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Corporate Research and Development Strategy and Stock Price Crash Risk

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ABSTRACT
This paper investigates the effect of research and development activity on stock price crash risk. Using a large sample of 3568 Chinese listed companies for the period 2007-2019, it is found that R&D expenditure in China is negatively associated with stock price crash risk, which suggests that the disclosure of innovation expenditures decreases the risk of dominant stock price fall. The robustness analyses suggest that the association between research and development ratio and crash risk is more pronounced in firms from emerging markets with high leverage, lower return on assets, non-Big 4 auditors, lower institutional shareholdings, and non-stated-owned enterprises. Our findings advance the understanding of research and development activity's attributes and the benefits of its disclosure in emerging markets.

Keywords: *Research and development, stock price crash risk, corporate governance, information disclosure, emerging market*

1. INTRODUCTION

Research and development (hereafter referred to as "R&D") is an important material for learning and developing corporate governance, which will facilitate firm growth. According to prior research, about 22 countries including 4 developing countries exhibit R&D expenditure above 0.75 percent of GDP [1]. However, R&D is a risky and unpredictable set of innovative activities undertaken by corporations and governments [2]. It involves an extremely high probability of failure because of the cost of managing associated tasks and the hysteresis effect on R&D output such as patents granted and sales improvement [3, 4]. A lot of research examines the disadvantage of high R&D expenditures including raising the likelihood of misclassifying, and the conservative accounting of R&D has to be adjusted which results in low returns of low book-to-market firms [5]. From these researches, high R&D directly demonstrates an operational risk which is better to be hidden from the firms' reports to protect corporations' shareholders from concerning their return.

Nevertheless, R&D has double-sidedness; controversially, it represents corporations' long-run value and management teams' forward-looking approach [6]. Both potential tangible value, such as granted patents and revenue generation, and intangible value of R&D, especially corporation reputation and investors' confidence, bring great advantages to companies overall [7]. Therefore, a question arises that, in the emerging markets, whether R&D activity represents a high-risk plan or a beneficial activity in the long run. This study of R&D's attribution is worthy for corporates' management teams to balance the long-term budgets and consider the necessity of innovative activities' disclosure to the market. Our paper utilizes stock price crash risk to examine the impact of firms' innovation and its real attribute in Chinese capital markets.

This study is motivated by two theoretical backgrounds on the impact of R&D on stock price crash risk. On one hand, in emerging markets, any corporation innovation involves a leap into the unknowable because of its relatively high failure rate on the output [8]. If the R&D fails such as denial of patent applications during the development period of the innovation project, shareholders will worry about the return of their investments, which may negatively influence the stock price and managers will be challenged on their performance and corporate management. Then, management teams will hide the negative information and potential risks which happen in this period because they have to consider their personal compensations, corporates' reputation, and investors' asymmetric reactions [9]. Then the stock price crash risk will increase with the later release of accumulated bad news [10].

On the other hand, previous studies point out that, even in the developed capital market, R&D expenditures are usually hidden on the financial statements for purpose. According to Ping-Sheng Koh, David M. Reeb, more than 60% of NYSE listed companies do not report any information on R&D [11]. Moreover, some studies recognize that isolating mechanisms with hiding R&D expenditures on financial statements provide corporations comparative advantage without mimic from rivals [12]. Thus, compared to companies that withhold R&D information, the disclosure of corporations' R&D activities to the public market somehow represents management teams' confidence about the firms' future development and high success rate on potential output [13]. In general, R&D exposure equivalents to a positive signal that most companies do not possess. When these positive signals elevate investors' confidence about the company and implicitly raises the stock price, corporations have more long-term motivations for management; also, such corporations in the emerging markets usually gain government R&D subsidies which have a certification effect, and then utilize this legitimation strategy to access bank finance [14]. Eventually, the internal risks of R&D activities are decreased, relieving stock price crash risk.

Compared with the developed capital markets, China provides a superior capital environment for innovation study. In order to improve its position in a global economic and technological competition, China highly motivates both domestic and multinational corporations to do investment in R&D [15]. This environment provides us sufficient information to examine the R&D ratio and its relative effects on the equity market. Besides, China, relatives to the mature markets, has weak internal and external governance and auditing systems which results in a high probability of R&D missing and expense shifting [16]. As the most important emerging market, it offers the best platform to understand the factual attribute of R&D activities. However, although previous studies have researched some specific results related to R&D activities for developed capital markets, they do not provide a general examination on their attributes in emerging markets.

