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Do Financing Constraints Moderate the Effect of Digital Transformation on Corporate Cash Holdings? Evidence from China

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Abstract

This study examines the impact of digital transformation on corporate cash holdings using panel data from 3,920 Chinese listed companies over the period from 2012 to 2021. By constructing a digital transformation index based on corporate annual reports, we explore how these transformations affect firm-level cash reserves, with a particular focus on the moderating role of financing constraints. The results indicate that digital transformation generally leads to a reduction in corporate cash holdings, although this effect is significantly weakened in the presence of strong financing constraints. Heterogeneity analysis further reveals that the negative impact of digital transformation on cash holdings is more pronounced in firms with lower levels of digital transformation and in non-loss-making companies. These findings provide valuable insights for corporate financial management and policymaking, highlighting the strategic importance of optimizing cash management practices under varying degrees of financial constraints in the context of digital transformation.

Keywords: digital transformation, corporate cash holdings, financing constraints, machine learning, China

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Introduction

With the advent of the digital age, enterprises have experienced a fundamental transformation in how they operate, innovate, and compete. Digital transformation, which involves integrating digital technologies into all aspects of business operations, has become a strategic imperative for firms striving to remain competitive and achieve sustainable growth [1]. While this shift has led to substantial research into the macroeconomic impacts of digital transformation [2–3], the microeconomic effects, particularly on corporate cash holdings, remain insufficiently explored. Addressing this gap can generate offer valuable insights for corporate financial management andpolicymakers.

In the context of China, the world's second-largest economy and an emerging hub for technological innovation, digital transformation has become a cornerstone of economic policy [4]. Initiatives such as "Made in China 2025" and the promotion of Industry 4.0 reflect the nation's commitment to fostering a digital economy. These policies aim not only to enhance productivity and innovation but also to drive a structural shift towards a more digital and resilient economic model. According to the "White Paper on China's Digital Economy Development" (2021) by the China Academy of Information and Communications Technology, the scale of China's digital economy has reached 39.2 trillion yuan (approximately 5.4 trillion USD), accounting for 38.6% of China's GDP [5]. The support from national strategies and the wealth of corporate data provide an ideal environment to examine the specific impact of digital transformation on corporate financial behaviors, particularly with regard to cash holdings.

Corporate cash holdings serve as a crucial financial buffer, enabling firms to navigate uncertainties, seize investment opportunities, and mitigate risks associated with external financing constraints [6]. Operating in the largest developing country, Chinese firms often hold substantial cash reserves due to high costs and limited financing channels [7]. Digital transformation, with its potential to enhance operational efficiency and reduce costs, could reduce the need for accumulating large cash reserves to ensure liquidity and financial flexibility. Investigating this dynamic within the Chinese context is of significant relevance to both academic researchers and corporate managers. Moreover, the moderating role of financing constraints adds another layer of complexity. Companies facing stringent financing constraints may encounter greater challenges in accessing capital, which impacts their cash-holding strategies. Understanding how financing constraints interact with digital transformation to impact cash holdings is of significant interest to corporate managers and policymakers.

Despite extensive research on digitalization, there is limited understanding of its financial implications, particularly in terms of how it affects cash management. This study aims to address this underexplored aspect by providing new insights into the financial implications of digital transformation. Utilizing panel data from 3,920 Chinese listed companies between 2012 and 2021, and employing machine learning techniques to extract digital transformation information from annual reports, this study offers empirical evidence on the intricate dynamics between digital transformation, cash holdings, and financial constraints. Our findings reveal that digital transformation generally reduces corporate cash holdings, indicating that the efficiencies and innovations brought about by digital initiatives enable firms to operate with less cash. However, the presence of financing constraints significantly mitigates this effect, suggesting that constrained firms may still hold higher cash reserves to guard against capital challenges. In addition, the heterogeneity test indicates that the negative impact of digital transformation on cash holdings is more pronounced in firms with a lower degree of digital transformation and in non-loss-making companies.

By elucidating these relationships, this paper contributes to the financial literature in two significant ways. First, by examining the relationship between digital transformation and corporate cash holdings through the lens of agency theory, this study enhances the understanding of how digital initiatives impact corporate financial behavior. This adds a new dimension to the agency theory framework, highlighting the role of digital transformation in mitigating agency problems and optimizing cash management strategies. Second, by exploring the moderating effect of financing constraints from the perspective of financial distress theory, our analysis reveals that firms facing greater financing constraints tend to hold higher cash reserves despite undergoing digital transformation, emphasizing the precautionary motive for cash holdings in a constrained financial environment. This insight enriches financial distress theory by integrating the impact of digital transformation on corporate liquidity management practices. At the same time, our findings on the effect of digital transformation on cash holdings provide valuable insights for corporate financial managers. By understanding how digital transformation influences cash reserves, companies can better strategize their financial management, optimize cash allocation, and improve liquidity management, particularly in firms with different levels of digital transformation or financial health. Furthermore, as China rapidly advances its digital transformation agenda, this study expands the literature on factors influencing corporate cash holdings and provides important grounds for developing digital policies and corporate financial strategies in emerging economies.

