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Asymmetric Cost Behavior and Investment in R&D: Evidence from China's Manufacturing Listed Companies

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Abstract: Asymmetric cost behavior or stickiness has drawn attention in recent years. Although studies have focused on the causes of and factors contributing to cost stickiness, few have investigated its economic consequences. This paper empirically examines how firms' asymmetric behavior influences their research and development (R&D) investment. Because cost stickiness increases innovation failure cost, we expect cost stickiness to reduce R&D expenditure. By using data from Chinese listed manufacturing firms between 2007 and 2015, we empirically test and confirm this hypothesis. On average, with one standard deviation added to the mean, R&D expenditure over total asset and that over total sales are reduced by 2.7% and 2.2%, respectively. Furthermore, the dampening effect of cost stickiness on R&D investment becomes more prominent with increasing risks faced by firms. Only SG&A cost stickiness exerts a dampening effect on R&D, whereas cost of goods sold (COGS) and total cost stickiness demonstrate no significant effects.

Keywords: sticky cost; R&D investment; economic consequence; risk

1. Introduction

Innovation is a source of long-term economic growth for a country [1]. During the current era of continuous economic downturn, countries worldwide are emphasizing the importance of innovation for economic growth. The importance of innovation lies in not only promoting the rate of economic growth but also improving the quality of economic growth, including reduction of energy consumption and alleviation of pollution [2–5]. Sustainability is regarded as one of the key drives for innovation. Sustainability oriented firms are more likely to generate product and process innovations [6]. Many modern managers now believe sustainability is not a burden which fails to generate immediate financial gains but an opportunity to lower input cost, gain a competitive edge, raise status, and ultimately generate more revenue through superior product and services. Therefore, it is crucial to obtain a better understanding of how innovation is affected by firm level characteristics such as cost behaviors in order to strengthen the bond between sustainable development and innovation.

However, innovation is deemed high-risk economic activity. A high rate of failure indicates that firms tend to be cautious when it comes to investing in research and development (R&D). Company-specific characteristics and external environments also pose a major influence on firms' R&D strategies. For example, Wang et al. discovered that both policy and market uncertainties drastically hinder R&D investment [7]. However, policy uncertainties only affect politically connected firms, whereas market uncertainties affect nonpolitically connected firms. Han et al. suggested that compared with male CEOs, female CEOs considerably improve the incremental and radical innovation behavior of firms [8]. Gender culture has positively facilitated the correlation between CEO gender and corporate incremental innovation behavior. Zhou et al. stated that firms' corporate social responsibility is positively correlated with their investment in technological innovation [9]. However, this effect is strongly dependent on the environment in which the firms are located.

Innovation incurs R&D expenditure. The invested R&D expenditure becomes a sunk cost if innovation fails; this can severely burden the firm. In other words, the cost characteristics of firms are likely to affect their R&D behavior. Anderson et al. suggest that compared with change in sales [10], firms' cost adjustment demonstrates asymmetric features. Costs increase more when sales increase than they fall when sales decrease by an equivalent amount; this phenomenon is called cost stickiness. Since the advent of the concept of cost stickiness, numerous studies have examined the causes of and factors contributing to cost stickiness. Other than Weiss [11], Ciftci et al. [12], Baumgarten et al. [13], and Rouxelin et al. [14], who have examined the effect of cost stickiness on analysts' forecasts, profitability, and unemployment rate, few authors have focused on the economic consequences of cost stickiness.

This paper expands the scope of the existing literature by investigating the effect of cost stickiness on R&D expenditure and by examining firms' innovation behavior from the perspective of asymmetric adjustment. On the basis of data from Chinese listed companies in the manufacturing sector between 2007 and 2015, three conclusions are drawn, as detailed in the following paragraphs.

First, firms with high cost stickiness are more cautious about R&D investment and spend less on R&D because it is much more difficult to reduce costs than to increase costs. On average, with one standard deviation added to the mean, R&D expenditure over total asset and that over total sales are reduced by 2.7% and 2.2%, respectively.

Second, the higher the risks encountered by firms, the more prominent the dampening effect of cost stickiness on R&D expenditure. Because innovation carries external risks, firms are more cautious regarding innovation and R&D [7]. Therefore, risks may aggravate the dampening effect of cost stickiness on R&D expenditure. To accommodate different types of risks, this paper examines the influence of macroeconomic, industry, and firm-level risks. The results demonstrate an enhanced dampening effect of cost stickiness, regardless of the risk category.

Third, Weiss indicated that different types of cost stickiness exist [11]. Initially, Anderson et al. only focused on SG&A costs; subsequent studies extended this to cost of goods sold (COGS) and total cost stickiness [10]. The effects of different types of cost stickiness are likely to vary. On the basis of SG&A cost stickiness, this paper further investigates the effect of COGS and total cost stickiness on R&D expenditure. The results reveal that only SG&A cost stickiness exhibits a significant dampening effect on R&D expenditure, whereas the other two cost stickiness types demonstrate no significant effects.

