetric cost behavior is called "cost stickiness". The opposite is "cost elasticity". Since Anderson et al. (2003), many authors have applied their models and found similar results across different studies.

The causes of asymmetric cost behavior are the fixed cost, the manager's moral hazard, and the gap between the adjustment cost and the manager's decision-making (Anderson et al., 2003; Anderson et al. 2007; Chen et al. 2012; Banker and Byzalov 2014; Prabowo et al., 2018; Oh and Choi, 2021). Subramaniam and Weidenmier (2003) found that manufacturing firms are more cost-sticky because of their high fixed costs. In a firm with many fixed costs, cost asymmetry can occur because surplus resources arise when revenues decrease (Anderson et al. 2007). Cost stickiness behavior can also leaded due to the manager's moral hazard when there is a tendency to build a managerial empire (Chen et al. 2012). Chen et al. (2012) argue that managers with empire-building incentives catch new resources too rapidly when volume increases but reduce the slack resources too slowly when volume declines. This asymmetric cost behavior happens mainly because of the gap between the adjustment cost and the manager's decision-making during the period of declining sales. When sales revenues decrease, managers must decide whether to maintain committed resources or reduce committed resources. Managers might delay reductions of committed resources until the decrease in demand is more certain (Anderson et al., 2003; Prabowo et al., 2018; Yoon, 2021).

Studies on cost stickiness can be divided into three groups. First, studies are that provide evidence of the existence of stickiness. Noreen and Soderstrom (1994) were among the first to examine stickiness, and the results of this research present evidence that overhead costs do not act proportionally to activity level. Extensive empirical studies about cost stickiness have

been trigged by the asymmetric cost behavior in Anderson et al. (2003). Many studies using the methodology of Anderson et al. (2003) have been made. A representative study in Korea that uses the methodology of Anderson et al. (2003) was by An et al. (2004). An et al. (2004) analyzed cost stickiness in Korea using the methodology of Anderson et al. (2003).

Second, studies are on the determinants that affect cost stickiness. Balakrishnan et al. (2004) found that current capacity utilization plays an important role in determining the extent of cost stickiness. A lot of studies examine the impact of corporate governance and internal control on cost stickiness (Calleja et al., 2006; Chen et al., 2012; Bugeja et al., 2015; Zhang et al., 2019; Li et al., 2020). Jang and Baek (2009) found that the cash flow of a company affects cost stickiness. Banker et al. (2013) analyzed companies from 19 OECD countries and found that the higher the national employment protection level, the higher the company's adjustment cost for labor resources.

Third, studies are on the economic consequences of cost stickiness. Weiss (2010) reported that the more the firm's cost stickiness, the lower the accuracy of the financial analyst's earnings forecasting because of the volatility of future earnings. Ciftci et al. (2016) and Han et al. (2019) examine stickiness focus on its incorporation into earnings forecasting models. Hong et al. (2020), and Tang et al. (2020) claimed that the more sticky the cost, the smaller the risk of a stock price crash.

2.1.2. R&D Costs

Many prior researches showed that R&D costs are essential to develop new technology and improve firm value (Sougiannis, 1994; Lev and Sougiannis, 1996; Aboody and Lev, 1998; Bulitz and Ettredge, 1989; Hirschey and Weygandt, 1985; Chamber et al. 1999; Cho and Park, 2013). Sougiannis (1994) and Lev and Sougiannis (1996) find that R&D costs are positively related to the firm's market value. They emphasize the importance of R&D. As the importance of R&D is emphasized, there have been various studies on R&D. Bublitz and Ettredge (1989) and Hirschey and Weygandt (1995) consider R&D to be the result of significant value creation efforts. Aboody and Lev (1998) and Chamber et al. (1999) verify the relationships between R&D expenditures and the stock market. Many studies verify that high R&D costs increase the firm value (Bublitz and Ettredge, 1989; Hirschey and Weygandt, 1985; Sougiannis, 1994; Ciftci and Cready, 2011).

Recent research has found that the R&D costs response to an equivalent sales change is asymmetric. There are many studies related to R&D stickiness. Scherer (1984) investigated the differential level of R&D costs by industry. Subramaniam and Watson (2016) found that R&D stickiness varies across industries. They argue that varying adjustment costs might cause R&D costs stickiness to vary as well by industry because of production environment and regulations differ by industry.

Recently, researchers have emphasized the importance of R&D expenses for the IT industry. Kwon et al. (2018) found that chaebol firms' R&D costs exhibit more sticky compared to non-chaebol firms. Yoon (2021) shows that there is statistically significant R&D stickiness for technology companies. This finding implies that the managers of technology companies do not reduce R&D even with declining revenue, and recognize R&D as an essential element (Kim, 2019; Moon et al., 2020; Yoon, 2021). Despite the prior extensive literature on R&D cost stickiness across different industries, the R&D stickiness of export firms has not been thoroughly examined.

2.2. Hypothesis Development

The traditional cost model assumes a linear relationship between cost change and sales change. If a volume changes by a certain ratio, costs will change by an equal ratio. Nevertheless, several researchers argue that the relationship between cost and volume is not perpetually linear (Cooper and Kaplan, 1998; Kama and Weiss, 2013; Banker and Byzalov, 2014). Some costs decrease less in response to sales increase than the increase in response to the same amount of sales increase. which leads to cost stickiness (Cooper and Kaplan 1998).

Anderson et al. (2003) focused on the managers' responses to change in product demand as the main cause of cost stickiness. They explained that when the demand for the product does not reach the supply due to a decrease in the demand for the product, the manager decides to reduce the surplus resource, and the CEO responds to the decrease of surplus. Resources are considered passively in consideration of adjusted cost when demand for a product increases. Because of this, cost stickiness occurs.

Because the production environment supplying goods and services, the market situation, and regulations differ by industry these factors, varying adjustment costs might cause the stickiness of R&D costs to vary as well by industry (Subramaniam and Watson, 2016; Mun and Hong, 2010). In the global competitive environment, R&D cost has become an essential element of innovation.

Exporters perform business under complicated external environments, including regional risks and cultural differences (Ji et al., 2021). Exporters are very sensitive to external business fluctuations. The way to survive in the competition is ultimately to acquire a competitive advantage. To do this, it is necessary to develop and possess valuable competencies that competitors cannot imitate. A representative activity that makes this possible is R&D. In a recession, a high level of time and cost can be required to make up for idle resources lost due to declining sales. Examples of R&D expenses for exporters include the salaries of R&D researchers and large equipment for developing innovative products. The managers of export firms cannot lay off their R&D researchers in the short term. They must continue to invest in R&D. Due to these factors, export firms can reduce R&D expenses when sales decrease, but the rate of reduction in R&D expenses might be less than the rate of the increase in R&D expenses for an increase in sales revenue.

The empirical results of Maican et al. (2020) show that R&D investments operate through both exporters and non-exporters and increase future firm value. Maican et al. (2020) argue that R&D investments have a greater impact on sales and profits in exporters than in non-exporters. In other words, R&D investments play an important role as a source of productivity in exporters relative to non-exporting firms.

As mentioned above, R&D expenses for exporting companies are essential to their operations, and reducing R&D can weaken their fundamental competitiveness. On the other hand, non-exporting companies do not consider R&D expenses as essential, allowing managers to adjust R&D expenses at their discretion. Therefore, we can expect that there is a difference between the degree of R&D stickiness for exports firms and that for non-export firms. The R&D expenses of export firms should have greater R&D stickiness than those of non-exports companies. Thus, the following research hypotheses can be established:

Hypothesis 1: The stickiness of R&D expense of the export firms is larger than that of non-export firms.

Hypothesis 2: As the proportion of export ratio, the stickiness of R&D expense will increase.

3. Research Design

3.1. Research Model

The purpose of this research is to examine whether R&D stickiness exists and whether it is more pronounced for export firms than non-exports firms. To achieve this research's objectives, we conduct the OLS.

Following prior studies (e.g., Anderson et al., 2003), we use the OLS on Equation (1) and Equation (1) to examine hypothesis 1 and 2. We set the model by using the variables of R&D cost, Sales, and Export ratio.

$$\begin{aligned}\text{logR\&D}_{i,t} = \beta_0 + \beta_1 logSALES_{i,t} + \beta_2 DEC_{i,t} * logSALES_{i,t} \\ + \beta_3 DUM_{i,t} * DEC_{i,t} * logSALES_{i,t} + \beta_4 DEC_{i,t} + \text{Yr Dum} \\ + \text{IND Dum}\end{aligned} \quad (1)$$

$$\begin{aligned}\text{logR\&D}_{i,t} = \beta_0 + \beta_1 logSALES_{i,t} + \beta_2 DEC_{i,t} * logSALES_{i,t} \\ + \beta_3 EXP_{i,t} * DEC_{i,t} * logSALES_{i,t} \\ + \beta_4 AINT_{i,t} * DEC_{i,t} * logSALES_{i,t} \\ + \beta_5 CDEC_{i,t} * DEC_{i,t} * logSALES_{i,t} + \beta_6 DEC_{i,t} + \beta_7 AINT_{i,t} \\ + \beta_8 CDEC_{i,t} + \text{Yr Dum} + \text{IND Dum}\end{aligned} \quad (2)$$

Where

$\text{R\&D}_{i,t}$	Research and development (R&D) costs for firm i in year t
$\text{logR\&D}_{i,t}$	Log-change in R&D expenditures for firm i in year t
$\text{SALES}_{i,t}$	Sales revenue for firm in year t
$\text{logSALES}_{i,t}$	Log-change in sales revenue
$\text{DUM}_{i,t}$	A dummy variable, which equals 1 when export ratio >0, 0 otherwise
$\text{DEC}_{i,t}$	A dummy variable, which equals 1 when sales in year t are smaller than sales in year t-1, and 0 otherwise
$\text{EXP}_{i,t}$	Export ratio for firm i in year t (from KIS-VALUE data base)
$\text{AINT}_{i,t}$	Logarithm of the ratio of total assets to sales revenue
$\text{CDEC}_{i,t}$	A dummy variable, which equals 1 when sales have decreased in two consecutive years (i.e. SALESi,t-2> SALESi,t-1> SALESi,t)
Yr Dum	Year dummies
IND Dum	Industry dummies(using KSIC two-digit industry classifications)

In Model (1), the slope coefficient β_1 measures the increase in R&D costs for a sales increase, while $\beta_1 + \beta_2$ measures the decrease in R&D costs for a sales decrease. If R&D costs are sticky, the slope for a sales decrease should be smaller than the slope for a sales increase. Thus, conditional on $\beta_1 > 0$, $\beta_2 < 0$ is expected. β_3 represents the effect of export firms on R&D cost stickiness. If the value of β_3 is positive and statistically significant, the R&D cost stickiness of export firm decrease. If the value of β_3 is negative and statistically significant, the R&D cost stickiness of the export firms increases.

In Model (2), the slope coefficient β_1 measures the increase in R&D costs for a sales increase,

while $\beta_1 + \beta_2$ measures the decrease in R&D costs for a sales decrease. If R&D costs are sticky, the slope for a sales decrease should be smaller than the slope for a sales increase. Thus, conditional on $\beta_1 > 0$, $\beta_2 < 0$ is expected.

Following previous studies on cost behavior, we control for the economic determinants of cost asymmetry (Anderson et al., 2003). We control for adjustment costs. They are measured by asset intensity (AINT), because adjustment costs are likely to be higher for firms that rely more on assets owned for R&D activities. Anderson et al. (2003) controlled for firms that use more employees to support a given volume of sales. Anderson et al. (2003) used EINT (number of employees) as a control variable. Because Anderson et al. (2003) analyzed the cost behavior of SG&A expenses, it was necessary to control the effect of EINT. However, since this research analyzes the behavior of R&D costs, the number of employees is not used as a control variable. The number of employees is unnecessary as a variable to control R&D adjustment costs in this research. Last, we include industry and year dummies to address the variations in cost behavior across industry and year.

To examine our hypothesis on the export effect of R&D cost behavior, we investigate whether the degree of R&D cost stickiness is different for export ratio in sales revenues.

3.2. Sample and Data

Table 1 describes the sample selection process. We start with all firms listed on the Korea Exchange (KRX) and identify those included in TS2000, a database developed by the Korea Listed Companies Association (KLCA). The export ratio data is extracted from KISVALUE. Firms that provide financial services (commercial banking, investment brokerage, and insurance) are excluded from the sample. The sample includes only publicly traded non-financial firms whose financial data were available in the database. The initial sample is composed of 5,855 firm-year observations and includes data for the fiscal years 2012–2020. We drop observations that have administrative issues, firms with impaired capital, observations with no export ratio data, and observations with no logR&D data. There were samples with export proportions less than 0 or greater than 1. This sample was excluded from the analysis. The final sample consists of 1,364 firm-year observations.

Table 1. Sample Selection Procedure

Sample Selection Criteria	Number of Firm-Years
Initial sample(All firm-year observation in Korea stock exchange during the period of year 2012 to 2020 excluding non-December firms and administrative issue firms)	5,855
Less observations with impaired capital	191
Less observations with no data on export ratio	2,954
Less observations with export ratio > 1 or export ratio<0	2
Less observations with no data on logR&D costs	1,344
Final sample	1,364

Table 2 shows the distribution of sample firms by year. The year with the most observations is the fiscal year of 2019, which accounted for 13.78% of the sample. The year with the least observations is the fiscal year 2013, which accounted for 9.38% of the sample.

Table 2. Year Distribution of the Sample

Year	Freq.	Percent
2012	135	9.90
2013	128	9.38
2014	138	10.12
2015	140	10.26
2016	143	10.48
2017	152	11.14
2018	166	12.17
2019	188	13.78
2020	174	12.76
Total	1,364	100

Table 3 shows the distribution of sample firms by industry based on the two digit classification of the Korea Standard Industry Code. The most frequent industry is chemicals manufacturing, which accounted for 14.66% of the sample.

Table 3. Industry Distribution of the Sample

Industry	Freq.	Percent
Manufacture of food products	42	3.08
Manufacture of beverages	8	0.59
Manufacture of tobacco products	9	0.66
Manufacture of textiles, except apparel	4	0.29
Manufacture of wearing apparel, clothing accessories and fur articles	13	0.95
Manufacture of leather, luggage and footwear	12	0.88
Manufacture of wood and of products of wood and cork; except furniture	8	0.59
Manufacture of pulp, paper and paper products	23	1.69
Manufacture of coke, briquettes and refined petroleum products	1	0.07
Manufacture of chemicals and chemical products; except pharmaceuticals and medicinal chemicals	200	14.66
Manufacture of pharmaceuticals, medicinal chemical and botanical products	187	13.71
Manufacture of rubber and plastics products	35	2.57
Manufacture of other non-metallic mineral products	48	3.52
Manufacture of basic metals	123	9.02
Manufacture of fabricated metal products, except machinery and furniture	33	2.42
Manufacture of electronic components, computer; visual, sounding and communication equipment	98	7.18
Manufacture of medical, precision and optical instruments, watches and clocks	4	0.29
Manufacture of electrical equipment	35	2.57
Manufacture of other machinery and equipment	85	6.23
Manufacture of motor vehicles, trailers and semitrailers	85	6.23
Manufacture of other transport equipment	24	1.76
Manufacture of furniture	12	0.88
Other manufacturing	4	0.29
Electricity, gas, steam and air conditioning supply	25	1.83
General construction	54	3.96

Table 3. (Continued)

Industry	Freq.	Percent
Specialized construction activities	13	0.95
Wholesale trade on own account or on a fee or contract basis	44	3.23
Retail trade, except motor vehicles and motorcycles	8	0.59
Water transport	1	0.07
Food and beverage service activities	6	0.44
Publishing activities	6	0.44
Motion picture, video and television program production, sound recording and music publishing activities	1	0.07
Broadcasting activities	3	0.22
Computer programming, consultancy and related activities	13	0.95
Information service activities	9	0.66
Professional services	56	4.11
Architectural, engineering and other scientific technical services	20	1.47
Business support services	2	0.15
Rental and leasing activities; except real estate	2	0.15
Education	1	0.07
Sports activities and amusement activities	7	0.51
Total	1,364	100

4. Analysis and Empirical results

4.1. Descriptive Statistics

Table 4 displays the descriptive statistics for the main variables. The mean values of logR&D and logSALES are 0.009 and 0.001, respectively. The mean value of the DEC variable is 0.47. This means that 47% of the firm-year in the sample had a decrease in sales compared to the previous year. The mean value of the CDEC variable is 0.271. This means that 27.1% of the firm-year in the sample had a consecutive two years decrease in sales. The mean value of AINT is 0.262. This represents that the size of assets is 26.2% of sales. The mean values of EXP is 0.287. This represents that exports accounted for an average of 28.7% of sales revenue. All variables are winsorized at lower and upper 1% level.

Table 4. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
logRND	1,364	.009	.615	-2.802	2.304
logSALES	1,364	.001	.173	-.563	.61
DEC×logSALES	1,364	-.059	.105	-.563	0
DUM×DEC×logSALES	1,364	-.055	.117	-1.364	0
EXP×DEC×logSALES	1,364	-.02	.052	-.34	0
AINT×DEC×logSALES	1,364	-.025	.08	-.491	.068
CDEC×DEC×logSALES	1,364	-.035	.082	-.438	0
DEC	1,364	.47	.499	0	1
AINT	1,364	.256	.507	-.834	2.03
CDEC	1,364	.271	.444	0	1
EXP	1,364	.287	.291	0	.99

4.2. Correlations

Table 5 presents the correlations between the variables of interest. As shown in Table 5, the indicators of logR&D are positively correlated with logSALES. The value of logR&D is negatively correlated with DEC, AINT, and CDEC. Also, the value of logSALES is negatively correlated with DEC, AINT, CDEC, and EXP. An unusual fact in the analysis of the correlations between variables is that EXP and logSALES have a negative correlation. This represents that as the export ratio increases, the sales growth rate will decrease.

Table 5. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1)logRND	1.000				
(2)logSALES	0.155***	1.000			
(3)DEC×logSALES	0.130***	0.805***	1.000		
(4)DUM×DEC×logSALE	0.057**	0.687***	0.860***	1.000	
(5)EXP×DEC×logSALE	0.044*	0.562***	0.702***	0.759***	1.000
(6)AINT×DEC×logSALE	0.095***	0.518***	0.673***	0.537***	0.372***
(7)CDEC×DEC×logSALE	0.092***	0.588***	0.721***	0.637***	0.555***
(8)DEC	-0.087***	-0.692***	-0.597***	-0.499***	-0.411***
(9)AINT	-0.059**	-0.189***	-0.194***	-0.112***	-0.054**
(10)CDEC	-0.067**	-0.471***	-0.424***	-0.370***	-0.323***
(11)EXP	0.002	-0.067**	-0.113***	-0.170***	-0.446***

Variables	(6)	(7)	(8)	(9)	(10)	(11)
(6)AINT×DEC×logSALE	1.000					
(7)CDEC×DEClogSALE	0.475***	1.000				
(8)DEC	-0.333***	-0.455***	1.000			
(9)AINT	-0.528***	-0.143***	0.121***	1.000		
(10)CDEC	-0.242***	-0.704***	0.647***	0.099***	1.000	
(11)EXP	0.008	-0.114***	0.125***	-0.109***	0.128***	1.000

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

4.3. Regression Results

Table 6 shows the effect of export on R&D cost stickiness. To examine whether R&D stickiness exists and whether it is more pronounced for export firms than non-exports firms. To test this hypothesis, we include Dum × DEC × logSALES as the interaction term in the research model. DUM is a dummy variable for export ratio. If the export ratio is 0, Dum is 0. If export ratio is larger than 0, DUM is 1.

In column (1), the coefficient of logSALES remains positive and statistically significant. And the coefficient of DEC × logSALES remains positive and statistically significant. This represents there is a cost elasticity of R&D cost. The coefficient of Dum × DEC × logSALES remains negative and statistically significant. This result shows that there is a cost stickiness of R&D cost when the export ratio is larger than 0. This represents there is R&D cost stickiness in export firms compared to non-export firms. Based on this result, hypothesis 1 is supported.

To examine the effect of export on R&D cost stickiness, we include EXP × DEC × logSALES as the interaction term in the research model. If the coefficient of the interaction term EXP × DEC × logSALES is negative (positive) and statistically significant, this implies that a high export ratio will intensify (reduce) R&D cost stickiness.

In column (2), the coefficient of logSALES remains positive and statistically significant. And the coefficient of DEC × logSALES remains positive and statistically significant. This represents that contrary to the cost stickiness of SG&A costs by Anderson et al. (2003), there is a cost elasticity of R&D costs. This result is consistent with prior researches (Moon et al. 2020; Hoon Jung 2020). The coefficient of EXP × DEC × logSALES remains negative and statistically significant. As explained above model (2), since $\beta_1+ \beta_2+ \beta_3$ is smaller than $\beta_1+ \beta_2$, there is a cost stickiness of R&D cost when the export ratio increases.

In column (3), we include control variables. EXP × DEC × logSALES remains negative and statistically significant. And the coefficient of DEC × logSALES remains positive but statistically insignificant. The coefficient of EXP × DEC × logSALES remains negative and statistically significant. As explained above model (1), since $\beta_1+ \beta_2+ \beta_3$ is smaller than $\beta_1+ \beta_2$, there is a cost stickiness of R&D cost when the export ratio increases.

Consequently, this empirical result demonstrates that as the proportion of exports increases, the cost stickiness of R&D costs is strengthened. Based on these results, hypothesis 2 is supported.

Table 6. The Effect of Export Ratio on R&D Cost Stickiness

VARIABLES	(1) logRND	(2) logRND	(3) logRND
Constant	-2.556 ***	0.300	-2.774 ***
	(0.000)	(0.620)	(0.000)
logSALES	0.516 ***	0.531 ***	0.514 ***
	(0.005)	(0.004)	(0.005)
DEC×logSALES	1.145 ***	0.524 *	0.619
	(0.003)	(0.099)	(0.155)
DUM×DEC×logSALES	-1.053 ***		
	(0.000)		
EXP×DEC×logSALES		-1.240 ***	-1.151 **
		(0.009)	(0.018)
AINT×DEC×logSALES			-0.017
			(0.962)
CDEC×DEC×logSALES			-0.298
			(0.487)
DEC	0.048	0.044	0.070
	(0.307)	(0.346)	(0.241)
AINT			-0.059
			(0.189)
CDEC			-0.050
			(0.489)
Yr Dum	Yes	Yes	Yes
IND Dum	Yes	Yes	Yes
Observations	1,364	1,364	1,364
R-squared	0.085	0.080	0.082

Notes: 1. p-value in parentheses.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

4.4. Additional Analysis

In the above, our research results show that firms with a high proportion of export have a positive view on R&D. According to Yim(2019), export volume increases innovation performance. Yim (2009) insists that these results support the learning by exporting hypothesis. Lin and Tang (2013) investigates how export affects firm innovation which is measured by R&D expense. Lin and Tang (2013) represents that exporters' R&D intensity is higher by 5%, R&D level by 33%, and exporters are also 4% more likely to invest in R&D.

The main test of this research investigated whether R&D stickiness exists and whether it is more pronounced for export firms than non-export firms. We expected that although the relationship between export and innovation is linear, the effect of export on R&D cost behavior may be non-linear. Because, even if the export share has a positive (+) effect on the absolute size of R&D expenditure, the effect on R&D stickiness may be non-linear. So, we tested this problem in additional analysis.

Table 7. The Non-linear Effect of Export ratio on R&D Cost Stickiness

VARIABLES	(1) logRND
Constant	-2.854 *** (0.000)
logSALES	0.509 *** (0.006)
DEC×logSALES	0.775 * (0.082)
EXP×DEC×logSALES	-3.572 ** (0.019)
EXP^2×DEC×logSALES	2.914 * (0.095)
AINT×DEC×logSALES	0.005 (0.989)
CDEC×DEC×logSALES	-0.271 (0.528)
DEC	0.066 (0.273)
AINT	-0.059 (0.190)
CDEC	-0.049 (0.496)
Yr Dum	Yes
IND Dum	Yes
Observations	1,364
R-squared	0.084

Notes: 1. p-value in parentheses.
2. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

To explore this expectation, we include a quadratic term of EXP in our model. The result shows that EXP×DEC×logSALES retains a negative coefficient which is -3.572 with statistically significant, while the coefficient of EXP^2×DEC×logSALES remains positive and statistically significant. Our additional analysis forms a reverse U-shaped curve between EXP on R&D cost stickiness. It appears that the effect of EXP on R&D cost stickiness is non-linear. Exporters with relatively low exports with export intensity under the threshold view R&D costs as beneficial and therefore promote further R&D investments under the decrease of revenue. On the contrary, when export intensity exceeds a certain threshold, the growth rate of R&D costs appears to be viewed negatively. Firms with relatively high export intensity do not support R&D costs, viewing them as taking away firms' resources from other more productive investments.

5. Conclusion and Discussion

This study examines whether R&D cost stickiness exists in export firms using 1,364 firm-year from 2012 to 2020 provided by Kis-Value and TS2000. R&D cost stickiness is tested by comparing the change in R&D cost and sales revenue during periods of increasing revenue with the change in R&D cost and sales revenue during periods of decreasing revenue. As a result, in export firms, statistically significant R&D cost stickiness appears. This means that the managers of export firms perceive their R&D as an essential factor for the survival of the firm and do not reduce their R&D expenses even when their sales decrease. But the managers of non-export firms reduce more their R&D expenses when revenue decreases. The managers of exports firms who know that R&D is essential to the export firms will decrease less on R&D when sales decrease than when sales increase.

In addition, the results of this research show that the effect of export ratio on R&D stickiness is non-linear, forming an inverse U-shaped curve. When the export ratio exceeds a certain threshold, the growth rate of R&D expenses appears to be viewed negatively. Firms with relatively high export ratio do not support their R&D costs, viewing them as taking away firms' resources from other more productive costs. Conversely, firms with an export ratio under the threshold view their R&D costs as beneficial, thus reduce less R&D costs when revenue decreases.

The results of this research can contribute in two ways. First, it can contribute academically to the expansion of empirical research on R&D cost stickiness. R&D cost stickiness varies by industry. As a result of this research, it is meaningful to expand the scope of R&D research by confirming that the managers of export firms recognize the importance of R&D to lead innovation. We expect that this research will contribute to further studies on R&D costs and cost stickiness.

Second, this research has implications from a business perspective. Our findings on export firms' R&D stickiness suggest that export firms' managers should consider keeping the stickiness of R&D when revenue decreases because it is essential for export firms to maintain their R&D stickiness to secure long-term competitiveness. Under the COVID-19 crisis, R&D stickiness can be used on a practical basis to emphasize the need for continuous investment in exporting firms' R&D activities.

The limitations of our current research are indicated as follows. First, we use R&D expense data reported on the income statements. Not only R&D expenses on the income statement

but also R&D expenditures classified as intangible assets on the financial statements can be considered R&D investments. A review of comprehensive R&D costs stickiness will be valuable research. Second, R&D cost stickiness is affected by various factors other than the factors controlled by our model.

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