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*Retraction*

# Retracted: Enterprise Digital Transformation and Stock Price Crash Risk: Evidences from China

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

## References

[1] X. Song, "Enterprise Digital Transformation and Stock Price Crash Risk: Evidences from China," *Discrete Dynamics in Nature and Society*, vol. 2022, Article ID 5389456, 11 pages, 2022.

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*Research Article*

# Enterprise Digital Transformation and Stock Price Crash Risk: Evidences from China

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With unstoppable rise of digital economy globally, digital transformation has become an inevitable choice for enterprises to survive and develop; both the public and the government are paying increasing attention to digital transformation. At the same time, the Chinese government takes more serious attitude towards systemic financial risks, emphasizing the importance of controlling systemic risks such as abnormal stock price in many public occasions. In this context, enterprise digital transformation and stock price crash risk have gained unprecedented attention. It is of great value for both industry and the government to analyze the influence and mechanism of enterprise digital transformation (EDT) on stock price crash risks. This study measures the degree/level of EDT of Chinese A-share publicly owned enterprises through document study and crawler technology, examining the influence and mechanism of digital transformation on companies' stock price crash risk. Conclusions of this paper may provide a theoretical and empirical basis for understanding digital transformation's consequences in capital market and provide a reference for the government and regulatory authorities to formulate support and disclosure policies for digital transformation.

## 1. Introduction

Digital economy has become an essential growth point of China's economy. Since the G20 Summit listed "digital economy" as an important topic for the first time in 2016, its contribution to China's GDP growth has reached 67.7% in 2019, from which it can be seen that digital economy has become a typical demonstration of the new economy. In such a context, as the core foundation of digital economy development, digital transformation has become inevitable for the survival and continuous development for both traditional enterprises and emerging companies [1, 2].

Essential connotation of enterprise digital transformation (EDT) is transformation from "industrialized management mode" to "digital management mode" [3], which refers to fundamental changes in the business logic, management theory, and organizational form of the enterprise [4, 5], and ultimate changes in economic growth mode, industrial layout, entrepreneurship model, and production and lifestyle [6], through the upgrading and rebuilding of the enterprise organizational structure and business model with the information technology [7]. The current research on EDT mainly pay attention to the relation of digital revolution to enterprise performance. It has been found that the improvement of EDT could encourage the innovation of corporate governance structure and the transformation of internal administration models [8], with the effects of cost reduction, strong innovation, and the improvement of enterprise production efficiency [9]. EDT could also considerably improve the performance of the main businesses [10] through the promotion of the internal information symmetry of enterprises and business model innovation [11].

The development of the capital market is closely related to the national economy. Any changes in the production and management decisions of an enterprise will affect its performance in the capital market to a certain extent. EDT is a systematic and thorough change at an overall level, and the consequences will certainly be reflected in its capital market activities [12]. During the transformation, stock price crash

risk could very likely harm Chinese capital market and its investors [13]. As a result of different foundation and development history from western market, China's securities market remains immature. After decades of development, China's securities market is still incomplete semistrong efficient [14]. Compared with western market, Chinese investors are blinder and more impulsive in judgment and behavior, with limited ability to analyze and interpret information. Nowadays, Chinese government take more serious attitude towards systemic financial risks, emphasizing the importance of controlling systemic risks such as abnormal stock price in many public occasions. In this context, EDT and stock price crash risk have received unprecedented attention, and it is of great value for both industry and the government to explore the impact and mechanism of EDT on stock price crash risks.

After worldwide credit risk since 2008, stock price crashes have aroused extensive attention from regulatory authorities and the industry. Academic researchers are also trying to explore the influencing factors and prevention methods of stock price crash risk from various perspectives [15]. While digital transformation has brought about reforms for enterprises regarding their organizational structure and management theory, what else changes will it bring to the internal management capabilities of enterprises? Are enterprises at different transformation stages receiving the same level of attention from the market, and how does the transformation affect the efficiency of information circulation in the market? Under the background that digital transformation has gained a wide-spread consensus for enterprises, research on the above questions has great practical significance in exploring influencing elements to stock price crash risk, which will help stock market play its role in pricing.