The remainder of this paper is organized as follows: second section presents the theoretical background and hypothesis development; third section details the research methodology; fourth section discusses the research findings and robustness checks; and the final section concludes the paper.

Theoretical Foundations and Hypothesis Development

Agency Theory

Agency theory provides a framework for understanding the relationship between principals (shareholders) and

agents (managers). Initially proposed by M. Jensen (1996) [8], the theory posits that due to differing objectives, there is often a divergence of interests between the two parties, leading to agency problems. These problems arise when managers do not always act in the best interest of shareholders. As discussed by S. Myers and N. Majluf (1984) [9], information asymmetry exacerbates agency problems by limiting shareholders' ability to monitor and control managerial behavior, a situation commonly referred to as the first-order agency problem.

In corporate finance, one of the central issues addressed by agency theory is the management of corporate resources, particularly cash holdings. Managers, when in control of excess cash, may be incentivized to retain it within the company rather than distribute it to shareholders. This retention enhances managerial discretion and reduces the need to seek external financing, which can be linked to managerial entrenchment. Entrenchment occurs when managers undertake actions that benefit themselves, such as investing in projects that enhance their personal power or job security, often at the expense of shareholder interests [8; 9].

Jensen's (1996) [8] free cash flow hypothesis further elaborates on how excess cash can lead to inefficient capital allocation. Managers may engage in empire-building or pursue personal perks, resulting in suboptimal investment decisions. Such opportunistic behavior not only deviates from the goal of maximizing shareholder wealth but can also lead to significant value destruction within the firm [10].

Moreover, as highlighted by A. Shleifer and R. Vishny (1997) [11], the degree to which these agency problems manifest themselves is influenced by a company's corporate governance structure. Firms with weak governance are more susceptible to managerial opportunism, exacerbating the inefficiencies associated with excess cash holdings [12]. This underscores the importance of aligning managerial incentives with shareholder interests through mechanisms such as performance-based compensation and rigorous oversight.

In summary, agency theory underscores the potential risks associated with excessive cash holdings, particularly in environments characterized by high information asymmetry and weak governance. These risks highlight the need for effective governance mechanisms to mitigate agency problems and ensure that cash management practices align with the goal of maximizing shareholder value.

Financial Distress Theory

Financial distress theory provides a critical perspective for understanding how financial constraints influence corporate behavior, particularly regarding cash holdings. This theory posits that firms facing severe financial distress may hold more cash as a precautionary measure [13]. Financially constrained companies have limited access to external capital markets, making them heavily reliant on internal funds to navigate periods of financial instability [14]. Consequently, these firms maintain higher cash reserves to ensure liquidity and financial flexibility.

In practice, financial distress in companies is a gradual process, typically evolving from a state of financial normalcy to a financial crisis. Many companies with financial distress experience a progressive deterioration in their financial condition, which ultimately leads to financial distress or bankruptcy. Cash flow is a crucial indicator for managers to assess the operational status of a company [13–14]; and the value of a company should be equal to the net present value of its expected cash flows. Previous studies have shown that if a company lacks sufficient cash to meet its debt obligations and cannot secure funds through other means, it will eventually face bankruptcy [15].

Digital Transformation

Recent studies have highlighted the transformative impact of digital technologies on firm performance and strategic operations. Scholars broadly define digital transformation as the integration of digital technologies – such as mobile computing, artificial intelligence, and cloud computing – into business processes to drive significant improvements in value creation and competitiveness [16]. This transformation is characterized by fundamental changes in organizational structures and processes, leading to enhanced productivity and innovative business models.

The process of digital transformation typically unfolds in three stages: digitization of information, the use of digital technologies to optimize existing processes, and strategic shifts in business models to leverage digital advancements [17]. Enterprises that adopt digital transformation strategies gain competitive advantages by improving production processes, reshaping organizational structures, and altering value-creation mechanisms [16–17].

Digital resources, such as big data and advanced technologies, are critical for enhancing firm performance and guiding management practices. These resources enable firms to better understand consumer demand, offer customized services, and strengthen supply chain relationships [18]. Furthermore, digital transformation facilitates business model innovation and efficiency improvements within platforms and ecosystems [19].

Despite these advancements, the impact of digital transformation on corporate finance remains underexplored. Researchers have primarily focused on operational improvements, overlooking how digital transformation influences financial behavior, particularly in areas like cash management and investment strategies. This gap underscores the need for further investigation into the financial consequences of digital transformation within firms.

Financing Constraints

In a perfect capital market, external and internal capital are completely interchangeable, meaning a firm's investment behavior is unaffected by its financial condition and is driven solely by its investment needs [20]. However, the reality of capital markets is far from perfect. Due to issues such as information asymmetry and agency problems, external financing costs are typically higher than internal financing costs, leading a firm's investment decisions to be

endogenous to its financing capacity. Firms generally have three primary channels for raising investment funds: retained earnings, debt financing, and equity financing [21]. Retained earnings are considered internal financing, while debt and equity represent external financing.