We test the above void by examining a sample of all listed companies from SHSE and SZSE which report the R&D expenditures on their annual reports including zero R&D firms over the period 2007-2019. Following prior studies, we use two measures of stock price crash risk: the negative conditional skewness of firm-specific weekly returns over the fiscal year (NCSKEW) and the down-to-up volatility (DUVOL) [17]. Our baseline results suggest a negative and significant relationship between the R&D ratio and stock price crash risk which proves our hypothesis that the disclosure of R&D implies a positive attribute to the public and decreases the potential stock price crashes. Further research also finds that the impact of corporate research and development strategies on stock price crash risk is more pronounced in a weaker monitoring system. Several robustness tests are conducted, using alternative sample, fixed-effect model, and one-step system GMM, to check the sensitivity of our results.

This study contributes to the extant literature in two ways. First, based on prior research, our research is the first one directly examines the relationship between corporate R&D strategy as a whole and stock price crash risk for the developing capital markets in China. Prior research focuses on the United States listed companies that have more rigorous corporation governance and rules monitored by US Statement of Financial Accounting Standards No. 2 (SFAS2) [11]. Their empirical result emphasizes the potential risks of innovation with a high probability of bad news emerging during the development period of R&D. Yet, our study considers the emerging market which contains more loopholes for corporations to hide their R&D activities and inversely gains a positive effect on the disclosure of R&D through our baseline results. In that situation, firms' disclosure of their R&D spending may convey a positive signal to the capital market that the research is going well.

Second, this study also contributes to the exploration of R&D's attributes. Prior related study separates innovation into two types, exploratory and exploitative innovation, and compares their stock price crash risks to help corporations' management teams decide which R&D category is better for them to approach [18]. While our paper considers R&D as a whole and its attributes in developing capital markets, which can help firms' management teams make decisions on conducting R&D activities, and plan for their disclosure of R&D expenditures during operation on their annual report to the public.

The remainder of this study is organized as follows. Section 2 develops the hypothesis. Section 3 describes the sample selection, model construction, and variable measurement. Section 4 conducts empirical analyses including presenting descriptive statistics and reporting baseline results. Section 5 performs robustness checks and Section 6 addresses the hysteresis effect and provides results of additional analyses. Section 7 concludes the paper.

2. HYPOTHESIS

Prior studies show that, on average, managers withhold bad news and emphasize good news in their public disclosures, and they argue a lot on the effects of the release of bad news if it accumulates up to a threshold [19]. Kothari *et al*. [20] examine that if the bad news leaks and good news reveals in the meanwhile, the negative reaction to the stock price dominates the positive one. However, this circumstance is rare; and the most common one is that if the amount of bad news reaches an upper limit that firms are costly or even unable to withhold anymore, the immediate release, without simultaneously revealing good news, will lead to large negative stock returns, forming stock price crashes [21].

Firms withhold bad news in public disclosures for many reasons including managers' compensation contracts, firms' credit rating, short interest, and other self-benefit reasons [22-25]. Therefore, many researchers start to study the factors that will influence and determine the stock price crash risk such as directors' and officers' liability insurance, mergers and acquirers', foreign investors, and stock liquidity; utilizing this risk function to examine the governance of these individual factors in today's market [21, 26-28]. This study also uses stock price crash risk to analyze R&D's dual character.

Following these ideas, there are two different theoretical views on the effect of R&D activities on stock price crash risk.

One view is that listed firms that anticipate R&D activities usually face high risks during the development period of innovation projects [9]. These risks come from the presence of sunk costs, real uncertainty, long time lags, adverse selection, and moral hazard [29]. Due to the various self-benefit orientated reasons, the management team usually withholds the temporary and perpetual bad news such as failure of the patent application to cover these risks made during the innovation process. While the R&D goes to the commercialization period which includes events about new product launches and awards, the absorption and accumulation of bad news reach the cap and leak out subsequently which causes the stock price crashes [9]. In order to protect firms from potential operating risks from R&D activities and investors' aggressive reactions to temporary bad news, corporations withhold the R&D information by shifting or hiding R&D expenditures from their financial statements.

Another view is that, in the emerging market, the disclosure of R&D activities benefits firms and decreases the extremely negative influence in the stock market, because when normal companies withhold R&D information, the action that discloses R&D expenditures represents a positive signal to the public [11]. Emerging markets do not audit as strictly as developed capital markets and then, with the potential risks of R&D and tax benefits, many companies shift their R&D expenditures to other components on the balance sheet [16]. Thus, the disclosure of R&D proves that this firm has a reliable long-term development strategy, robust inner governance, and adequate confidence in their potential output and return which lowers the risk of stock price drops in the future.

Based on the above discussion, we propose two competing hypotheses for the effect of R&D expenditure on stock price crash risk.

H1a. The investment in R&D increases future stock price crash risk, other things being equal.

H1b. The investment in R&D decreases future stock price crash risk, other things being equal.

3. RESEARCH DESIGN

3.1. Construction of Sample

Our sample initially comprised all listed firms which disclose R&D expenditures and ratio on SHSE and SZSE from 2007 to 2019. We choose 2007 as the beginning year because R&D expenditure has been required to put in the annual reports since 2007 which provides more reliable statistics without manual collection.

Following the literature studied by Wen *et al*. [30], Chen, Kim, & Yao [31], Li *et a*l. [32], we (1) exclude the stocks that trade for less than 30 weeks in one year; (2) screened out by companies from the financial industry (e.g., banks, security companies, investment trusts) as they provide absolutely different capital structure and do not include R&D spending; (3) dropped the sample companies which will be delisted soon since their balance sheets are not valuable for this study; (4) dropped the observations with missing information for the control variables.

Finally, we get an available sample of 21756 observations, representing 3568 firms with R&D expenditures.

Table 1 Descriptive statistics. This table shows the summary statistics of the stock crash risk measures, RD ratio, and other control variables in Chinese A-shares markets from 2007 to 2019.

Variable	Obs.	Mean	Std. dev.	Minimum	Median	Maximum
$NCSKEW_{t+1}$	21756	-0.295	0.696	-2.385	-0.253	1.502
$DUVOL_{t+1}$	21756	-0.195	0.472	-1.340	-0.191	0.964
RD_t	21756	0.012	0.017	0.000	0.004	0.091

$NCSKEW_t$	21756	-0.269	0.674	-2.306	-0.232	1.440
$DUVOL_t$	21756	-0.178	0.467	-1.306	-0.176	0.984
Ret_t	21756	-0.001	0.001	-0.006	-0.001	-0.000
$Sigma_t$	21756	0.048	0.018	0.017	0.045	0.107
$Size_t$	21756	22.115	1.323	19.144	21.956	25.927
Age_t	21756	2.797	0.372	1.386	2.833	3.434
BM_t	21756	0.634	0.244	0.119	0.638	1.129
ROA_t	21756	0.040	0.057	-0.246	0.036	0.211
Lev_t	21756	0.462	0.205	0.049	0.463	0.973

3.2. Models

To examine the effect of corporate R&D expenditure on stock price crash risk, we employ the following basic empirical model using the ordinary least squares (OLS):

$$NCSKEW_{t+1}(DUVOL_{t+1}) = \beta_0 + \beta_1 RD_t + \sum_{q=2}^{i}(q_{th}\ Control\ Variable_t) + \varepsilon_t \quad (1)$$

Where β_i represents regression coefficients; ε_t is the error term; and control variables contain, $Sigma_t$, Ret_t, $Size_t$, Age_t, BM_t, Roa_t, Lev_t, $Growth_t$, year dummies. $NCSKEW_{t+1}$ and $DUVOL_{t+1}$ are two measures of stock price crash risk. $R\&D\_Ratio_t$ represents R&D expenditure over firm's market value. A negative (positive) β_1 suggests that the R&D ratio tends to decrease (increase) stock price crash risk.