Unfortunately, currently there is no such research on the association of EDT with the stock price fluctuations. People can only speculate the influence direction and possible mechanism of EDT on stock price crash risk from current relevant references. Therefore, this paper intends to introduce the related research of EDT and to explore its influence direction and procedure on stock price crash risks.

The following three perspectives show this paper's possible contributions. Firstly, this paper may provide a new point of view about the business consequences of digital transformation. Unlike existing researches that focus on digital transformation's effect on the business performance, this paper associates enterprises' digital transformation in the new era with its capital market performance and explores the inherent relation between digital transformation and stock price crash risks. Secondly, this study may enrich current research on stock price crash risks. Through verifying two major theories of stock price crash - "Agency Theory" and "Information Theory", this study explores digital transformation's influence path on stock price crash risks. Third, this paper tries to measure the degree of EDT through crawlers' technology and text analysis, which may provide reference and inspiration for the quantitative evaluation of EDT and its economic effects.

This paper may offer benefits and inspiration to global readers in the following respects. China's stock market is the second largest one in the world, while it is also the largest emerging market. Expected to attract more capital, Chinese government is implementing a greater opening-up policy. In this respect, it is very necessary for foreign investors to have an in-depth understanding of the Chinese securities market and its listed companies. This paper can provide experience and advice for researchers and scholars, enabling global investors to gain more information about Chinese market. Thereby, information asymmetry could be reduced, which will facilitate information interpretation and analysis by foreign investors and researchers and strengthen the connection between Chinese market and the world. At the same time, China's cases in this paper can be taken as a reference for countries in digital transformation, leading them to follow closely these topics and consider the economic effects of digital transformation.

Following the introduction are seven parts. The second part is to review the relevant research on EDT and stock price crash risk, putting forward research hypotheses with theoretical analysis. The third part is the research design. The fourth part contains result reports. The fifth part shows the analysis of the influence mechanism. The sixth part shows robustness test. The last comes to research conclusion.

## 2. Theoretical Mechanism and Hypothesis

*2.1. EDT and Stock Price Crash Risk.* Stock price crash risk means the chance of a sharp fall to an enterprise's stock price [16]. As a common and bad economic consequence, this risk disturbs financial market and damage individual wealth of investors [13]. There have been extensive discussions on the influencing factors of stock price crash risk. Current researchers commonly attribute causes of this risk to the agency problems in enterprise management [17], the information asymmetry inside and outside enterprises [18] and the policy systems [19, 20].

In addition, the influencing elements of this risk are also investigated from different aspects, including shareholdings [21], institutional investors [15], characteristics of senior executives [13], analysts [22], and margin trading system [23].

The above-mentioned studies up to date provide a wealth of experience and theoretical support for the analysis of the influence of EDT on stock price crash risks. With the current study as starting point, this paper is aimed to explore the impact and possible mechanism of EDT on stock price crash risks through two specific aspects "Agency Theory" and "Information Theory".

Scholars in favor of "Agency Theory" argue that the main explanation for share prices crash risk is that the management level tries to hide the negative news and excessive risks. They choose to hide negative enterprise information depending on various demands including maximizing their own equity value [28], establishing the business kingdom [18], making in-service consumption [29], and promoting their career and salary gap [30]. As the cost of hiding negative information becomes higher and higher, company's management personnel would finally give up hiding information but choose to release the negative information

once for all. The stock price thereof will be greatly impacted in a short time, and then the crash might occur. Similarly, it happens when excessive investment is triggered by regional bribery [27] and decision-making errors due to incomplete information [28]. All will cause enterprise losses, damage enterprise value, and increase risks of future stock price crash.