In practice, financial markets are not perfectly efficient, and there exists information asymmetry between external investors (such as creditors and shareholders) and corporate managers. Unlike managers, external investors do not have comprehensive knowledge of the firm's investment projects [22]. This information gap can lead to opportunistic behavior by managers, who may prioritize personal gain over the interests of external investors [23]. Although external fund providers can anticipate potential conflicts of interest with managers, the high costs of monitoring and the free-rider problem often prevent them from effectively reducing information asymmetry [24]. To control risks, external investors typically adopt two strategies: raising the interest rate on funds supplied or implementing credit rationing, where only some loan applicants receive funding while others are denied. This situation imposes financing constraints on corporate investment [25].

One challenge faced by empirical research is the measurement of financing constraints. A common approach is to consider a firm's balance sheet information, such as cash holdings or leverage ratios [26]. However, cash holdings, for example, represent an endogenous financial choice, and it is unclear whether this variable always correlates with improved liquidity access. For instance, if a firm cannot secure alternative financing, it might decide to increase its cash holdings. Alternatively, some studies employ survey data or leverage bank-firm relationship data to utilize exogenous shocks from banks and their impact on firms (e.g., K. Bae et al., 2002 [27]).

It is important to note that scholars have varied understandings of financing constraints. To reflect the alignment between a firm's financing capacity and the external financing environment, most existing studies choose to measure financing constraints using indices such as the KZ Index, SA Index, WW Index and FC Index. The SA Index, constructed using only firm size and firm age, primarily analyzes the extent of internal information asymmetry within a firm to assess whether the financing market is affected by incomplete information [28]. T. Whited and G. Wu (2006) [29] developed the WW Index by selecting variables such as the ratio of operating cash flow to total assets, a dummy variable for dividend payments, the ratio of long-term debt to total assets, the logarithm of total assets, industry sales growth, and sales revenue growth. S. Fazzari et al. (1988) [30] used dividend payout ratios and firm size as proxies for financing constraints, focusing on those arising from information asymmetry. Meanwhile, S. Kaplan and L. Zingales (1997) [31] defined financing constraints using financial variables, emphasizing constraints due to financial distress.

The WW Index is considered one of the better metrics for measuring financial constraints. It offers several advantages over other indices, such as the KZ index, the SA index, and the FC index. First, the WW index is based on a structural model of corporate investment, which provides a more robust theoretical foundation compared to the reduced-form models on which the KZ and SA indices rely. This stronger theoretical grounding enables the WW index to align more closely with economic theory when capturing firms' financing constraints. Second, the WW index places a greater emphasis on firm-specific financial frictions, making it more sensitive to variations in financial constraints across firms. It accounts for critical factors such as cash flow sensitivity to investment and corporate leverage, which are key to identifying financial constraints accurately. Third, the WW index is more effective at mitigating potential endogeneity issues, particularly those associated with the KZ index, which may be influenced by variables like leverage and dividend policy that are themselves affected by other firm-specific factors. This reduction in endogeneity is especially beneficial when examining the sensitivity of investment to cash flow.

Corporate Cash Holdings

The study of corporate cash holdings is evolving into a new theoretical framework, with key determinants such as precautionary, agency, and transaction motives shaping firm behavior.

Precautionary Motive. Cash holdings serve as a buffer for firms to seize potential investment opportunities, especially under financial constraints. Actually, internal financing is less costly and more readily available than financing from external sources [9]. Consequently, firms facing significant financing constraints tend to accumulate cash reserves as a precaution [32]. This tendency intensifies in uncertain environments, where increased risks prompt firms to hold more cash.

Agency Motive. Agency problems arise from the separation of ownership and management, where managers may hoard excess cash for personal gain or empire-building activities [8]. Additionally, controlling shareholders can exploit cash holdings to the detriment of minority shareholders [33]. Corporate governance plays a crucial role in mitigating these agency issues. For instance, stronger shareholder rights are associated with lower cash holdings, as firms in countries with better protection hold less cash [34].

Transaction Motive. Cash is essential for daily operations, especially since non-cash assets are less liquid. Firms maintain cash to meet operational needs, with factors such as firm size, wage costs, and transaction costs influencing cash holdings [35]. Moreover, companies with substantial cash reserves often invest more in R&D, leading to higher asset growth [36–37].

While digital transformation is recognized for reshaping business models and organizational structures, its impact on corporate finance, particularly cash holdings, remains underexplored. As digital transformation influences resource allocation, understanding its effect on cash holdings is crucial for enriching the literature on the economic consequences of digital strategies.

Hypothesis Development

Managers' agency motives are often built upon information asymmetry with shareholders, allowing them to engage in personal consumption and empire-building [8]. Digital transformation simplifies and enhances the efficiency of a company's information structure. By improving information processes, digital investments can reduce the costs associated with collecting and disseminating internal information, thus mitigating information asymmetry.