3.3. Variables

Followed by Chen *et al*. [17], we employed $NCSKEW_{t+1}$ and $DUVOL_{t+1}$ as our measurements of stock crash risk. $NCSKEW_{t+1}$ is the negative conditional skewness of firm-specific weekly returns over the fiscal year at time t+1 and is calculated using the formula described below:

$$NCSKEW_{i,t} = -\left[n(n-1)^{3/2}\sum W_{i,t}^3\right] / \left[(n-1)(n-2)(\sum W_{i,t}^3)^{3/2}\right] \quad (2)$$

Where n is the trading weeks for stock i in year t+1 and w is firm-specific weekly return in year t. A Higher value of $NCSKEW_{t+1}$ indicates a higher crash risk for a stock.

$DUVOL_t$ is the down-to-up volatility at time t calculated using the formula below:

$$DUVOL_{i,t} = \log\left\{\left[(n_u-1)\sum_{Down} W_{i,t}^2\right] / \left[(n_d-1)\sum_{Up} W_{i,t}^2\right]\right\} \quad (3)$$

Where n_u and n_d are the number of weeks that rise and decline, respectively. The higher the value of $DUVOL_{t+1}$ is, the greater the crash risk is.

3.4. Control Variables

We adopt variables that have been demonstrated in previous studies. All variables below are continuous and winsorized at 1% for both tails. $NCSKEW_t$ is the negative skewness of firm-specific weekly returns in the year t, measuring the stock price crash risks [29]. A high value of $NCSKEW_t$ in the previous year is likely to have high skewness in the following year [29]. The Variable $DUVOL_t$ is the down-to-top volatility. Chen *et al.* found a high $DUVOL_t$ value in the year t will also result in a greater possibility of stock price crash risk in year t+1 [29]. We also added the RD_t as our input of expenditures in R&D, using a company's last 12 months of expenditures on research and development divided by its market value.

Furthermore, we include Ret_t , which is the arithmetic average of firm-specific weekly returns in year t. Chen *et al.* show a positive correlation between stock price crash risk and high returns [29]. Variable $Sigma_t$ is the standard deviation of firm-specific weekly returns over the year t. A large value of $Sigma_t$ is likely to increase the stock price crash risk according to Chen *et al.* We add control variable $Size_t$, calculated by the natural logarithm of the book value of total assets in year t. Chen *et al.* also found size will increase stock price risk [29]. Age_t is another variable that we want to use here, which is the years listed for each stock. BM_t is the book-to-market ratio in year t and ROA_t is measured by the net profit in year t divided by the corresponding total asset. We also add Lev_t, the financial leverage, defined by the book value of total debt divided by the value of the total asset. Hutton *et al.* show that financial leverage negatively correlated with the stock price crash risk [29].

4. EMPIRICAL ANALYSES

4.1. Descriptive Statistics

Table 1 provides descriptive statistics for variables. The means for two stock crash risk measures, $NCSKEW_{t+1}$ and $DUVOL_{t+1}$ are -0.295 and -0.195. The average of RD_t is 0.012, this indicates that the average annual R&D expenditure of Chinese listed companies in the sample accounts for 1.2% of their market capitalization. Other descriptive information can be found in the table.

4.2. Correlation Analysis

We calculate the Pearson correlation between variables and display the significance of each pair of correlation results. The correlations between variables are all statistically significantly close to 0 except that ROA and Lev (0.49), BM and Size (0.53), Size and Age (0.20) are significantly correlated. We also test for VIF. The largest values are ROA, Lev, NCSKEW, and DUVOL. All of their values are close to 4. Thus, we conclude that multicollinearity is not a big problem to our result.

4.3. Univariate Analysis

The first and the third column of Table 2 displays the results of univariate analysis. The coefficients of NCSKEW and DUVOL are both negative and significant at 1% level. The results suggest a negative relationship between stock price crash risks and the R&D ratio.

4.4. Multivariate analysis

Table 2 displays the ordinary least square regression results of our models. $DUVOL_{t+1}$ measures down-to-top volatility at time t+1. The coefficient of RD_t is negative (-1.049) and significant at the 1% level. It suggests the increase in expenditure of R&D will decrease the stock price crash risk. Table 2 presents the coefficient of RD_t (-1.116) on $NCSKEW_{t+1}$ is also negative and significant at the 5% level. It also demonstrates the positive impact of R&D expenditures, suggesting more expenditure would decrease stock price crash risk. Thus, we can take H1b that the investment in R&D decreases future stock price crash risk, other things being equal. The signs of significant variables Ret_t, $Sigma_t$, $Size_t$, and BM_t are the same as Yuan *et al*. However, the impact of ROA_t and Lev_t remained insignificant in our result.