While scholars like Jin and Myers [16] who are in favor of "Information Theory" believe that the main explanation for stock price crash risk is the information asymmetry, making it hard for people to find the negative information and investment projects in time, which is likely to cause miscalculation of the stock price. Meanwhile, information asymmetry provides the company's management with an opaquer information environment that they would be able to hide more negative information, with an increase of stock price crash risk in the future [29]. Hutton et al. [30] founnd the opaqueness of enterprise's information environment have positive correlation with the executive manipulation of the information disclosure. Enterprise information opacity measured by its earnings can well explain the stock price crash. Short selling [23] and internal governance [31] also provide support for this view by reducing risk through the price discovered function and improving the efficiency of stock price information.

According to above discussion, this paper tries to analyze the possible influence direction and mechanism of EDT on stock price crash risk through the following aspects.

Firstly, EDT can help improve the internal management capacity and alleviate the "principle-agent" problem and thus reduce stock price crash risk. From one point of view, through digital transformation, enterprises can better process massive, nonstructured, and nonstandard information with the help of digital technology, thus improving the information utilization [32]. From another point of view, EDT can also help eliminate the boundaries between departments, making the internal information flow more smoothly and thus significantly improving the internal control of enterprises. It can ultimately urge enterprises to gradually improve its organizational structure, production mode, and decision-making mechanism [33], to achieve the dual goals of "efficiency improvement" and "risk reduction" [13]. Digital transformation can enhance enterprises' insights into all aspects of company operation, helping them make management decisions and improve operation efficiency [4]. To sum up, the improvement of internal management ability and information circulation efficiency is a great help for company to reduce decision-making errors and to improve investment efficiency [8]. Meanwhile, with the quantitative analysis ability of digital transformation, the executive decision-making about cost control and investment decisions becomes more standardized, and the discretionary power is greatly reduced. The above analysis has alleviated the agency problem in some way [34]. With the alleviation of the agency problem and the reduction of the manipulable space for earnings management, the executives will focus more on the main business. The short-sighted behavior such as hiding negative information will be greatly reduced, and ultimately stock price crash risk will be reduced too.

Secondly, EDT helps companies obtain more market attention, reduce information asymmetry, finally reducing stock price crash risks. From one point of view, enterprises have improved their internal data mining and processing capabilities through digital technology. Companies benefit from the standardized data processing results with an easier output and interpretation of information. It helps the company to alleviate information asymmetry inside and outside and meanwhile helps the market understand companies' production and operation status promptly [13]. From another point of view, digital transformation could also help enterprises attract the attention of analysts, improve the information environment, alleviate information asymmetry inside and outside enterprises, and ultimately reduce enterprise stock price crash risks. Analysts and investors' limited attention narrows their capabilities to interpret the market information [35]. Under the background that digital transformation has become a broad consensus, enterprises with a higher digital transformation level are more likely to be reported by media and to arouse analysts' attention [12]. Media reports not only attract analysts' attention, but also improve the quality and reputation of news release for enterprises [36, 42]. It helps to reduce the divergency of analysts, decrease forecast errors, alleviate information asymmetry, and ultimately reduce stock price crash risks. Then this paper proposes relevant hypothesis below.

H1: better EDT could reduce stock price crash risk.

Actually, enterprises sometimes choose to disclose information with strategic purposes, when they intend to exaggerate the degree and effect of transformation [43] and hide corresponding negative consequences and information. For enterprises with more bubbles in their stock price, it may make the market blindly optimistic, overestimate their transformation degree and operation status, and miss the opportunity to find bubbles, thus weakening the suppression effect of digital transformation on stock price crash risk. Then the second hypothesis is proposed below.

H2: effect of EDT on reducing stock price crash risk decreases as the level of stock price bubble rises.