On the one hand, digital transformation provides stakeholders with technological tools to more effectively monitor managerial opportunistic behavior [38]. For example, Z. Riaz et al. (2022) [39] demonstrated that digitalization enhances information transparency and corporate governance levels, thereby curbing financial corruption within companies. On the other hand, digital tools such as enterprise resource planning systems and financial management software enable real-time monitoring and management of cash flows, improving the transparency and accuracy of fund utilization [40]. This helps firms optimize cash flow management, reducing waste due to information asymmetry or mismanagement, consequently lowering cash holdings. Based on the above discussion, we propose the following hypothesis:

H1: Digital transformation has a negative and significant effect on corporate cash holdings.

During digital transformation, firms typically require substantial investments to acquire technologies, train personnel, and upgrade systems. These investments can strain cash flows, particularly in the short term, potentially adversely affecting corporate liquidity [41]. Financial distress theory emphasizes that firms facing financing constraints often struggle to alleviate short-term cash needs through external financing [11]. Consequently, such firms may adopt a more cautious approach to cash management during digital transformation, driven by a precautionary motive to retain cash buffers, thereby mitigating potential financial pressures and risks arising from the transformation. For instance, they may prefer holding more cash reserves to safeguard against operational risks or uncertainties stemming from digital transformation [42]. Thus, we posit the following hypothesis:

H2: Financial constraints play a moderating role in mitigating the negative effect of digital transformation on corporate cash holdings.

Digital transformation, characterized by the integration of advanced technologies into business operations, typically enhances efficiency, reduces operational costs, and optimizes resource allocation [7]. These improvements often lead to a decreased need for large cash reserves, as digitalized processes streamline financial management, enabling firms to better predict cash flows and manage working capital [16]. However, firms with a lower degree of digital transformation may not fully realize these benefits. In such firms, the inefficiencies and uncertainties inherent in a lower level of digitalization can lead to a stronger reliance on cash holdings as a buffer against operational risks and unforeseen contingencies. Therefore, the negative impact of digital transformation on cash holdings is likely to be more pronounced in firms that have not yet fully embraced digitalization, as they still rely on traditional, less efficient cash management practices. Thus, we formulate the following hypothesis:

H3: The effect of digital transformation on cash holdings is more pronounced in firms with a lower degree of digital transformation.

Digital transformation typically enhances operational efficiency, streamlines financial processes, and reduces the need for large cash reserves by enabling better cash flow predictions and more efficient capital management [43]. In firms that are not experiencing losses, the benefits of digital transformation are more fully realized, as these firms already have strong financial positions and stable cash flows [44]. As a result, they are less dependent on holding excess cash as a precautionary measure. Not facing the immediate pressure of covering losses, these firms can confidently invest in digital technologies that further reduce their reliance on cash reserves. Thus, the negative impact of digital transformation on cash holdings is expected to be more pronounced in non-loss-making firms, as they can more aggressively optimize their cash management practices through digitalization, unlike firms with losses that might still need to maintain higher cash levels for financial security. Thus, we propose the following hypothesis:

H4: The effect of digital transformation on cash holdings is more pronounced in firms that are not facing losses.

Methods

Sample and Data

Our sample includes A-share listed companies in China from 2012 to 2021. The digital transformation data is sourced from corporate annual reports, while the WW index and other financial data are taken from the China Stock Market & Accounting Research (CSMAR) database. We conducted the following preprocessing steps on the initial sample: First, due to governance structure differences in the financial industry, companies from this sector were excluded. Second, companies flagged with "ST" by the China Securities Regulatory Commission for two consecutive years of insolvency, indicating severe financial distress, were removed to mitigate their disproportionate impact. Third, companies lacking accounting and related financial data were excluded. The final sample consists of 26,694 annual observations from 3,920 enterprises. Lastly, to mitigate the influence of extreme values, we winsorized all continuous variables at the 1st and 99th percentiles.

Variable Measurement and Estimations Techniques

The dependent variable in this study is corporate cash holdings (CCH). Following T. Opler (1999) [45], we measure CCH using the ratio of cash and cash equivalents divided by total assets.

Digital transformation (DT) serves as the independent variable of interest in this study. Annual reports reflect company strategies and future digital directions, suggesting that textual analysis of annual reports can effectively capture the strategic orientations of firms [46]. Building on W. Tu and J. He (2022) [47], this study employed Python web scraping to construct measures of digital transformation. First, we utilized terms such as "artificial intelligence", "cloud computing", "blockchain", "big data", and "digital technology application" as seed words. Second, the Python modules Jieba and Re were employed for text extraction, cleaning, matching, and frequency counting, including segmentation and stop-word removal to create the study's corpus. Third, the corpus underwent training using a machine-learning word2vec model to generate word vectors and compute semantic similarities among words. This facilitated the identification of words semantically related to the seed words. Fourth, leveraging the generated five-dimensional seed dictionary, the study computed the frequency of occurrence of key digital transformation terms across firms. Given the typical right-skewed nature of such data, frequencies were subsequently natural logarithm transformed, and adjusted by adding 1 (i.e., LN (frequency of keyword occurrence + 1)), to measure the extent of digital transformation among all A-share listed companies in China.