The contribution of this paper to the existing literature is twofold. First, it extends the research on the economic consequences of cost stickiness. Studies examining the effect of cost stickiness on profitability [13,15,16], analysts' forecasts [11,12], and unemployment [14] have only focused on cost and profit aspects, but very few have explored other key aspects of firm behavior. This paper examines the relationship between cost stickiness and innovation by integrating risks associated with innovation failure and sticky cost behavior, thus broadening the scope of research on the economic consequence of cost stickiness.

Second, this paper enriches the research on influential factors toward innovation. Innovation is essential in maintaining long-term competitiveness. Because of the risk of innovation failure, weighing the input and output of R&D is crucial. Firms potentially cut back on R&D expenditure with increasing risks [7]. At the same time, the risks associated with the irreversibility of input cost compels the firms to be more cautious about R&D investment [17]. Cost stickiness will aggravate such risks. The empirical results of this paper show that asymmetry of input cost inhibits R&D investment. Thus, our research not only extends existing literature on the effect of influential factors such as risks, the institution, and environment on firms' innovation [7,18], but also contributes to theories on the effect of firms' cost characteristics on investment [17].

The remainder of this paper is structured as follows. The literature review and hypothesis development are presented in Section 2, research design is described in Section 3, empirical results are presented in Section 4, and finally, the conclusion is stated in Section 5.

2. Related Literature and Hypothesis Development

2.1. Sticky Cost

Traditional theories posit a linear cost–sales relationship. In other words, cost changes in response to change in sales; the extent of cost change is irrelevant to whether sales increase or decrease. Norren and Soderstrom [19] and Anderson et al. [10] have discovered that the rate of cost increase when sales increase is greater than the rate of cost reduction when sales decrease by an equivalent amount; this phenomenon is referred to as cost stickiness. Moreover, cost stickiness exists widely among the operating costs, total costs, and employee remuneration of different firms across different countries [20].

Many theories explain the causes or origins of cost stickiness. Cost adjustment theory states that when sales decrease, managers make decisions by weighing up resource allocation costs and idle costs. If resource allocation costs surpass those of maintaining current status, the managers will not reallocate resources immediately, thus resulting in cost stickiness. Manager's expectation theory posits that if a manager is optimistic about future sales of products, the manager will retain idling assets to prevent resource allocation costs. By contrast, if the manager is pessimistic regarding future sales, the manager will cut back idling assets, thus resulting in anti-cost stickiness [10,21]. Opportunism theory states that under a series of opportunistic motivations, such as initial public offerings, seasoned equity offerings, earnings management, and imperialism, managers are motivated to alter resource allocation and cost structures for their own interest, thus causing cost or anti-cost stickiness through asymmetric cost and sales adjustment. In addition to the aforementioned theories, other contributing factors affect cost stickiness, such as decline in earnings and managers' behavior of evading loss. Furthermore, uncertainties in demand increases cost stickiness [22], and firms operating under sufficient capacity utilization demonstrate higher cost stickiness, whereas firms with excess capacity utilization demonstrate low cost stickiness [23].

Cost stickiness may also be affected by macro-economic factors. Ibrahim's study based on data of Egyptian firms reveals that SG&A costs show a stickiness quality during periods of prosperity and an anti-stickiness quality during periods of recession [24]. In fact, this is consistent with manager's expectation theory. During periods of prosperity, managers are likely to be optimistic about the future, thus resulting in cost stickiness. On the contrary, pessimistic expectations during recession result in a reduction in cost stickiness, even anti-cost stickiness. Uncertainties about the macro-economic environment also affect cost stickiness. For example, Lee et al. discovered that firms' asymmetric cost behaviors are stronger during election years when policy-related uncertainties are higher compared to non-election years [25].

Compared with the abundance of research on the causes of cost stickiness, few studies have examined its economic consequences. Weiss revealed that analysts' earnings forecasts are more accurate with less sticky cost behavior [11]. Additionally, analysts' coverage priorities and investors' beliefs regarding the value of firms are affected by cost stickiness. Ciftci et al. suggested that errors in earnings forecasts are the result of analysts converging to average behavior in recognizing cost stickiness and cost variability [12]. Rouxelin et al. stated that firms with higher sticky cost behavior demonstrate significantly lower unemployment rates in the current and subsequent quarter [14]. Homburg et al. discovered that the rise in firms' cost stickiness is accompanied by increasing credit risks [26]. Specifically, firms' credit default swap spreads can increase significantly. With the advent and development of methods to quantify sticky cost behavior [11], research on the economic consequences of cost stickiness can be expanded, thus improving understanding of firms' complex cost behavior.

2.2. Innovation and Risks

Innovation is essential for long-term regional economic development. However, unlike regular or conventional investment, firms encounter greater risks of failure because innovation is largely unpredictable [27]. Therefore, the magnitude of risks faced by innovating firms and their risk-taking abilities are keys to innovation.