## 3. Research Design

*3.1. Sample and Data.* Initial sample of this study is A-share public enterprises in China, between 2013 and 2020. Then the following processing is made: (1) to exclude enterprises with annual stock earnings data of less than 26 weeks; (2) to exclude financial enterprises; (3) to exclude ST and the delisting enterprises during the period; (4) to exclude enterprises whose data are less than five years; (5) and to carry out 1% and 99% winsorization processing regarding continuous variables at the microlevel in order to reduce the impact of outliers on the results. The data of internal control quality in this paper comes from DIB internal control and risk management database. Other data can be found in CSMAR.

*3.2. Variables Setting*

*3.2.1. Stock Price Crash Risk.* Based on existing studies [43–58], this paper measures stock price crash risk by

NCSKEW (negative coefficient of skewness) and DUVOL (down-to-up volatility). The specific calculation methods are as follows.

Firstly, using formula (1) to eliminate the influence of annual market elements on the return rate of every firm:

$$R_{i.t} = \alpha_i + \beta_1 R_{m,t-2} + \beta_2 R_{m,t-1} + \beta_3 R_{m,t} + \beta_4 R_{m,t+1} + \beta_5 R_{m,t+2} + \varepsilon_{i,t}. \quad (1)$$

In the formula, $R_{i,t}$ is the weekly return rate of the enterprise $i$ in week $t$ of the current year and $R_{m,t}$ is the average return rate in the market weighted by circulating market capitalization in week $t$, both of which adopt the value after considering the reinvestment of cash dividends. To control the impact of nonsynchronous stock trading, the lagging and leading term of market returns are added into formula (1). The specific weekly return rate is $W_{i,t} = \ln(1 + \varepsilon_{i,t})$. Residual $\varepsilon_{m,t}$ represents information in the stock return that is not reflected in the market return.

Two variables of stock price crash risk are proposed after the definition of $W_{i,t}$:

(1) Negative Coefficient of Skewness (NCSKEW)

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

In the formula, $n$ is the number of trading weeks of enterprise $i$ in that year. Larger *NCSKEW* refers to bigger negative stock return rate's skewness coefficient and greater stock price crash risk.

(2) Down-to-Up Volatility (DUVOL)

$$DUVOL_{i,t} = \log\left\{\frac{\left[(n_u-1)\sum_{\text{DOWN}} W_{i,t}^2\right]}{\left[(n_d-1)\sum_{\text{UP}} W_{i,t}^2\right]}\right\}. \quad (3)$$

In the formula, $n_u$ ($n_d$) is the number of weeks in which enterprise $i$'s specific return $W_{i,t}$ is bigger than (smaller than) the mean. The higher *DUVOL*, the more leftward the yield's distribution, and the greater the stock price crash risks.

*3.2.2. Enterprise Digital Transformation.* Most of the existing research on EDT mainly focuses on qualitative analysis from the perspectives of policy suggestions [4] [41] and theoretical analysis [42]. Some scholars began measuring the digital transformation level of enterprises from the microenterprise perspective and considered indicators such as digital intangible assets [43], e-commerce sales revenue [44], and the frequency of words related to digital transformation [12]. According to the research of Lin and Xie [58], word frequency represents the importance level an enterprise has given to the key issues (represented by the word). Based on this, this paper takes the research of Zhao et al. [59] as a reference and establishes a thesaurus containing 99 digital transformation words from four aspects which are digital technology application, Internet business model, intelligent manufacturing, and modern information system (details are omitted in this paper due to limited space). Using the processing functions of Jieba and text analysis in *Python*, this paper tries to analyze all texts of the annual reports of Chinese A-share public enterprises between 2013 and 2020 and to calculate the sum and the logarithm of the frequency of words related to digital transformation. This information after processing will be used as the final index to measure the level of EDT.

*3.2.3. Stock Price Bubble.* Referring to the researches of Dass et al. [53] and Pan et al. [54], this paper selects the price-to-sales ratio as a measurement of stock price bubble. The higher the price-to-sales ratio, the greater the stock price bubble. Price/sales ratio (*PB*) = closing price of the stock on the last trading day in this year/sales revenue per share in the preceding year.