Furthermore, the WW index is constructed using the generalized method of moments (GMM) to estimate the investment Euler equation. Unlike the KZ index, the WW index more accurately reflects firm characteristics associated with external financing constraints. It captures the common movements in returns among constrained firms, indicating the presence of a financial constraints factor. As a result, we employ the WW index obtained from the CSMAR database as a moderating variable to enhance the robustness of our analysis. Generally, a higher WW index indicates more severe financial constraints faced by the company.

Moreover, the study identifies several control factors potentially affecting corporate cash holdings, aligning with prior research. These include Firm Age (natural logarithm of years since establishment plus one), Return on Assets (net income divided by total assets), Financial Leverage (total debts divided by total assets), Board Size (natural logarithm of total board directors), and Ownership Concentration (percentage of shares owned by the largest shareholder). Refer to Table 1 for variable details and measurements.

To test hypothesis H1 to H4, we construct the following empirical models:

$$CCH_{i,t} = \alpha_0 + \alpha_1 DT_{i,t} + \alpha_2 FA_{i,t} + \alpha_3 ROA_{i,t} + \alpha_4 LEV_{i,t} + \\ + \alpha_5 BS_{i,t} + \alpha_6 TOP1_{i,t} + Year + Firm + \varepsilon; \quad (1)$$

$$CCH_{i,t} = \alpha_0 + \alpha_1 DT_{i,t} + \alpha_2 FC_{i,t} + \alpha_3 FC * DT_{i,t} + \\ + \alpha_4 FA_{i,t} + \alpha_5 ROA_{i,t} + \alpha_6 LEV_{i,t} + \alpha_7 BS_{i,t} + \\ + \alpha_8 TOP1_{i,t} + Year + Firm + \varepsilon, \quad (2)$$

where α_0 denotes the intercept, $\alpha_1 - \alpha_8$ are the coefficients to be estimated. This study added dummy variables that control for year and firm fixed effects (Year and Firm); ε is the error term; i denotes the cross-sectional dimension for firms; and t denotes the time series dimension.

Table 1. Summary of Variable Descriptions and Measurements

	Measurement
Panel A: Dependent Variables	
Corporate Cash Holdings (CCH)	The ratio of cash and cash equivalents divided by total assets
Panel B: Independent Variables	
Digital Transformation (DT)	The natural logarithm of the frequency of keyword occurrence plus one
Panel C: Moderating Variables	
Financing Constraints (FC)	The WW index
Panel D: Control Variables	
Firm Age (FA)	The natural logarithm of the number of years since the firm's establishment plus one
Return on Assets (ROA)	The book value of net income divided by total assets
Financial Leverage (LEV)	The book value of total debts divided by total assets
Board Size (BS)	The natural logarithm of the total number of directors on the firm's board
Ownership Concentration (TOP1)	The percentage of shares owned by the largest shareholder

Source: prepared by the author.

Findings and Discussion

Descriptive Statistics and Correlation Matrix

The descriptive statistics for the key variables in our study are presented in Table 2, including the mean, standard deviation, minimum, and maximum values. For CCH, the mean and standard deviation are 0.049 and 0.067; for DT, 1.417 and 1.389; and, for FC, –1.025 and 0.073, respectively. Regarding control variables, the sample firms exhibit an average FA of 2.922, LEV of 0.422, ROA of 0.041, BS of 2.122, and TOP1 of 34.284.

Table 2. Descriptive Statistics

Variables	N	Mean	Std	Min	Max
CCH	26,694	0.049	0.067	-0.159	0.241
DT	26,694	1.417	1.389	0	5.056
FC	22,494	-1.025	0.073	-1.226	-0.845
FA	26,694	2.922	0.319	1.609	3.496
LEV	26,694	0.422	0.203	0.050	0.893
ROA	26,694	0.041	0.063	-0.239	0.222
BS	26,694	2.122	0.198	1.609	2.708
TOP1	26,694	34.245	14.820	8.630	74.180

Source: prepared by the author.

Table 3. Pearson Correlation

	CCH	DT	FC	FA	LEV	ROA	BS	TOP1	VIF
CCH	1.000								-
DT	-0.027***	1.000							1.03
FC	-0.223***	-0.006	1.000						1.49
FA	0.006	0.019***	-0.081***	1.000					1.06
LEV	-0.170***	-0.070***	-0.322***	0.163***	1.000				1.52
ROA	0.413***	0.016***	-0.266***	-0.081***	-0.359***	1.000			1.44
BS	0.041***	-0.082***	-0.230***	0.053***	0.154***	-0.005	1.000		1.07
TOP1	0.099***	-0.116***	-0.243***	-0.090***	0.059***	0.127***	0.027***	1.000	1.10

Note: this table shows the correlation coefficients for the main variables defined in Table 1. The lower triangle in this table shows the Pearson correlation coefficients. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$, respectively.

Source: prepared by the author.

Table 3 presents the results of the Pearson correlation matrix, used to evaluate potential multicollinearity among independent variables. The coefficients range from –0.359 to 0.413, and the highest variance inflation factor (VIF) value is only 1.52, which is well below the critical threshold. These results indicate that multicollinearity is not a significant concern in this study. Moreover, preliminary findings suggest a negative impact of DT on CCH, aligning with our hypothesis H1. However, further validation is warranted.

Baseline Results

To assess the impact of digital transformation (DT) on corporate cash holdings (CCH), this study investigates the relationship between DT and CCH in column (1) of Table 4. The results indicate that DT significantly reduces CCH, with a coefficient of –0.002 at the 1% significance level ($\alpha_1 = -0.002$, $p < 0.01$). Additionally, five control variables were included in the panel data model to further empirically test this relationship. The estimation results in column (2) show that the coefficient for the key explanatory variable DT remains significantly negative ($\alpha_1 = -0.002$, $p < 0.01$). Economically, this effect is substantial, as a one standard deviation increase in DT is associated with a 4.15% decrease in the standard deviation of CCH. These findings support Hypothesis 1 and align with X. Qu and B. Zhu (2023) [48]'s perspective, which posits that digital technology adoption reduces the strategic aggressiveness of companies, thereby lowering their cash holdings.

Regarding the control variables, firm age (FA) positively impacts cash flow, suggesting that older firms possess more operational experience and tend to hold more cash to manage uncertainties and potential risks. Furthermore, there is a positive relationship between return on assets (ROA) and CCH, implying that firms with higher ROA may retain cash for future high-return investment opportunities, enhancing profitability. Overall, these control variable results are consistent with prior studies, such as C. Hadlock and J. Pierce (2010) [28].

Table 4. Baseline Regression Results

	(1) CCH	(2) CCH
DT	-0.002***	-0.002***
	(-2.663)	(-2.997)
FA		0.018**
		(1.990)
LEV		-0.007
		(-1.314)
ROA		0.256***
		(20.792)
BS		-0.003
		(-0.764)
TOP1		-0.000
		(-0.965)
Cons	0.049***	0.002
	(35.596)	(0.086)
Year FE	Yes	Yes
Firm FE	Yes	Yes
N	26694	26694
Adj. R^2	0.016	0.070

Note: statistical significance is denoted by ***, **, and *, representing levels of significance at the 1%, 5%, and 10% thresholds, respectively. T-statistics (shown in parentheses) are calculated using standard errors adjusted for firm-level clustering. All variables are defined in Table 1.

Source: prepared by the author.

Robustness Check

So far, the baseline results reveal a negative relationship between digital transformation and corporate cash holdings. In this section, we employ additional methodologies to ensure the robustness of our findings.

First, adjusting cluster-robust standard errors to the industry level. Standard errors play a pivotal role in statistical inference, directly impacting the significance of coefficients, confidence intervals, and ultimately hypothesis testing conclusions. Therefore, accurately estimating standard errors is paramount in empirical analysis. Expanding robust standard errors to the industry level allows for a more comprehensive consideration of shared characteristics and market influences among firms within the same industry. This approach further mitigates biases introduced by data structure or sampling methods. The results in columns (1) of Table 5 demonstrate that after clustering robust standard errors at the industry level, the negative coefficient of DT is statistically significant at the 1% level, confirming the robustness of our findings.

Second, adding province and city fixed effects. Considering the potential specific characteristics and environmental influences across different provinces and cities, we introduce these fixed effects to further reduce biases introduced by geographic or administrative differences. By incorporating these fixed effects, we ensure that the statistical inferences of our results are robust across different geographic and urban contexts, thereby enhancing the credibility and generalizability of our findings. We assign dummy variables based on the registered locations of the sample firms at the province and city levels. Columns (2) of Table 5 present results that exhibit consistent coefficient signs and significance levels with the baseline regressions, confirming that geographic or administrative differences do not affect the robustness of our conclusions.

Third, using propensity score matching (PSM) method. In empirical research, sample selection bias can lead to biased estimates. PSM addresses this by matching individuals in the treatment group with those in the control group based on the similarity of observed characteristics, thereby creating a more balanced sample. This approach better simulates the conditions of a randomized experiment, reducing the impact of confounding variables and ensuring more reliable and valid estimates of the treatment effect. Specifically, we aim to ensure that firms with DT (treatment group) and without DT (control group) are comparable in other respects. To achieve this, we use control variables consistent with the baseline regression as covariates and implement 1:1 nearest neighbor matching. Columns (3) of Table 5 report the re-estimated results using the propensity score matching methods. The results show that the impact of DT on CCH remains significantly negative, indicating that the results are robust even after applying PSM.

Fourth, using generalized method of moments (GMM) approach. GMM estimation technique is employed to address endogeneity issues. When an explanatory variable is correlated with the error term, conventional estimation methods such as OLS may yield biased results. GMM overcomes this by introducing instrumental variables that are correlated with the explanatory variables but uncorrelated with the error term, providing consistent estimates. Specifically, we utilize the two-step system GMM estimation technique to eliminate time-invariant omitted variables (i.e., fixed effects) and to mitigate estimation bias stemming from reverse causality.