Table 2 R&D ratio and stock price crash risks. This table provides the results from the ordinary least squares regression of the impact of R&D ratio and other explanatory variables on next period stock price crash risk. The dependent variables NCSKEW and DUVOL are measured over year t + 1. The test variable is R&D ratio. The T-values of robust standard errors based on company and year aggregation are reported in parentheses. And the effects of different periods and industries were also considered.

	(1)	(2)	(3)	(4)
	$DUVOL_{t+1}$	$DUVOL_{t+1}$	$NCSKEW_{t+1}$	$NCSKEW_{t+1}$
RD_t	-1.1649***	-1.049***	-1.771***	-1.116*
	(-3.000)	(-2.684)	(-2.701)	(-1.958)
$NCSKEW_t$				-0.081***
				(-10.704)
$DUVOL_t$		-0.085***		
		(-12.119)		
Ret_t		42.612***		78.664***
		(2.785)		(3.453)
$Sigma_t$		2.425***		4.673***
		(2.655)		(3.439)
$Size_t$		0.020**		0.041***
		(2.208)		(3.094)
Age_t		-0.138***		-0.197***
		(-2.919)		(-2.780)
BM_t		-0.337***		-0.520***
		(-11.507)		(-12.000)
ROA_t		-0.023		-0.087
		(-0.277)		(-0.734)
Lev_t		0.012		0.027
		(0.360)		(0.517)

Constant	-0.178***	0.006	-0.267***	-0.309
	(-35.812)	(0.026)	(-31.993)	(-0.986)
Year fixed effects	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES
Observations	21756	21756	21756	21756
Adjusted R^2	0.007	0.076	0.006	0.075

$*$ Indicates significance at the 10% level (two-tailed).
$**$ Indicates significance at the 5% level (two-tailed).
$***$ Indicates significance at the 1% level (two-tailed).

5. ROBUSTNESS CHECKS

In this section, we employed alternative sample method, fixed effect model, and system GMM to check the sensitivity and robustness of our results.

5.1. Alternative Sample

We utilize alternative methods of stock price crash risk which are $NCSKEW_{Mdeq}$ and $DUVOL_{Mdeq}$ calculated through the equal-weighted average method of the listed stocks in the market. The results of univariant and multivariant regressions are similar to that of the previous regression. The coefficient RD_t is negative and significant at 5% level, suggesting that the increase in the expenditure of R&D will decrease the stock price crash risk. We also use the equal-weighted average method to calculate $NCSKEW_{Mdos}$ and $DUVOL_{Mdos}$. The conclusion is still the same as what we get from empirical study. Thus, we conclude that our result is not driven by the choice of the sample but valid across the whole market.

5.2. Endogeneity

Our regression results may have potential endogeneity problems. For example, as we mentioned in the introduction part, the company may hide the true R&D expenditures on financial statements to provide corporations a comparative advantage without mimic from rivals. Also, China has relatively unmatured internal and external governance and auditing systems which results in a high probability of R&D missing and expense shifting.

5.2.1. Fixed Effect Model

To check if our model is driven by time-invariant characteristics, we re-estimate our model using random effect and fixed effect model then test the results by Hausman test. The P-value of the Hausman test is 0.000, suggesting that the difference in coefficients is systematic and we should employ fixed effect model. The results are displayed in Table 2. The coefficient of R&D is still negative and significant at 1% level. It implies that our model is not driven by time-invariants and firm specific characteristics.