*3.2.4. Control Variables.* In regression, this paper controls dumb variables including *RET*, *SIGMA*, *DTURN*, *Tobin_Q*, *BM*, *SIZE*, *ROA*, *LEV*, *AbsACC*, *Ind*, and *Year*. Considering that there may be a time lag in the impact of digital transformation [56] and avoiding potential reverse causality problems, the explained variables are all selected from the data of the preceding period (*t-1*), and all the other variables from the data of the current period ($t$) in the regression equation. This paper also controls the explained variables of the current period.

*3.3. Model Design.* H1 is tested by the model of

$$\text{Crash}_{i,t+1} = \beta_0 + \beta_1 DCG_{i,t} + \gamma\text{Controls}_{i,t} + \text{Ind} + \text{Year} + \varepsilon_{i,t+1}. \quad (4)$$

*Crash* is measured by *NCSKEW* and *DUVOL*. Data of the future period are used in regression. *DCG* represents the degree of EDT, *Controls* represents control variables including current *Crash*, *RET*, *Tobin_Q*, *LEV*, etc., $i$ represents the enterprise, and $t$ represents the time.

H2 is tested by

$$\text{Crash}_{i,t+1} = \beta_0 + \beta_1 DCG_{i.t} + \beta_2 DCG_{i.t} \times PB_{i,t} + \gamma\text{Controls}_{i,t} + \text{Ind} + \text{Year} + \varepsilon_{i,t+1}. \quad (5)$$

In (5), the interactions of stock price bubble (*PB*) and digital transformation (*DCG*) are introduced. By comparing whether the signs of $\beta_1$ and $\beta_2$ are identical or not, this formula is to investigate the changing trend of EDT reducing stock price crash risk when bubble rises. Please note that $i$ refers to firm and $t$ is the time.

## 4. Analysis of Results

*4.1. Variable Characteristics.* Mathematical characteristics of variables are demonstrated in Table 1. The mean values of *NCSKEW* and *FDUVOL* are -0.282 and -0.194, respectively, close to the results in the existing research [15, 29]. According to this event, stock price crash risk could be

Table 1: Variable characteristics.

| Variable | Obs | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|---|
| *NCSKEW* | 10986 | −0.282 | 0.748 | −5.170 | 4.166 |
| *FDUVOL* | 10986 | −0.194 | 0.501 | −3.178 | 2.287 |
| *DCG* | 10986 | 0.342 | 0.579 | 0 | 7.160 |
| *RET* | 10986 | 0.004 | 0.011 | −0.050 | 0.264 |
| *SIGMA* | 10986 | 0.064 | 0.028 | 0.014 | 0.326 |
| *DTURN* | 10986 | −0.052 | 0.411 | −3.541 | 3.972 |
| *Tobin_Q* | 10986 | 0.210 | 0.169 | 0.070 | 8.650 |
| *BM* | 10986 | 0.611 | 0.255 | 0.012 | 1.430 |
| *SIZE* | 10986 | 4.065 | 1.321 | 0.435 | 10.10 |
| *ROA* | 10986 | 0.046 | 0.061 | −0.645 | 0.675 |
| *LEV* | 10986 | 0.431 | 0.199 | 0.008 | 1.352 |
| *AbsACC* | 10986 | 0.058 | 0.083 | 0 | 2.172 |

believed to have rational indicators. The mean and standard deviation of EDT are 0.342 and 0.579, respectively. The degree of transformation varies significantly among different enterprises, with min and max being 0 and 7.16, respectively.

*4.2. Basic Analysis: Enterprise Digital Transformation and Stock Price Crash Risks.* This paper uses a time and entity fixed effects regression model, in which the variables of both time and industry dummy are controlled. Table 2 shows a significantly negative correlation between enterprise digital transformation (*DCG*) and stock price crash risks at 1% level. It indicates that enterprises can diminish stock price crash risks through digital transformation, which supports H1. