

Black Swan Event and Cash Holding at Firm Level: The Influence of COVID-19 on Listed Companies in North America

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Abstract: *The Black Swan event represents an unpredictable occurrence with significant repercussions for societal and economic functions, as well as political stability. Using the COVID-19 outbreak in 2020 as a case study, this research delves into the impact of Black Swan events on the level of corporates' cash holdings. The study categorizes firms into two dimensions based on two aspects of characters of enterprises: 1. Sensitive enterprises which belonging to industries seriously affected by the epidemic versus non-sensitive enterprises which belong to low-effected industries. 2. Research and Development (R&D)-intensive companies versus those with limited R&D investments. Employing the Difference-in-Differences (DID) methodology, the study conducts comparative quasi-natural experiments on these two groups. The findings reveal that the COVID-19 pandemic positively influences the cash holding level of highly sensitive enterprises, while negatively affecting the cash holding level of R&D-intensive companies. These outcomes shed light on the preservation incentives for firms to hold cash in the face of crisis and external financing dilemma of R&D-intensive enterprises magnified by the Black Swan event.*

Keywords - *Black Swan Event, Covid-19, Cash Holdings, R&D, DID Method*

I. Introduction

Taleb (2009) introduced the concept of the 'Black Swan' to refer to unforeseeable events in our lives. These events possess three key attributes: (1) They are outliers, exceeding the bounds of normal expectations. (2) They have significant impacts. (3) Explanations for their occurrence are typically retrospective, making them appear interpretable and predictable.

When identifying the attributes of Black Swan events, their classification seems to depend on individual interpretations. For instance, Higgins (2013) regarded contagious diseases like the Avian Influenza in Asia (2008) and SARS in Hong Kong (2002) as Black Swan events. These events represent large-scale disruptions with the potential to severely disrupt economic activities, social cohesion, and even political stability. These diverse risk patterns can propagate and affect global systems, whether they manifest in healthcare, climate, society, or finance (Higgins, 2013). Therefore, studying the impact of Black Swan events on the global economy and gaining insights into how future economic entities should respond to uncertain crisis events is of paramount importance.

The COVID-19 pandemic from 2019 to 2022 posed a significant challenge to economic activities, social cohesion, and political stability worldwide, making it the most recent globally resonating Black Swan event. Global enterprises struggled to survive this unprecedented health crisis, making it essential for scholars and policymakers to understand how the coronavirus (COVID-19) pandemic affected financial markets and institutions, subsequently influencing the real economy. Thus far, the 21st century has been an era of Black Swans, and this era is far from over. Among the upcoming Black Swans, the prevalence of coronavirus is unlikely to be the world's last (Briancon, 2020). Statistics show that in 2020, the world's real GDP declined by 3.6%, and global merchandise trade fell by 5.3% (WTO). Most companies experienced issues such as declining performance (Fu and Shen, 2020), plummeting stock prices, and other severe challenges (Narayan and Phan,

2020). For instance, in the first quarter of 2020, production levels sharply decreased, leading to a complete standstill in the tourism and hospitality sectors. Moreover, the impact of the pandemic on company performance is reflected in increased market volatility (Baek et al., 2020) and reduced market returns (Narayan et al., 2020). On one hand, businesses characterized by services, social interactions, and population mobility faced operational difficulties, struggling to generate income and cash flow. On the other hand, necessary fixed costs and personnel expenses prompted cash outflows. Prolonged 'cash deficits' created significant liquidity pressures for industries heavily affected by the pandemic (Qin et al., 2020).

Although financing capabilities vary across industries and firms, managers tend to increase their corporate cash holdings in the short term through external financing to mitigate the cash flow pressure brought on by crises (Qin et al., 2020). Moreover, different industries exhibit varying degrees of sensitivity to the pandemic. Industries characterized by factors like labour-intensity, social interaction, and cross-border trade are more significantly affected by the pandemic (Qin et al., 2020), resulting in higher short-term financing needs. In other words, compared to companies with minor impacts, these companies may opt to hold more cash to hedge against pandemic-related risks. At the same time, R&D-intensive enterprises may face greater financing challenges during Black Swan events compared to enterprises with lower R&D investments, which will impact their cash holding levels. To further substantiate these two hypotheses, this study employs a Difference-in-Differences (DID) method to investigate the impact of the COVID-19 pandemic on corporate cash holdings, and the results align with the hypothesis.