5.2.2. One Step System GMM

In the previous section we estimate our model using ordinary least squares and fixed effect model. However, since we incorporate lag terms of $NCSKEW_{t+1}$ and $DUVOL_{t+1}$ in our model, the demeaning method of fixed effect model may still contain endogeneity problems. We estimate this model using system GMM method here to mitigate potential problems. We utilize two terms of lags of $NCSKEW_{t+1}$ ($DUVOL_{t+1}$), one term lag of RD_t, one term lag Big4, and SOE as instrument variables. For $NCSKEW_{t+1}$ ($DUVOL_{t+1}$), the P value of AR (1) gives 0.000 (0.720), while AR (2) gives 0.889 (0.487), suggesting that we pass the autocorrelation test. The value of Hansen test of overidentifying is 0.263 (0.085) and Sargan test gives a value of 0.986 (0.936). Thus, our choice of instrument variables is valid. Table 3 shows the coefficients and significance level of one step system GMM. The coefficients of RD_t are still negative and significant at 1% level. These results prove the previous hypothesis that the increase of expenditure in R&D will decrease the stock price crash risk.

Table 3 This table displays the coefficients and t values for each variable using system GMM. The dependent variables are NCSKEW and DUVOL measured in t+1 period. All variables are defined in section 3.4

	(1)	(2)
	$NCSKEW_{t+1}$	$DUVOL_{t+1}$
RD_t	-3.149***	-1.660***
	(-3.633)	(-3.299)
Ret_t	-25.935	-58.609

	(-0.602)	(-1.574)
$Sigma_t$	-10.241***	-9.340***
	(-3.713)	(-4.023)
$Size_t$	0.023	-0.011
	(1.164)	(-0.937)
Age_t	-0.422***	-0.245***
	(-6.621)	(-6.666)
BM_t	-1.052***	-0.590***
	(-11.822)	(-10.644)
ROA_t	-0.602	-0.010
	(-0.887)	(-0.026)
Lev_t	-0.460	-0.152
	(-1.628)	(-1.089)
Constant	1.787***	1.565***
	(5.814)	(7.620)

* Indicates significance at the 10% level (two-tailed).
** Indicates significance at the 5% level (two-tailed).
*** Indicates significance at the 1% level (two-tailed).

6. FURTHER RESEARCH

This section is mainly composed of four parts. The first three parts are conducted to examine the moderating effects of the monitoring mechanism. Typically, Firms with high institutional shareholding, audited by the Big Four or owned by the state will have a stronger monitoring mechanism. In particular, in China's capital market, the monitoring system of state-owned enterprises is completely different from that of non-state-owned enterprises. Therefore, the hypothesis is that the relationship between corporate research and development activity will be more pronounced in firms with weaker monitoring mechanisms. The last part of this section is conducted to examine the research and development activity disclosure effect on market attention.

6.1. Institutional Shareholding

We divide the sample into two subsets: the higher institution shareholding subset with the institution shareholding ratio above the median of the same year and industry, and the lower institution shareholding subset with the institution shareholding ratio below the median. We adopt NCSKEW as the measurement of stock price crash risk to run the regression on these two subsets separately. According to the results provided in column (1) and (2) of Table 4, the estimated coefficient of R&D ratio for lower institution shareholding ratio is -1.353 at the significance level of 1%, while the coefficient for higher institution shareholding ratio is higher at -0.670 but is not significant. The results indicate that the effect R&D ratio on the next period stock price crash risk is more pronounced in the companies with a lower institution shareholding ratio.

6.2. State-Owned Enterprise

We separate the original sample into another two subsets: the state-owned enterprise and nonstate-owned enterprise. We adopt NCSKEW as the measurement of stock price crash risk to run our model on these two subsets separately. According to the results provided in columns (3) and (4) of Table 4, the estimated coefficient of R&D ratio for non-SOE is -1.004 at the significance level of 5%, while the coefficient for higher institution shareholding ratio is higher at -0.848 but is not significant. The results indicate that the effect R&D ratio on the next period stock price crash risk is more pronounced in the non-state-owned enterprise.

6.3. Big 4 Auditors

We divide the original sample into another two subsets: Companies that employ the big 4 auditors for their annual reports and those that do not employ the big 4 auditors companies. We adopted NCSKEW as the measurement of stock price crash risk to run regression on these two subsets separately. According to the results provided in columns (5) and (6) of Table 4, the estimated coefficient of R&D ratio for non-Big4 is -1.019 at the significance level of 1%, while the coefficient for higher institution shareholding ratio is higher at -0.837 but is not significant. The results indicate that the effect R&D ratio on the next period stock price crash risk is more pronounced in the companies that employ the big 4 auditors for their annual reports.