Real options theory posits that current investment in irreversible capital may be reduced by uncertainty through the mechanism of increasing the value of information obtained by waiting [28–31]. On the basis of real options theory, Czarnitzki and Toole suggested that firms' R&D investments decline in response to elevating market uncertainties [32]. Wang et al. discovered that R&D investment is adversely affected by policy and market uncertainties [7]. However, these uncertainties only show a clear impact on their corresponding firms; in other words, policy uncertainties exert a considerable effect on politically connected firms, whereas market uncertainties affect nonpolitically connected firms.

Miller et al. suggested that firms are required to have high risk-taking abilities to support continuous product innovation [33]. Covin and Slsvin suggested that managers' higher willingness to take risks is associated with innovation [34]. Specifically, the more radical their behavior is, the more supportive they are of innovation. Brown and Osborne also indicated that innovation is closely related to active risk-taking behavior from the perspective of public service research [35]. Therefore, existing studies have confirmed the concept that firms' motivation decreases with increasing risk and that higher risk-taking ability is associated with innovation.

2.3. Hypothesis Development

The research on firms' R&D investment is mainly built on real options theory. A key problem with option pricing is uncertainty. That is, holding options tend to yield uncertain interest. However, real options differ from financial options in terms of investment cost. The cost of financial options is a one-off premium, whereas real options often require continuous investment, which escalates uncertainty. Pindyck indicated that under a ceteris paribus assumption, an increase in fluctuations of cost input exposes firms to greater risks, which subsequently reduces R&D investment [17].

Compared with symmetric cost-input fluctuations, the key characteristic of cost stickiness is asymmetry, which presents in the form of greater difficulties experienced by firms when they negatively adjust costs in contrast to when they positively adjust costs. The direct consequence of asymmetry is the increasing risks encountered by firms. Weiss discovered that firms with high cost stickiness cannot cut expenditure in time when faced with sales fluctuations because of demand changes [11]. This subsequently leads to volatile earnings, which can result in inaccuracies in analysts' forecasts. Homburg et al. stated that from the perspective of investors, cost stickiness significantly elevates the credit default swap spreads of firms, thus increasing the credit risks [26].

Therefore, fluctuations in cost input increase firms' investment risks, and cost stickiness further aggravates the asymmetry of cost adjustment, which makes it difficult for firms to reduce losses in adverse environments. Hence, firms with high cost stickiness are more cautious about R&D investment. These firms are likely to cut back R&D investment, which results in a decline in the current-period R&D expenditure. Accordingly, we state our first hypothesis:

Hypothesis 1. *An increase in cost stickiness has a negative effect on corporate R&D investment.*

Firms must consider various types of risks in decision making. Studies have shown that firms tend to postpone investment in response to increasing risks. This effect exists equally for macroeconomic, policy, market, and operating risks [29,36,37]. One major feature of risks is the multi-period overlapping effect. Specifically, although a firm that is reducing its R&D expenditure because of sticky cost behavior is exposed to various types of risks, the dampening effect on R&D may be aggravated. Hypotheses 2, 3, and 4 cover the risk-related portion of our research.

Hypothesis 2. *The negative effects of cost stickiness on corporate R&D investment are more prominent for firms facing higher macro level risks than for other firms.*

Hypothesis 3. *The negative effects of cost stickiness on corporate R&D investment are more prominent for firms facing higher industry-level risks than for other firms.*

Hypothesis 4. *The negative effects of cost stickiness on corporate R&D investment are more prominent for firms facing higher firm-level risks than for other firms.*

3. Research Design

3.1. Data and Sample Selection

Considering that China implemented new accounting standards on 1 January 2007, this paper selects data from listed manufacturing companies in the Shanghai and Shenzhen A-share market between 2007 and 2015 as samples of interest. The manufacturing sector is relatively stable and firms demonstrate genuine demand in R&D. Subindustries within the manufacturing sector exhibit comparability. Relevant studies, such as those by Wang and Liu et al., have also been based on manufacturing sector data [38,39].

On the basis of previous research, we apply the following treatment to the data: eliminating samples with total liabilities greater than total assets, eliminating samples with negative revenue or negative total assets, and eliminating samples with missing key explanatory variables. The treated samples contain 4470 annual firm-level observations. Table 1 reports the annual and industrial distributions of the samples. The firm-level financial data are adopted from the China Stock Market & Accounting Research (CSMAR) database. The macroeconomic data are from the National Bureau of Statistics. The manufacturing sector is divided into secondary industries (C0–C9) according to the guidelines for classification of listed companies issued by the China Securities Regulatory Commission in 2001. To account for interference caused by extreme values or outliers, Winsor tailing is applied to continuous variables at the 1% and 99% levels.

Table 1. Sample Distribution.

Panel A		
Year	**Observations**	**Percent (%)**
2007	77	1.6
2008	99	2.1
2009	154	3.2
2010	178	3.7
2011	180	3.8
2012	768	16.1
2013	1005	21.1
2014	1124	23.6
2015	1185	24.8
Total	4770	100.0
Panel B		
Industry	**Observations**	**Percent (%)**
Food/Beverage (C0)	261	5.5
Textile/Clothing/Leather (C1)	269	5.6
Wood/Furniture (C2)	45	0.9
Paper/Printing (C3)	168	3.5
Petroleum/Plastics (C4)	766	16.1
Electronics (C5)	480	10.1
Metal/Non-metal (C6)	576	12.1
Machinery (C7)	1602	33.6
Chemical/Pharmaceutical (C8)	476	10.0
Other manufacturing (C9)	127	2.7
Total	4770	100.0

3.2. Models

The following model is constructed to investigate the influence of cost stickiness on firms' R&D investment:

$$RD_{i,t} = \alpha + \beta_1 CostSticky_{i,t-1} + \beta_2 Lev_{i,t} + \beta_3 MB_{i,t} + \beta_4 Listage_{i,t} + \beta_5 Top1_{i,t} + \beta_6 ROA_{i,t} + \beta_7 Tang_{i,t} + \beta_8 Size_{i,t} + Year\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon_{i,t} \quad (1)$$

The dependent variable is firms' R&D investment. The new accounting standards issued in 2007 state that firms must disclose R&D investment in accounting reports; this requirement thus constitutes an essential reason for us to select samples after 2007. On the basis of the results of Wang et al. [7], we use total R&D expenditure divided by total assets (*RD1*) and total R&D expenditure divided by total sales (*RD2*) as the dependent variables.

Being a key indicator of interest in this paper, cost stickiness is the explanatory variable. Cost stickiness generally refers to a phenomenon in which costs increase more when sales increase than they decrease when sales decrease by an equivalent amount. Since Anderson et al. proposed the idea of cost stickiness, studies have mainly discussed the cause of or factors contributing to sticky costs [10]. Few studies have focused on the economic consequences of cost stickiness [11,12,26]. The reason is that in addition to the perspectives of investigation, accurately quantifying cost stickiness empirically is extremely difficult. Some studies have estimated cost stickiness by constructing time- and industry-level regression models. However, such methods sacrifice the time- and industry-level variations and thus hinder its validity in predicting economic consequences. Weiss proposed a new method of estimating cost stickiness, which involves taking the cost and sales changes in the last four quarters to calculate a firm's current cost stickiness [11]. This method has been widely adopted by subsequent studies as follows:

$$CostSticky_{i,t} = \ln\left(\frac{\Delta SG\&A}{\Delta Sales}\right)_{i,T(+)} - \ln\left(\frac{\Delta SG\&A}{\Delta Sales}\right)_{i,T(-)},\ T(-),\ T(+) \in \{t, \ldots, t-3\} \quad (2)$$

where $T(-)$ and $T(+)$ denote the most recent quarters that the firm recorded a sales decrease and increase, respectively; $\Delta SG\&A$ the difference between the SG&A expenses in year t and those in the previous year; and $\Delta Sale$ the difference between sales revenue in year t and that of the previous year. In addition, referring to Weiss [11], we set the assessment period for the past 2 years for robustness checks: $T(-),\ T(+) \in \{t, \ldots, t-7\}$.

On the basis of the results of Weiss [11], Wang [38], Liu et al. [39], and Wang et al. [7], we introduce the following control variables into our model: leverage (*Lev*) is firms' financing structure, total liability over total assets; market-to-book ratio (*MB*) is firms' growth prospects, market value over net assets; age (*Listage*) is firms' maturity, natural logarithm of firms' listing age; *TOP*1 is shareholding and ownership characteristics, holding ratio of the largest shareholder; (*ROA*) is profitability, net profit over total assets; tangible asset (*Tang*) is mortgage and financing ability, fixed assets over total assets; and size (*Size*) is firm size, natural logarithm of total assets on book. In addition, industry and year fixed effect is introduced. We construct the following models to test our hypotheses:

$$RD_{i,t} = \alpha + \beta_1 CostSticky_{i,t-1} + \beta_2 CostSticky_{i,t-1} \times MacroRisk_t + \beta_3 MacroRisk_t + \beta_4 Lev_{i,t} + \beta_5 MB_{i,t} + \beta_6 Listage_{i,t} + \beta_7 Top1_{i,t} + \beta_8 ROA_{i,t} + \beta_9 Tang_{i,t} + \beta_{10} Size_{i,t} + Year\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon_{i,t} \quad (3)$$

$$RD_{i,t} = \alpha + \beta_1 CostSticky_{i,t-1} + \beta_2 CostSticky_{i,t-1} \times IndustryRisk_t + \beta_3 IndustryRisk_t + \beta_4 Lev_{i,t} + \beta_5 MB_{i,t} + \beta_6 Listage_{i,t} + \beta_7 Top1_{i,t} + \beta_8 ROA_{i,t} + \beta_9 Tang_{i,t} + \beta_{10} Size_{i,t} + Year\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon_{i,t} \quad (4)$$

$$RD_{i,t} = \alpha + \beta_1 CostSticky_{i,t-1} + \beta_2 CostSticky_{i,t-1} \times FirmRisk_t + \beta_3 FirmRisk_t + \beta_4 Lev_{i,t} + \beta_5 MB_{i,t} + \beta_6 Listage_{i,t} + \beta_7 Top1_{i,t} + \beta_8 ROA_{i,t} + \beta_9 Tang_{i,t} + \beta_{10} Size_{i,t} + Year\ Fixed\ Effects + Industry\ Fixed\ Effects + \varepsilon_{i,t} \quad (5)$$