Research on the economic impacts of Black Swan events is limited. Many preceding research have primarily focused on investigating adjustments in national quarantine policies and evaluating market responses to the COVID-19 pandemic. For instance, Narayan and Phan (2020) delved into the examination of stock market reactions to the outbreak of COVID-19, while Narayan (2020) conducted a comprehensive analysis of the intricate relationship between COVID-19 and oil prices. Furthermore, various studies have sought to ascertain the repercussions of the pandemic on company performance. However, it's noteworthy that there remains a dearth of scholarly inquiry into the impact of COVID-19 on the dynamic fluctuations in cash holdings of firms.

Cash holding levels are crucial for companies to manage risks associated with Black Swan events and avoid business crises. This study was inspired by the research conducted by Qin et al. (2020), who found that the COVID-19 pandemic had a significantly positive impact on cash holdings in severely affected Chinese industries, with goodwill and goodwill impairment weakening this positive impact. To further validate and complement the theories of the relationship between Black Swan events and cash holding levels, I focused on publicly listed North American companies and explored the impact of the COVID-19 pandemic on firms with varying degrees of R&D intensity. Consequently, this paper makes several contributions.

Firstly, this study sheds light on the prevention motives behind adjustments in corporate cash flow levels. Many previous studies have indicated that companies take measures to enhance their liquidity levels in response to crises. Thus, the results of this paper offer more robust support for this theory.

Secondly, building upon the research of Qin et al. (2020), which focused on the most severely affected Chinese publicly listed companies, this study examines publicly listed North American companies, thus complementing the enterprises' cash holding levels theory during Black Swan events.

Lastly, this paper delves into the relationship between Black Swan events and cash holding levels of R&D-intensive enterprises.

II. Theoretical Framework and Hypotheses

2.1 The Influence of COVID-19 on Cash Holding Level of Enterprises with Different Sensitivity

Cash flow is often regarded as the lifeblood of businesses, sustaining their day-to-day operations (Opler, 1999). Firms maintain a certain level of cash holdings for three primary motives: precautionary, transactional,

and speculative (Opler et al., 1999). Moreover, there exists a significant positive relationship between future cash flows and corporate cash holdings (Acharya et al., 2012). However, the COVID-19 pandemic exacerbated the liquidity levels of global companies. Quarantine policies led to a standstill in industry market transactions, resulting in a substantial decrease in corporate revenue levels. Meanwhile, fixed expenses of companies remained intact and possibly escalated to meet the requirements of pandemic containment policies (Qin et al., 2020). These factors significantly impacted companies' liquidity performance.

Phadnis et al. (2021) assert that Black Swan events disrupt financial market liquidity. Just and Echouffo-Tcheugui (2020) employ a Markov-switching approach to identify evidence of enhanced correlation and decreased liquidity during crisis periods, signifying elevated market uncertainty and risk aversion levels. Bartik (2020) further corroborates this finding when studying the impact of the coronavirus. Colak and Oztekin (2021) discuss the effects of the COVID-19 pandemic on global bank lending. Using the Difference-in-Differences (DID) method, they find that countries heavily affected by the coronavirus experienced weakened bank lending, affirming the adverse impact of crises on corporate borrowing.

Based on the aforementioned discussions, maintaining a certain level of cash is advantageous for firms in ensuring liquidity during 'Black Swan events,' allowing them to meet fixed costs and expenses, mitigating short-term uncertainties posed by crises. Additionally, as 'Black Swan events' impact lending, the precautionary increase in cash levels can reduce the ongoing need for external financing (Opler et al., 1999). Therefore, I hypothesize that, for sensitive industries (characterized by labour-intensity, social interaction, cross-border trade, etc.), there exists a stronger prevention motive to enhance cash flow levels to manage potential operational risks. Hence, my first research hypothesis is as follows:

H1: Holding all other factors constant, the COVID-19 pandemic has a positive impact on the cash holdings of firms in highly sensitive industries. Firms in sensitive industries will possess higher cash holdings.