In GMM models, serial correlation in the error term can lead to biased estimates. The AR(1) test is applied to examine whether the error term exhibits first-order autocorrelation. If AR(1) is present and highly significant, this suggests the existence of first-order autocorrelation, which is acceptable, as the differenced error term should exhibit autocorrelation. However, the AR(2) test is used to detect the presence of second-order autocorrelation. The presence of second-order autocorrelation would indicate that the instrumental variables might be correlated with

the error term, leading to biased estimates. For GMM, it is crucial that the AR(2) test results are not significant (i.e., the null hypothesis of no second-order autocorrelation cannot be rejected) to ensure the validity of the instrumental variables. Finally, the Hansen test (also known as the Hansen J test) is conducted to assess the overall validity of the instrumental variables used in the model. The null hypothesis of the Hansen test is that the instruments are exogenous, meaning they are uncorrelated with the error term. If the test results are not significant (i.e., the null hypothesis cannot be rejected), it indicates that the choice of instruments is appropriate, and the model does not suffer from over-identification. Upon passing these three tests, columns (4) of Table 5 report the re-estimated results using GMM. The findings reveal that the coefficient for DT remains significantly negative at the 5% level, suggesting that the results remain robust even after applying GMM.

Table 5. Robustness Check

	Clustering Level (Industry)	Additional FE	PSM	GMM
	(1)	(2)	(3)	(4)
	CCH	CCH	CCH	CCH
DT	-0.002***	-0.002***	-0.002***	-0.003**
	(-3.001)	(-2.743)	(-3.073)	(-2.025)
L.CCH				0.309***
				(3.960)
Control Variables	Yes	Yes	Yes	Yes
Additional FE	No	Yes	No	No
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
AR(1)				0.000
AR(2)				0.162
Hansen J				0.197
No. of Firm				3439
No. of IV				33
N	26150	26149	26602	22048
Adj. R^2	0.374	0.368	0.069	

Note: statistical significance is denoted by ***, **, and *, representing levels of significance at the 1%, 5%, and 10% thresholds, respectively. T-statistics (shown in parentheses) are calculated using standard errors adjusted for firm-level clustering. All variables are defined in Table 1.
Source: calculated by the author.

The Moderating Role of Financing Constraints

This study incorporates financing constraints (FC) as a moderating variable to examine its role in the relationship between digital transformation (DT) and corporate cash holdings (CCH). Columns (1) and (2) of Table 6 illustrate the moderating effect of FC on the DT-CCH relationship. The results show that the interaction term between DT and FC (DT#FC) is positive and significant, both in column (1), where no additional variables are controlled, and in column (2), where additional controls are included. This indicates that under severe financing constraints, firms face greater difficulties and higher costs in obtaining financing, leading them to adopt a more cautious approach to digital transformation. Specifically, they prioritize internal cash management and retention, mitigating the negative impact of DT on CCH. These findings provide support for Hypothesis 2.

Table 6. Moderating Effect

	(1) CCH	(2) CCH
DT#FC	0.013**	0.016***
	(2.051)	(2.615)
DT	-0.003***	-0.002***
	(-4.014)	(-3.569)
FC	-0.264***	-0.178***
	(-17.627)	(-11.744)
Control Variables	No	Yes
Year FE	Yes	Yes
Firm FE	Yes	Yes
N	22 494	22 494
Adj. R^2	0.047	0.078

Note: statistical significance is denoted by ***, **, and *, representing levels of significance at the 1%, 5%, and 10% thresholds, respectively. T-statistics (shown in parentheses) are calculated using standard errors adjusted for firm-level clustering. All variables are defined in Table 1.

Source: calculated by the author.

Heterogeneity Test

Firms with high digital transformation level. vs. firms with low digital transformation level. To test the hypothesis that the impact of digital transformation (DT) on corporate cash holdings (CCH) is more pronounced in firms with a lower degree of digital transformation, we ranked the sample firms based on the level of digital transformation in their respective cities. Firms ranked in the top quartile were classified as having a high degree of digital transformation, while the others were categorized as having a low degree of digital transformation. We then conducted a subsample regression analysis on model (1). The results, presented in Table 7, show the regression outcomes for firms with high (Column 1) and low (Column 2) levels of digital transformation. The findings indicate that the impact of DT on CCH is significantly negative only in the group of firms with low digital transformation, suggesting that digital transformation has a more substantial effect on cash holdings in firms with a higher degree of transformation. These results support hypothesis H3.

Firms facing losses vs. firms not facing losses. To examine whether firm profitability influences the heterogeneity of the regression results, we conducted subsample regressions based on model (1). Firms were classified as firms facing losses if their total revenues were insufficient to cover total expenses during the sample period, dividing the sample was divided into "firms facing losses" and "firms not facing losses" subsamples. The regression results are presented in Table 7, with column (3) showing the results for firms facing losses and column (4) for firms not facing losses. The findings indicate that the impact of DT on CCH is significantly negative only for firms not facing losses, thereby supporting hypothesis H4.