6.4. R&D Disclosure Effect

Since R&D spending is an uncertain item, a company may choose not to disclose its own R&D information if the company's innovation and research are not well-capitalized. Therefore, companies that disclose R&D information in the market may receive more attention. Capital markets will monitor the progress of these firms' research and development and their ability to convert to patents. Consequently, firms with a high degree of market supervision may find it more difficult to hide negative news in their R&D situation.

Following Rongli, Y., Jian, S., & Feng, Cao [21], we adopt the number of analysts following the tracks of insured firms as the proxy measurement of the market attention on the R&D disclosed firms and examine the R&D disclosure effect on the market attention. We still use the same R&D ratio as the measurement of firms' R&D disclosure. According to Yu [33], five control variables are added to the model: firm size (MV_t, in terms of the natural logarithm of total market value of a firm), past performance (ROA_{t-1}, in terms of the return on assets in last year), growth($Growth_t$, in terms of the growth in asset), external financing activities (Fin_t, in terms of net cash proceeds from equity and debt financing scaled by total assets), and volatility of business ($OCSD_t$, the standard deviation of yearly operating cash flows in past three years, scaled by operating profits). The year and industry effects are also taken into consideration in control variables. The model for examination is conducted as follow:

$$Analyst_t = \alpha + \beta_1 R\&D_t + \beta_2 MV_t + \beta_3 ROA_{t-1} + \beta_4 Growth_t + \beta_5 Fin_t + \beta_6 OCSD_t + Year\ Dummies + Industry\ Dummies + \varepsilon_i \quad (4)$$

We run the regression of the model (4) and the results are provided in Table 5. The coefficients of R&O ratio in the four models are all significant in 1%. The results indicate that firms that disclose their R&O spending will catch more attention from the capital market, and the effect is more pronounced in the next period. Firm size, past profitability performance, and growth all have a positive effect on the number of analysts following, except external financing activities have a negative effect. The effect of the cash flow volatility is not significant. The estimated coefficients of the control variables all have consistent signals with Yu [33].

Table 4 This table reports the results of moderating effects of monitoring mechanisms on the relationship between future stock price crash risk and R&D ratio by dividing the original sample into two groups based on these mechanisms. Three variables are considered to proxy for monitoring mechanisms: the proportion of institution shareholdings, the Big 4 auditors, the state-owned enterprise. The dependent variables NCSKEW is adopt measured over year t + 1's stock price crash risk. The test variable is R&D. Reported in parentheses are t-values based on robust standard errors clustered by both industry and year.

	(1)	(2)	(3)	(4)	(5)	(6)
	Lower Institution	*Higher Institution*	*Non SOE*	*SOE*	*Non Big4*	*Big4*
RD_t	-1.353***	-0.670	-1.004**	-0.848	-1.019***	-0.837
	(-2.627)	(-1.127)	(-2.011)	(-1.395)	(-2.631)	(-0.566)
Ret_t	59.949***	17.048	40.946*	26.351	40.815***	-46.439
	(2.841)	(0.736)	(1.917)	(1.176)	(2.594)	(-0.620)
$Sigma_t$	4.308***	1.274	3.121**	1.561	2.892***	-3.426
	(3.316)	(0.952)	(2.376)	(1.201)	(3.063)	(-0.854)
$Size_t$	0.033**	0.017	0.040***	0.019	0.022**	-0.027
	(2.214)	(1.183)	(3.080)	(1.373)	(2.501)	(-0.627)
Age_t	-0.228***	0.005	-0.183***	0.059	-0.163***	0.226
	(-3.367)	(0.062)	(-3.137)	(0.762)	(-3.424)	(1.294)
BM_t	-0.330***	-0.333***	-0.347***	-0.359***	-0.327***	-0.556***
	(-7.034)	(-8.108)	(-8.591)	(-8.498)	(-10.886)	(-5.213)
ROA_t	-0.051	-0.016	-0.048	0.028	0.000	-0.406
	(-0.470)	(-0.114)	(-0.450)	(0.211)	(0.004)	(-1.090)

Lev_t	-0.028	-0.034	0.035	0.002	0.018	-0.067
	(-0.529)	(-0.632)	(0.727)	(0.043)	(0.519)	(-0.419)
Constant	0.069	-0.266	-0.720***	-0.148	-0.034	0.512
	(0.196)	(-0.749)	(-2.642)	(-0.430)	(-0.155)	(0.479)
Year fixed effects	YES	YES	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES	YES	YES
Observations	10878	10878	11093	10663	20250	1506
Adjusted R^2	0.085	0.064	0.083	0.066	0.074	0.109

∗ Indicates significance at the 10% level (two-tailed).
∗∗ Indicates significance at the 5% level (two-tailed).
∗∗∗ Indicates significance at the 1% level (two-tailed).

Table 5 This Table reports the examination results of the R&D disclosure effects. RD ratio is the test variable and there are another five control variables. The table shows the effects of the R&D disclosure on the number of analysts follow. The model (3) and (4) consider the future effect in next period. Reported in parentheses are t-values based on robust standard errors clustered by both firm and year.

	(1)	(2)	(3)	(4)
	$Analyst_t$	$Analyst_t$	$Analyst_{t+1}$	$Analyst_{t+1}$
RD_t	2.043***	1.968***	3.930***	3.886***
	(3.138)	(3.043)	(5.460)	(5.431)
MV_t	0.354***	0.352***	0.294***	0.292***
	(26.236)	(26.331)	(20.766)	(21.122)
ROA_{t-1}	3.149***	3.037***	1.663***	1.552***
	(17.963)	(17.550)	(9.900)	(9.398)
$Growth_t$	0.074***	0.078***	0.163***	0.164***
	(5.712)	(5.990)	(12.269)	(12.241)
Fin_t	-0.662***	-0.652***	-0.181***	-0.173***
	(-11.874)	(-11.731)	(-3.397)	(-3.265)
$OCSD_t$	-0.012	-0.022	0.034	0.015
	(-0.234)	(-0.425)	(0.601)	(0.276)
Constant	-3.831***	-3.451***	-2.339***	-2.458***
	(-19.086)	(-11.539)	(-11.046)	(-6.857)
Year fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	No	Yes	No	Yes
Observations	16236	16236	16236	16236
Adjusted R^2	0.228	0.241	0.130	0.146

∗ Indicates significance at the 10% level (two-tailed).
∗∗ Indicates significance at the 5% level (two-tailed).
∗∗∗ Indicates significance at the 1% level (two-tailed).

7. CONCLUSIONS

This paper examines the impact of the R&D ratio on stock price crash risk. Using a sample of Chinese listed firms which disclose the R&D information on the annual report from 2007 through 2019, we find that the R&D activity is negatively associated with stock price crash risk. Further researches suggest that the relationship is more pronounced in firms from emerging markets with high leverage, lower return on assets, non-Big 4 auditors, lower institutional shareholdings, and non-stated-owned enterprises. Moreover, we find that the disclosure of R&D expenditures has a positive effect on the number of analysts following.

Our findings prove that, in the emerging market which does not have rigorous regulations, many public firms hide their R&D expenditures due to tax benefits and concerns about potential failure. Under this background, the disclosure of R&D activities promotes companies' reputation, represents management teams' confidence, and motivates the success of innovation, eventually facilitating stockholders' assurance and credit loan possibilities from commercial banks.

Our paper contradicts the prior study result on a positive relationship between innovation and stock price crash risk for US exploration-oriented firms. The reason could be that in some developing regions, such as China, the regulations on public films and monitoring system are not completely established, where the innovation strategies convey a different signal to the capital market. It is proved that the association is different between the developed capital market and emerging market, benefiting firms and investors in the emerging market who want to manage crash risk. Especially in the sample firms with poor supervision, the impact of corporate disclosure innovation strategy on the stock price crash risk is more pronounced. Our findings help the management team in this large market understand more fully the attributes of R&D and make decisions properly in the disclosure of R&D activities. Moreover, our results about the dominant impact of R&D expenditure on stock price crash risk motivate regulators in the emerging market to consider more rigorous regulations on the disclosure of R&D information.

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