2.2 The Impact of the COVID-19 Pandemic on Cash Holdings of R&D-Intensive Firms

Sustained investment in research and development (R&D) is of paramount importance to enterprises. Such investments aid firms in building knowledge and technological capabilities, fostering innovation, enhancing competitiveness, improving performance, and ensuring their future competitive standing (Somaya et al., 2008; Lome et al., 2016; Barney, 1991; Cuervo-Cazurra and Un, 2010; Silvestre and Țircă, 2019). Numerous previous studies have examined whether the intensity of R&D expenditure by firms can mitigate the adverse effects of the COVID-19 pandemic on firm performance (Bose et al., 2021). Research has shown that R&D-intensive firms exhibit greater flexibility when facing crises and escalating uncertainty (Lome et al., 2016). While financial recessions can lead to a decline in market demand, they also present new opportunities for innovative companies (Voight and Moncada-Paternó-Castello, 2009). Whether firms can seize these opportunities depends on their adaptive capabilities established and developed through continuous R&D activities (Lome et al., 2016). These findings underscore the crucial role of R&D investment for long-term success in competitive markets.

However, some studies argue that R&D-intensive firms have become more vulnerable in the face of Black Swan events. The cash holdings of high R&D firms are more severely affected during pandemics. Firstly, high R&D firms often offer more specialized products and services, making them susceptible to customer-driven losses during economic crises (Opler and Titman, 1994). Secondly, Black Swan events can exacerbate the internal financing disadvantages of high R&D companies. For these firms, a significant portion of R&D expenses, representing intangible assets, is difficult to convert into cash flows in the short term to cope with crises (Opler and Titman, 1994). Moreover, companies with higher R&D expenditures are more likely to face external financing difficulties. The Organisation for Economic Co-operation and Development (OECD) in 2021 summarized the reasons why R&D-intensive firms face challenges in financing: the specific characteristics of intangible assets include uncertain returns, non-competitiveness, and substantial synergies, all of which often increase information asymmetry, making it challenging for them to serve as collateral. Consequently, during crisis shocks, information asymmetry renders it more difficult for R&D-intensive firms to attract investment from external investors (Opler and Titman, 1994).

In summary, under the impact of Black Swan events, firms with high levels of R&D investment face lower cash flow levels. Based on this, my second hypothesis is as follows:

H2: Holding all other factors constant, the COVID-19 pandemic has a negative impact on the cash holdings of highly R&D-intensive enterprises. Companies with higher R&D investments exhibit lower liquidity levels.

III. Data and Research Design

3.1 Data

The study sample encompasses corporations publicly listed on North American stock exchanges. Data pertaining to their cash reserves and other pertinent financial metrics at the firm level were meticulously gathered spanning from the first quarter of 2018 to the first quarter of 2022, drawing exclusively from Compustat as the primary data source. To uphold rigorous comparability standards across the study cohort, several meticulous criteria were scrupulously applied: (1) The exclusion of financially distressed entities; (2) The omission of data originating from banking institutions, securities firms, and other financial entities; (3) The removal of corporations exhibiting substantial lacunae in their dataset. Furthermore, to effectively address potential outlier influence, all variables were winsorized at the 0.01 and 0.99 percentiles.

3.2 Difference-in-Differences Method for Two Regressions

The allocation of entities into treatment and control groups lacked the randomness typically associated with experimental designs. Consequently, utilizing a basic Ordinary Least Squares (OLS) regression model presents a substantial risk of endogeneity issues stemming from the potential omission of variables that might exhibit correlation with the selection bias.

The Difference-in-Differences (DID) methodology adeptly circumvents the endogeneity challenge inherent in assessing treatment effects. Precisely, contrasting the levels of the treatment and control groups may inadvertently encapsulate myriad disparities between these two groups, thereby possibly yielding biased estimations of the pandemic's impact. In contrast, DID methodology scrutinizes the divergent behaviors of the two groups within a panel regression framework. This differentiation effectively isolates firms' behavioral responses to the 'Black Swan event' from the other disparities observed in different years. Consequently, this approach facilitates a robust analysis of the consequences of exogenous shocks on firms.