We define interaction terms to investigate the effect of risk on the influences exerted by cost stickiness on R&D expenditure. Real GDP growth rate is used to represent macroeconomic risk; a lower rate indicates a higher risk. The rapid growth of China has slowed since the 2008 global financial crisis. The slowing trend has become more prominent since 2012. Therefore, real GDP growth rate is adequate for reflecting macroeconomic risks encountered by firms during our sample period. Risks at the industry level are represented by leverage; a higher leverage indicates more severe debt repayment pressure, and a higher leverage ratio indicates a higher risk. The leverage of Chinese firms has increased considerably in recent years. Thus, leverage is considered a good measure of risks at the industry level. Finally, stock price is a crucial indicator of individual firm performance. Therefore, we take stock price volatility as a measure of risks encountered by a firm itself. A firm's stock prices are strongly correlated with stock market performance. Thus, we adopt the method of Callen and Fang and Kim et al. in stock price crash analysis [40,41], which involves computing a regression of annual weekly returns of stock *i* and market average weekly returns to obtain the firm-specific weekly return rate of listed companies free from influences by market factors.

$$r_{i,t} = \alpha + \beta_1 r_{m,t-2} + \beta_2 r_{m,t-1} + \beta_3 r_{m,t} + \beta_4 r_{m,t+1} + \beta_5 r_{m,t+2} + \varepsilon_{i,t} \quad (6)$$

where $r_{i,t}$ is the return on reinvestment of stock i in week t, with cash dividend being considered; $r_{m,t}$ the average return rate calculated through weighted average by circulating the market value of A-share in week t; and ε the return on stocks not explained by the market. We define $w_{i,t} = \ln(1 + \varepsilon_{i,t})$ as the firm-specific weekly return rate of listed companies and its standard deviation as the indicator of firm-level risks. A higher value inherently signifies greater risks.

3.3. Summary Statistics and Analysis

Table 2 presents summary statistics for relevant variables. The mean ratios of R&D expenditure for total assets and total sales are 1.99% and 3.62%, respectively. These results are quite close to those of Wang et al. [7]. The mean value of *CostSticky* is 0.0449, indicating that sample firms exhibit cost stickiness, which is consistent with the results of Weiss [11]. Regarding the control variables, the mean value of *Lev* is 0.4137, which is similar to that reported by Wang et al. [7] but considerably lower than that found by Anton's [42] study, which was based on firms in emerging European markets. Two reasons possibly underlie this inconsistency. First, the Chinese corporate bond market is less developed, and the proportion of firms financing through direct issuance of bonds is also lower, which thereby reduces leverage. Second, our sample does not include the real estate industry, which tends to have high leverage; this causes a decrease in leverage in the summary statistics. The mean market-to-book ratio is 2.9510, indicating good growth prospects. This is consistent with findings from European markets [42]. The average *ROA* is 0.0473, with more than 75% of firms presenting values >0, which demonstrates overall good performance. This is also in line with the findings of Wang et al. [7]. The definitions of the variables are shown in detail in Table 3.

Table 4 presents the results of the correlation analysis of the main variables. The correlation coefficient of the two R&D indicators *RD1* and *RD2* is 0.6497, which is consistent with expected outcome. The correlation coefficient between the *CostSticky* and R&D variables is negative, which is consistent with our hypotheses. Regarding the control variables, *Lev*, *Listage*, and *Size* demonstrate negative correlations with the R&D variables, whereas *MB* and *ROA* exhibit positive correlations with the R&D variables. These findings signify that smaller, profitable, and growing firms tend to invest more in R&D, which is consistent with the literature.

Table 2. Summary Statistics.

Variables	Mean	Median	Q1	Q3	STD
RD1	0.0199	0.0174	0.0092	0.0271	0.0148
RD2	0.0362	0.0323	0.0164	0.0453	0.0308
CostSticky	0.0449	−0.0057	−0.6748	0.6923	1.3501
Lev	0.4137	0.4029	0.2554	0.5661	0.1983
MB	2.9510	2.2241	1.3602	3.6288	2.5142
Listage	1.8927	1.7918	1.3863	2.6391	0.7758
Top1	35.183	33.585	23.983	44.486	14.479
ROA	0.0473	0.0382	0.0120	0.0774	0.0668
Tang	0.2534	0.2268	0.1512	0.3371	0.1404
Size	21.862	21.714	21.060	22.455	1.1250

Table 3. List of variables.

Variables	Definition
RD1	R&D expenditure/total Asset
RD2	R&D expenditure/total Sales
CostSticky	Cost stickiness, calculated from Equation (2)
GDP	Real GDP growth rate
IndLev	Industry leverage, median leverage of the industry
SPVol	Stock price volatility, standard deviation of annual abnormal return
Lev	Leverage, total liability/total asset
MB	Market-to-book ratio, market value/net asset
Listage	Age, natural logarithm of listed age
Top1	Holding ratio of the largest shareholder
ROA	Return on asset, net profit/total asset
Tang	Tangible asset ratio, fixed asset/total asset
Size	Firm size, natural logarithm of total asset in book

Table 4. Correlation Analysis.

	RD1	*RD2*	*CostSticky*	*Lev*	*MB*	*Listage*	*Top1*	*ROA*	*Tang*
RD2	**0.64**								
CostSticky	**−0.02**	**−0.03**							
Lev	**−0.15**	**−0.31**	**0.03**						
MB	**0.07**	**0.05**	0.00	0.18					
Listage	**−0.14**	**−0.23**	0.00	**0.36**	**0.26**				
Top1	−0.01	**−0.09**	0.01	**0.05**	**−0.19**	**−0.09**			
ROA	**0.20**	**0.06**	**0.03**	**−0.35**	**−0.04**	**−0.13**	**0.09**		
Tang	**−0.10**	**−0.20**	**0.02**	**0.19**	**−0.09**	**0.04**	**0.04**	**−0.20**	
Size	**−0.15**	**−0.22**	0.01	**0.34**	**−0.19**	**0.29**	**0.17**	**0.13**	**0.09**

Note: This table reports the Pearson correlation coefficients between independent variables. The definitions of the variables are shown in detail in Table 3. The boldfaced numbers denote statistical significance below 10%.

4. Empirical Results

4.1. Effect of Cost Stickiness on R&D Expenditure

Table 5 presents the results obtained from testing Hypothesis 1, which is the effect of cost stickiness on R&D expenditure. The coefficients between cost stickiness and R&D are negative and significant ($\beta = -0.0004$, $p < 0.01$ and $\beta = -0.0006$, $p < 0.05$, respectively). Regarding value, with each standard deviation increase from the mean cost stickiness, R&D expenditure over total asset and that over total sales are reduced by 2.7% and 2.2%, respectively. These results support Hypothesis 1: increasing cost stickiness significantly reduces firms' expenditure on R&D. Regarding the control variables, *Lev*, and *Listage* show a significant negative relationship with R&D expenditure, whereas *MB* is positively correlated with R&D. The results are generally consistent with expectations and the literature [7,18].

Table 5. Effect of cost stickiness on R&D expenditure.

	(1)	(2)
	RD1	***RD2***
CostSticky	−0.0004 *** (0.0001)	−0.0006 ** (0.0003)
Lev	−0.0027 * (0.0014)	−0.0356 *** (0.0030)
MB	0.0007 *** (0.0001)	0.0013 *** (0.0002)
Listage	−0.0012 *** (0.0003)	−0.0059 *** (0.0007)
Top1	0.0000 (0.0000)	−0.0001 *** (0.0000)
ROA	0.0458 *** (0.0040)	−0.0217 ** (0.0088)
Tang	0.0006 (0.0016)	−0.0096 *** (0.0031)
Size	−0.0006 ** (0.0003)	0.0006 (0.0005)
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Adj. R^2	0.165	0.249
Observations	4770	4770

Note: This table reports the impact of cost stickiness on R&D expenditure. All models are based on Equation (1). The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis. *, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

4.2. Robustness Check

Determining the level of R&D investment is considered a strategic decision of firms. Once R&D fails, investment is turned into a sunk cost. Although we focus more on the influence of cost stickiness on R&D investment based on real options theory, R&D investment may in turn affect firms' cost behavior. Therefore, an endogeneity problem, specifically reverse causality, may exist in the analysis. Arellano and Bond proposed that the lag level and lag difference of endogenous variables can be used as instrument variables (i.e., for system generalized method of moments (GMM) estimation) [43]. By using this method, we re-estimate Model 1, and the results are presented in Table 6: the coefficient for cost stickiness and R&D investment remains negative and significant. Therefore, the conclusion of this paper holds, even after the consideration of an endogeneity problem engendered by reverse causality.

Firms adopt different strategies at different stages of their life cycles; naturally, firms' choice of R&D may also be affected. Because firms demonstrate greater uncertainties in their early stages, we treat the samples further by eliminating observations with a listing duration of less than five years. Observations with 10 or fewer employees are also excluded from the samples to eliminate overly small firms. Model 1 is re-estimated using the treated sample, and Table 7 presents the results. The coefficient for cost stickiness on R&D investment is negative and significant, indicating the robustness of our analysis.

In addition to the aforementioned tests, we conducted the following analyses to check for the robustness of our empirical results. (1) Lagged variable analysis: we re-perform the analysis with lagged control variables by considering interference with the current-period control variables. (2) Fixed effect model: considering the unobservable firm-level factors, we re-perform the analysis by controlling individual fixed effects through a fixed effect model. (3) Adjusting R&D indicators: because discrepancies may exist among industries in terms of R&D expenditure, we re-perform the analysis after median-adjustment treatment on the dependent variable. (4) Altering cost stickiness indicator: On the basis of the results of Weiss [11], data from the past two years or eight quarters are used to compute cost stickiness and to reexamine the empirical analysis. Table 8 presents the results for these robustness checks. The coefficients for *CostSticky* remain negative and significant, which further affirm our research's robustness and validity.

Table 6. Effect of cost stickiness on R&D expenditure: System GMM.

	(1)	(2)
	RD1	***RD2***
CostSticky	−0.0031 * (0.0016)	−0.0093 ** (0.0044)
Lev	−0.0389 (0.0412)	−0.293 ** (0.128)
MB	−0.0012 (0.0018)	−0.0048 (0.0044)
Listage	0.0010 (0.0010)	0.0249 (0.0239)
Top1	0.0006 (0.0005)	0.0012 (0.0011)
ROA	−0.0292 (0.0707)	−0.475 *** (0.161)
Tang	0.0336 (0.0391)	−0.0177 (0.102)
Size	−0.0253 ** (0.0113)	−0.0258 (0.0263)
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
AR (1) (*p*-value)	0.037	0.005
AR (2) (*p*-value)	0.535	0.934
Hansen (*p*-value)	0.114	0.558
Observations	4770	4770

Note: This table reports the impact of cost stickiness on R&D expenditure. All models are based on Equation (1). The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis. *, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

Table 7. Effect of cost stickiness on R&D expenditure: Clean sample.

	(1)	(2)
	RD1	***RD2***
CostSticky	−0.0006 *** (0.0002)	−0.0009 *** (0.0003)
Lev	−0.0060 *** (0.0018)	−0.0306 *** (0.0036)
MB	0.0005 *** (0.0001)	0.0010 *** (0.0002)
Listage	−0.0037 *** (0.0006)	−0.0104 *** (0.0013)
Top1	0.0000 (0.0000)	−0.0001 *** (0.0000)
ROA	0.0395 *** (0.0048)	−0.0133 (0.0102)

Table 7. *Cont.*

	(1)	(2)
	RD1	***RD2***
Tang	0.0029 (0.0020)	−0.0035 (0.0035)
Size	−0.0006 * (0.0003)	0.0005 (0.0006)
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Adj. R^2	0.183	0.240
Observations	3036	3036

Note: This table reports the impact of cost stickiness on R&D expenditure. All models are based on Equation (1). The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis. *, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

Table 8. Effect of cost stickiness on R&D expenditure: Robustness check.

Panel A				
	(1)	**(2)**	**(3)**	**(4)**
	Lagged Control Variable	**Fixed Effect Model**	**Median Adjustment**	**Alternative Cost Indicator**
	RD1	***RD1***	***RD1***	***RD1***
CostSticky	−0.0004 *** (0.0001)	−0.0002 * (0.0001)	−0.0004 *** (0.0001)	−0.0004 *** (0.0001)
Control variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES
Adj. R^2	0.159	0.084	0.165	0.164
Observations	4683	4770	4770	4868
Panel B				
	(1)	**(2)**	**(3)**	**(4)**
	Lagged Control Variable	**Fixed Effect Model**	**Median Adjustment**	**Alternative Cost Indicator**
	RD2	***RD2***	***RD2***	***RD2***
CostSticky	−0.0006 ** (0.0003)	−0.0005 ** (0.0002)	−0.0006 ** (0.0003)	−0.0006 ** (0.0002)
Control variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES
Adj. R^2	0.251	0.060	0.250	0.250
Observations	4683	4770	4770	4868

Note: This table reports the robustness check of impact of cost stickiness on R&D expenditure. All models are based on Equation (1). The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis. *, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

4.3. Additional Test

Columns 1 and 2 of Table 9 present the moderating effect of macroeconomic risks. The interaction coefficient of cost stickiness and real GDP growth is significantly positive. Thus, as economic growth slows down with increasing macroeconomic risks, the dampening effect of cost stickiness on R&D becomes more prominent. This is consistent with Hypothesis 2. Columns 3 and 4 of Table 6 report the effect of industrial risks. The interaction coefficient of cost stickiness and industrial leverage is negative and significant. This shows that as leverage or industrial risk increases, the dampening effect of cost stickiness on R&D becomes more prominent. This is consistent with Hypothesis 3.

Table 9. Moderating effect of macroeconomic and industrial risks.

	(1)	(2)	(3)	(4)
	RD1	*RD2*	*RD1*	*RD2*
*CostSticky * GDP*	0.0213 ** (0.0095)	0.0390 ** (0.0177)		
*CostSticky * IndLev*			−0.0065 *** (0.0025)	−0.0117 ** (0.0046)
CostSticky	−0.0025 *** (0.0009)	−0.0044 ** (0.0018)	0.0022 ** (0.0010)	0.0041 ** (0.0020)
Control variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES
Adj. R^2	0.166	0.250	0.167	0.251
Observations	4770	4770	4770	4770

Note: This table reports the moderating effect of macroeconomic and industrial risks. All models are based on Equations (2) and (3). The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis. **, *** denote statistical significance at 5%, and 1%, respectively.