Table 7. Heterogeneity Test

	H-DT=1 (1)	H-DT=0 (2)	Loss=1 (3)	Loss=0 (4)
	CCH			
DT	-0.002	-0.002**	-0.005	-0.001**
	(-0.930)	(-1.975)	(-1.517)	(-1.994)
Control Variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
N	6749	19 945	2787	23 907
Adj. R^2	0.060	0.076	0.009	0.089

Note: statistical significance is denoted by ***, **, and *, representing levels of significance at the 1%, 5%, and 10% thresholds, respectively. T-statistics (shown in parentheses) are calculated using standard errors adjusted for firm-level clustering. All variables are defined in Table 1.

Source: calculated by the author.

Discussion and Conclusion

Utilizing data from Chinese firms between 2012 and 2021, this study offers significant insights into the relationship between digital transformation and corporate cash holdings, particularly within the context of financing constraints. Our findings demonstrate a notable negative impact of digital transformation on corporate cash holdings, indicating that firms undergoing digital transformation tend to hold less cash. This can be attributed to the efficiency improvements and enhanced liquidity management typically associated with digital initiatives. By employing advanced technologies and streamlined processes, firms can reduce the asymmetry of information, thereby mitigating managerial motives to hoard excessive cash. Previous studies have identified digital transformation as a strategic component of leadership agendas, shaping internal organizational structures, operational processes, and value creation models [22; 49]. However, its impact on corporate cash holdings has not been thoroughly investigated in prior literature. From a microeconomic perspective of firms, our paper supplements existing evidence on the microeconomic consequences of digitalization.

Indeed, firms facing financing constraints often struggle to secure adequate external funding, potentially leading to inefficient resource allocation. For instance, such firms may face challenges in investing in high-return projects, which can affect their long-term growth and competitiveness [23; 50]. Focusing on financially constrained firms can assist policymakers in understanding how difficulties in accessing funds influence corporate investment decisions and

operational efficiency, thereby facilitating the development of effective financial policies and support measures. Our study also aligns with financial distress theory, showing how financial distress constraints inhibit corporate operations and development, thereby increasing precautionary motives for cash holdings. This conclusion holds particular relevance in China, where high corporate debt levels are prevalent, highlighting the importance for policymakers to consider corporate financial conditions when devising national digitalization strategies to promote healthy digital transformation and rational fund allocation.

Additionally, the heterogeneity tests reveal that the impact of digital transformation on corporate cash holdings is more pronounced in firms with lower levels of digital transformation and in those not facing losses. This result suggests that firms with less advanced digital capabilities may experience greater operational inefficiencies and uncertainties, leading them to hold onto cash. As digital transformation progresses, these firms are likely to reduce cash holdings as they become more confident in leveraging digital technologies to optimize cash flow management, reduce transaction costs, and mitigate risks. In contrast, non-loss-making firms, which typically have stronger financial health and operational stability, might have the flexibility to strategically reduce cash reserves as they pursue digital initiatives. These firms can more effectively deploy cash towards value-enhancing investments, such as technology upgrades and innovation, without the immediate pressure of financial distress. This behavior aligns with the notion that financially stable firms are better positioned to capitalize on the efficiencies and opportunities brought about by digital transformation, thereby justifying a lower cash cushion.

This study makes several theoretical contributions. On the one hand, from the perspective of agency theory, it reveals that digital transformation diminishes the motives offirms holding cash for agency reasons. Empirical analysis supports the view that digital transformation reduces the tendency of management to hold excessive cash due to self-interest motives, thereby lowering agency costs. This validation broadensthe application of agency theory in the digital age, offering a new perspective on how technological advancements influence corporate governance. On the other hand, the study explores financing constraints as a manifestation of financial distress and how they moderate the relationship between digital transformation and corporate cash holdings. Our findings support the cash precautionary motive posited by financial distress theory, indicating that firms facing higher financing constraints tend to maintain greater cash reserves during digital transformation to mitigate potential risks and uncertainties. This discovery deepens our understanding of financial distress theory, illustrating firms' cash management strategies under financial pressure and enriching the theoretical framework.

Our study offers insights for stakeholders and policymakers. The findings demonstrate that digital transformation reduces corporate cash holdings, albeit financing constraints may influence this process. Therefore, as firms advance in their digital transformation, managers should concurrently assess their financing conditions and implement measures to ensure stable cash flows, such as optimizing internal fund management and diversifying financing channels. For policymakers, governments and regulatory bodies can facilitate digital transformation and overall economic development by providing easier access to financing and financial support, thereby helping firms overcome financing challenges.

However, our study has limitations. Our data sample is exclusively confined to Chinese listed companies, which restricts the basis for developing cross-national comparative research. Future studies could compare financial behaviors under digital transformation and financing constraints across different countries and regions to reveal the influences of culture, institutions, and economic environments on corporate behavior, thereby providing broader evidence to support theoretical research. Additionally, future research could explore the impact of other moderating variables on the relationship between digital transformation and corporate cash holdings, such as corporate governance structures and market competitiveness, to further deepen the understanding of this relationship.

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