3.2.1 The Impact of COVID-19 on Firms with Varying Sensitivity Levels

My first research endeavor involves examining the effect of COVID-19 on the cash holdings of firms with different sensitivity levels. In this study, the treatment group comprises companies significantly affected by the pandemic, while the control group consists of those less affected.

To test the first hypothesis, I adopt the model constructed by Qin et al. (2020), as follows:

$$\text{Cashholdings}_{it} = \beta_0 + \beta_1 \text{Treated}_{it} * \text{Period}_{it} + \beta_2 \text{Treated}_{it} + \beta_3 \text{Period}_{it} + \beta_4 \text{SIZE}_{it} + \beta_5 \text{LEV}_{it} + \beta_6 \text{GROWTH}_{it} + \beta_7 \text{NROA}_{it} + \beta_8 \text{FCF}_{it} + \beta_9 \text{TR}_{it} + \beta_{10} \text{ENT} + \beta_{11} \text{TIME} + \varepsilon_{it} \quad (1)$$

The dependent variable *Cashholdings* represents a firm's cash holdings, expressed as the ratio of cash to current revenue. *Treated* is a dummy variable indicating the extent of impact from the pandemic; if a company operates in an industry highly affected by the pandemic outbreak, the dummy variable is set to 1, otherwise 0. Based on the guidelines of 2012 China Securities Regulatory Commission industry classification, eight industries were identified as highly impacted sectors, including tourism, entertainment, food services, transportation, real estate, construction, accommodation, and manufacturing for export. I categorized companies based on their two-digit SIC codes. *Period* is a dummy variable representing the pandemic period. According to Sanford's (2020) report, the true impact of the pandemic began in early 2020. Thus, it equals 1 when observed from the first quarter of 2020, otherwise 0.

The focal point of this study is the coefficient β_1 of the interaction term, which represents the difference-in-difference estimator. It reflects the variation in cash holdings of firms with different sensitivity levels before and after the pandemic. Consistent with my theoretical hypothesis, I anticipate a positive coefficient for the interaction term, indicating that the pandemic has a stimulating effect on the cash holdings of firms with high sensitivity.

Adopting Qin et al.'s (2020) model, I also incorporate a series of control variables to mitigate potential influences on the results. These include firm size (*SIZE*), leverage ratio (*LEV*), revenue growth rate (*GROWTH*), net return on assets (*NROA*), free cash flow (*FCF*), and accounts receivable turnover rate (*TR*). Specifically, *Size* represents the logarithm of total assets, as larger firms are presumed to have access to better financing channels for cash acquisition (Gao, Harford, and Li, 2013). *LEV* reflects the firm's debt situation, with higher leverage demanding more cash for debt repayment (Gao, Harford, and Li, 2013). Moreover, *NROA* indicates the ratio of net income to total assets, with higher cash holdings leading to missed investment opportunities (Clarkson, Gao, and Herbohn, 2020). *Growth* represents the revenue growth rate, with high-growth firms being more inclined to continue investing (Gao, Harford, and Li, 2013). Free cash flow (*FCF*) and accounts receivable turnover rate (*TR*) respectively measure the firm's cash flow condition and working capital management status. Effective management of both can lead to a reduction in cash holdings (Gao, Harford, and Li, 2013).

Furthermore, I control for time and firm fixed effects to mitigate any potential interference from omitted variables.