Table 10 reports the moderating effect of firm-level risks. Columns 1 and 2 of Table 10 present a negative and significant relationship between cost stickiness and stock price volatility, indicating that as stock price fluctuations increase along with higher risks, the dampening effect of cost stickiness on R&D becomes more prominent. Firm-level risks may be caused by unobservable variations of individual firms. To account for this issue, we take the first difference of stock price volatility as a proxy variable for risk. Columns 3 and 4 of Table 10 present the results. The coefficient of interaction remains negative and significant, supporting Hypothesis 4.

Table 10. Moderating effect of firm level risks.

	(1)	(2)	(3)	(4)
	RD1	*RD2*	*RD1*	*RD2*
*CostSticky * SPVol*	−0.0109 * (0.0060)	−0.0273 ** (0.0136)		
*CostSticky * DSPVol*			−0.0167 *** (0.0058)	−0.0308 ** (0.0126)
CostSticky	0.0002 (0.0003)	0.0009 (0.0007)	−0.0003 ** (0.0001)	−0.0004 (0.0003)
Control variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES
Adj. R^2	0.167	0.251	0.167	0.251
Observations	4769	4769	4763	4763

Note: This table reports the moderating effect of firm level risks. All models are based on Equation (4). The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis. *, **, *** denote statistical significance at 10%, 5%, and 1%, respectively.

4.4. Comparisons with Other Types of Cost Stickiness

Weiss [11] examined the influence of three types of cost stickiness, namely SG&A, COGS, and total cost stickiness, on analysts' earnings forecasts, and they suggested that only SG&A and total cost stickiness amplified forecast bias. This shows that different measures of cost stickiness may have different impacts on firms' behavior. Because R&D expenditure is listed under managing costs in financial statements in China, SG&A should theoretically have the most direct influence on R&D expenditure. This is also what the empirical part of this paper examines. For completeness, we also examine the effect of COGS and total cost stickiness on R&D expenditure. The method of computing relevant indicators is similar to SG&A. The results are provided in Table 11. The coefficients for COGS and total cost stickiness are nonsignificant, indicating that different types of cost stickiness indeed have different effects and R&D behavior is only responsive to SG&A.

Table 11. The effect of other types of cost stickiness.

	Panel A			
	(1)	**(2)**	**(3)**	**(4)**
	Past 4 Quarters		**Past 8 Quarters**	
	RD1	***RD2***	***RD1***	***RD2***
COGCostSticky	0.0002 (0.0003)	0.0007 (0.0006)	0.0001 (0.0003)	0.0004 (0.0006)
Control variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES
Adj. R^2	0.159	0.264	0.159	0.263
Observations	5828	5828	5876	5876
	Panel B			
	(1)	**(2)**	**(3)**	**(4)**
	Past 4 Quarters		**Past 8 Quarters**	
	RD1	***RD2***	***RD1***	***RD2***
TCostSticky	−0.0002 (0.0003)	0.0001 (0.0006)	−0.0002 (0.0003)	0.0001 (0.0006)
Control variables	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Industry Fixed Effects	YES	YES	YES	YES
Adj. R^2	0.159	0.259	0.159	0.258
Observations	5815	5815	5857	5857

Note: This table reports the effect of other types of cost stickiness. The definitions of the variables are shown in detail in Table 3. The standard errors are clustered by industry and year and reported in the parenthesis.

5. Conclusions

Innovation is crucial to a country's long-term economic development. Because of high failure rates associated with innovation, firms must tread lightly to balance certain costs and uncertain future gains. Such technique is almost artisan.

Real options theory states that risks cause firms to postpone their investment and reduce R&D expenditure. Building on studies confirming the effects of macroeconomic, policy, and firm-level risks on decision making, we examine the influences of sticky cost behavior on R&D development. Cost stickiness amplifies the risks firms encounter when they face difficulties in reducing costs in response to a decrease in demand. Therefore, firms become more cautious about investing in R&D. Our empirical results reveal that on average, with one standard deviation added to the mean, Chinese listed firms' R&D expenditure over total asset and that over total sales are reduced by 2.7% and 2.2%, respectively. The dampening effect of cost stickiness is simultaneously aggravated with increasing macroeconomic, industry, and firm-level risks, as a result of the risk overlapping effect.

On the basis of data from Chinese listed manufacturing firms, this paper expands the research on firms' innovation from the perspective of firms' cost behavior. Notably, the cost behavior of firms is affected by the institutional environment in which they are located. For example, in the 2008 version of the Labor Law of the People's Republic of China, the minimum wage clause has clearly increased the cost stickiness of firms. This paper focuses only on Chinese firms, and factors such as law, political, and institutional environment at the national level may be neglected. However, this limits the generalization of our conclusion to some extent. Thus, a future analysis encompassing samples and institutional factors at a transnational level may further enrich and expand the findings of this research.

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