3.2.2 COVID-19 and Firms with Varied R&D Investments

Another set of control experiments in my study compares the impact of COVID-19 on the cash flow levels of firms with different levels of R&D investments. Here, the treatment group consists of R&D-intensive firms, while the control group comprises other firms. I employ the following model to test the second hypothesis:

$$Cashholdings_{it} = \lambda_0 + \lambda_1 RD_{it} * Period_{it} + \lambda_2 RD_{it} + \lambda_3 Period_{it} + \lambda_4 SIZE_{it} + \lambda_5 LEV_{it} + \lambda_6 GROWTH_{it} + \lambda_7 NROA_{it} + \lambda_8 FCF_{it} + \lambda_9 TR_{it} + \lambda_{10} ENT + \beta_{11} TIME + \varepsilon_{it} \quad (2)$$

In this model, *RD* is a virtual variable representing research and development (R&D) intensity. If a company has higher R&D expenditure, it equals 1, otherwise 0. Companies are allocated into four quartiles based on the ratio of R&D expenses to sales in the first quarter of 2018, representing R&D intensity. Subsequently, companies spending more on R&D are classified into the fourth quartile, which reports the highest R&D expenses to sales ratio. The meanings of the other variables are consistent with Formula (1).

IV. Descriptive Statistics and Parallel Trend Test

4.1 Descriptive Statistics

The descriptive statistics are presented in Table 1. The mean of the dependent variable, *Cash Holdings*, is 1.0379. The maximum and minimum values are 24.4490 and -25.3389, respectively, with a standard deviation of 10.3163. This indicates significant variability in the cash holding levels across firms. Furthermore, for R&D-intensive North American publicly traded companies, there is relatively little variance, with a standard deviation of 0.6034. Table 1 provides the descriptive statistics for the other control variables as well.

Table 1: Pooled Firm-Quarter Descriptive Statistics

VARIABLES	(1) N	(2) Mean	(3) Std. Dev.	(4) Min.	(5) Max.
<i>Cash Holdings</i>	15,657	1.0379	10.3163	-25.3389	24.4490
<i>RD</i>	15,657	0.2928	0.6034	0	2.5277
<i>Size</i>	15,657	6.5053	2.3692	2.0358	10.6237

<i>LEV</i>	15,657	0.2388	0.2077	0	0.6945
<i>GROWTH</i>	15,657	0.0444	0.2260	-0.4199	0.7089
<i>NROA</i>	15,657	-0.0201	0.0644	-0.2006	0.0531
<i>FCF</i>	15,657	0.9519	1.6786	-3.3617	5.0614
<i>TR</i>	15,657	0.0023	0.0023	0.0003	0.0101

This table reports summary statistics for the main variables used in the analyses. All firm-quarter observations are between the first quarter of 2018 and the first quarter of 2022.

4.2 Parallel Trend Test

I tested the parallel trend of the two groups of comparative experiments respectively, and the results are shown in Figures 1 and 2.

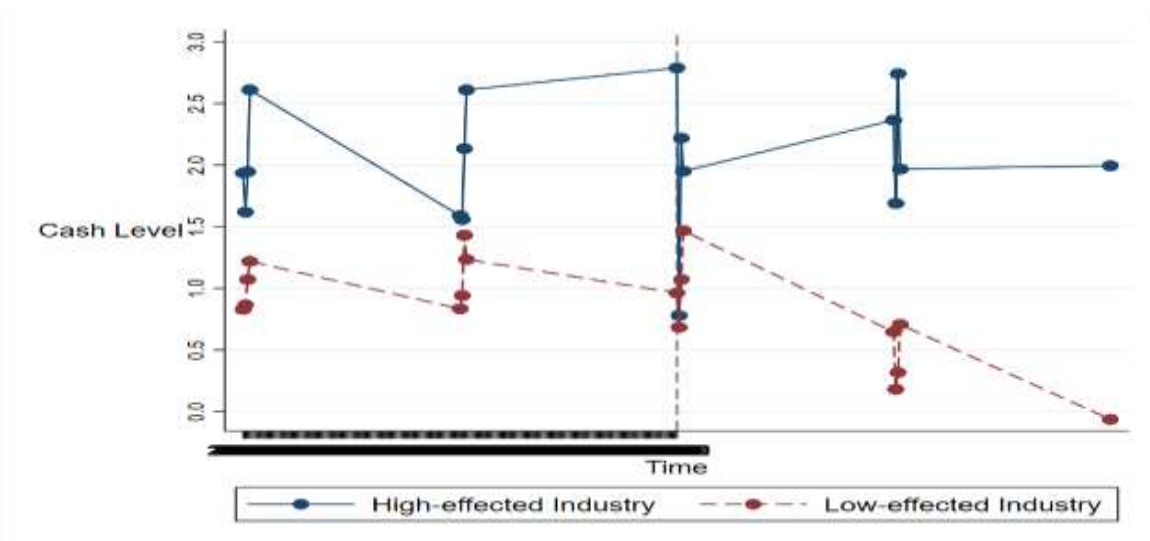


Figure 1

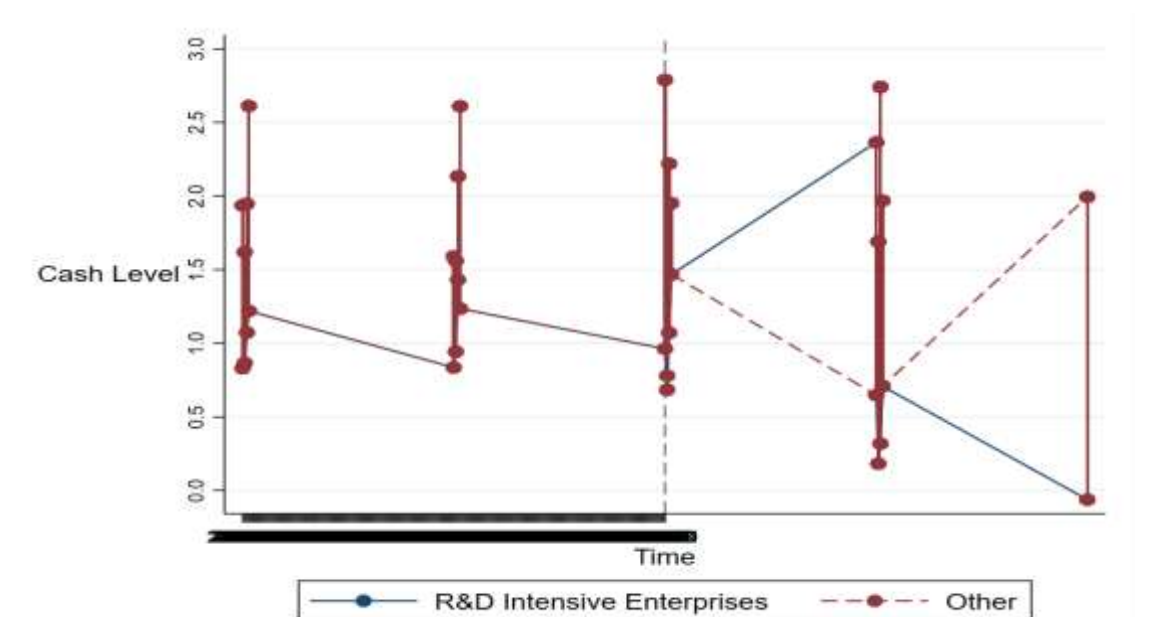


Figure 2

From the figures, it is evident that for our two comparative experiments, one involving high sensitivity and low sensitivity industries, and the other concerning high and low R&D investment firms, both Figure 1 and Figure 2 exhibit nearly identical trends before the outbreak of the pandemic. Hence, I have opted to employ the Difference-in-Differences (DID) method in my subsequent analyses.

V. RESULTS

5.1 The Result of Hypothesis 1

Table 2 reports the effects of the COVID-19 pandemic on cash flow holdings for firms in different sensitivity industries. The regression coefficient of Treated*Period is positive, with a value of 0.7541, and is statistically significant at the 0.1 level. This indicates that, under the influence of the pandemic, firms in high sensitivity industries increased their cash holdings relative to those in low sensitivity industries, as a means to buffer against systemic risks. This confirms my first hypothesis. As explained by Qin, et al. (2020), the equilibrium of supply and demand in the market for publicly listed companies, as well as production within the corporate supply chain, were significantly disrupted by the outbreak of COVID-19. This led to a collapse in sales and cash inflows. Inherent capital flow patterns became challenging to maintain, and the only way to increase cash holdings in response to operational risks was through short-term borrowing. The rapid elevation of cash flow levels by firms severely affected by the pandemic to mitigate operational risks also underscores the preventive motive for holding cash.

Table 2: The impact of COVID-19 on cash holdings: High effected vs Low Effected

Independent Variables	Coefficient Estimate	p-value
<i>Treated*Period</i>	0.7541	0.082
<i>Treated</i>	-0.4203	0.200
<i>Period</i>	-0.6684	0.000
<i>SIZE</i>	-0.2098	0.000
<i>LEV</i>	-0.4383	0.303
<i>GROWTH</i>	-0.1606	0.650
<i>NROA</i>	38.6983	0.000
<i>FCF</i>	0.1818	0.000
<i>TR</i>	57.0666	0.117
CONSTANT	0.6148	0.047
n		15,657
Adjusted R-squared		0.0730

5.2 The Result of Hypothesis 2

Table 3 presents the effects of the COVID-19 pandemic on the cash holding levels of firms with varying levels of R&D investment. The coefficient of the interaction term is negative, with a value of -1.6193, and is statistically significant at the 1% level. This indicates that the sudden crisis of the COVID-19 pandemic inhibited the ability of R&D-intensive firms to rapidly raise cash. This aligns with my second hypothesis. R&D-intensive firms faced greater liquidity constraints during the crisis compared to their non-R&D-intensive counterparts. This result is consistent with the literature on cash flow constraints amplifying issues during economic downturns (Zhang, 2015; Opler and Titman, 1993). For R&D-intensive firms with a higher proportion of non-current assets, asymmetric information reduced their credit limits, and elevated systemic risks hindered their financing avenues and scale. Consequently, the management of R&D-intensive firms faced significant challenges in increasing their cash flows in the short term when confronted with the economic downturn.

Table 3: The impact of COVID-19 on cash holdings: R&D Intensive Enterprises vs Others

Independent Variables	Coefficient Estimate	p-value
<i>RD*Period</i>	-1.6193	0.000
<i>RD</i>	-2.9593	0.000
<i>Period</i>	-0.0716	0.694
<i>SIZE</i>	0.1913	0.000
<i>LEV</i>	-1.0050	0.016
<i>GROWTH</i>	-0.0773	0.825
<i>NROA</i>	25.8365	0.000
<i>FCF</i>	0.1511	0.001
<i>TR</i>	-3.2782	0.925
CONSTANT	1.4105	0.000
n		15,657
Adjusted R-squared		0.0930

VI. Robustness Tests

To get more robust outcomes, I employed cash and cash equivalents as alternative dependent variables. Cash and cash equivalents, measured as a ratio to current operating revenue, served as indicators to assess a firm's cash holding level. The obtained results are presented in Tables 4 and 5, respectively.

**Table 4: The impact of COVID-19 on cash holdings: High effected vs Low Effected
Robustness test by replacing dependent variable**

Independent Variables	Coefficient Estimate	p-value
<i>Treated*Period</i>	0.9736	0.035
<i>Treated</i>	-0.4838	0.166
<i>Period</i>	-0.6642	0.000
<i>SIZE</i>	0.2051	0.000
<i>LEV</i>	-1.0945	0.016
<i>GROWTH</i>	-0.0414	0.912
<i>NROA</i>	50.1967	0.000
<i>FCF</i>	0.1382	0.006
<i>TR</i>	102.8126	0.008
CONSTANT	1.1878	0.000
N		15,657
Adjusted R-squared		0.099

**Table 5: The impact of COVID-19 on cash holdings: R&D Intensive Enterprises vs Others
Robustness test by replacing dependent variable**

Independent Variables	Coefficient Estimate	p-value
<i>Rd*Period</i>	-1.5138	0.000
<i>RD</i>	-4.0292	0.000
<i>Period</i>	-0.0399	0.836

SIZE	0.1821	0.000
LEV	-1.8014	0.000
GROWTH	0.0786	0.832
NROA	33.8710	0.000
FCF	0.0989	0.048
TR	29.2892	0.426
CONSTANT	2.2604	0.000
N		15,657
Adjusted R-squared		0.1253

For both of the aforementioned hypotheses, consistent results were observed when using alternative dependent variables. In the case of the first hypothesis test, employing the ratio of cash and cash equivalents to current operating revenue as an indicator of cash holding level yielded an interaction coefficient of 0.9736, significant at the 5% level. This suggests a positive impact of the pandemic on the cash flow holding level in sensitive industries. Concerning the second hypothesis, the interaction coefficient was -1.5138, significant at the 0.01 level, indicating a significant negative effect of the pandemic's shock on the cash flow of R&D-intensive enterprises. These findings align with the previous results.

VII. CONCLUSION

This study delves into alterations in cash holding levels among publicly traded companies in the North American region prior to and following the onset of the COVID-19 pandemic. Two distinct sets of comparative experiments have been crafted, predicated upon differing corporate characteristics. The initial set of experiments seeks to elucidate the pandemic's influence on cash reserve levels within industries characterized by varying degrees of sensitivity. Notably, these investigations reveal a substantial and positive impact of the COVID-19 pandemic on cash holdings within sensitive industries. This underscores the prevention motivation of underpinning cash reserve management, as a greater number of firms opted to augment their cash reserves as a safeguard against systemic risks.

The second set of experiments investigates the effect of the pandemic on the cash holdings of R&D-intensive companies. The results reveal a significant negative impact of the pandemic on the cash holding levels of R&D-intensive enterprises, highlighting the vulnerability magnified in R&D-intensive companies during Black Swan events. Holding non-current assets and limited external financing emerged as major obstacles for R&D-intensive companies to maintain cash holding levels.

Cash holding levels have long been a crucial research topic in corporate finance due to their pivotal role in a company's operations. In the occurrence of Black Swan events, abrupt financial crises within companies may ensue due to a confluence of factors, including industry-specific economic shutdowns, disparities in market supply and demand, and unforeseen liquidity shortages. At the firm level, disruptions in cash flow represent a direct antecedent to bankruptcy. Within the context of the supply chain, inter-firm commercial relations can be profoundly impacted by uncontrollable instances of bad debt, thereby diminishing the cash flows generated from operational endeavors. Furthermore, the heightened costs associated with epidemic prevention measures in response to the COVID-19 pandemic have emerged as a significant source of strain on cash flows. In response, management is compelled to bolster cash reserves as a means of ensuring the firm's resilience during turbulent periods and to offset escalating fixed expenses. Nonetheless, non-systemic risks, such as overly ambitious merger and acquisition activities, constrict a firm's credit capacity, thereby complicating efforts to sustain adequate cash holdings and liquidity.

For R&D-intensive companies, the impact of Black Swan events seems unjust, primarily due to external financing constraints. When the cash flows of R&D-intensive companies are more adversely affected by Black Swan events, they may need to make more significant adjustments to their financing strategies. Policymakers

should promote more sustainable R&D projects by setting limits on the R&D expenditure intensity of public enterprises simultaneously. In conclusion, companies with different characteristics should maintain constant attention to cash flows. Prompt and effective communication between managerial authorities and shareholders is imperative to secure essential cash flow support. This strategic approach aids in sustaining elevated cash holding level to effectively navigate and mitigate unforeseen risks.

APPENDIX

VARIABLES	VARIABLES DEFINITION
Cash holdings	Enterprise cash holding level: monetary capital/current operating income.
Treated	The dummy variable of “outbreak impact degree” is 1 if the enterprise belongs to the high-impact region/industry, otherwise it is 0.
Period	The dummy variable of “outbreak time” is 1 after the outbreak, or 0 otherwise
RD	The dummy variable representing research and development (R&D) intensity. If a company has higher R&D expenditure, it equals 1, otherwise 0.
Size	The size of an enterprise is measured by the logarithm of its total assets
Lev	The asset-liability ratio is the total liabilities/total assets measure.
Growth	Growth rate of operating income
NROA	Net profit margin on total assets, net profit/ending balance on total assets.
FCF	Free cash flow, EBITDA + depreciation and amortization – working capital increase – capital expenditure.
TR	Trade receivable turnover/1000, Trade receivable turnover = Revenue/average trade receivable balance.
ENT	Used to control enterprise fixed effect.
YEAR	Used to control the fixed effect of year.

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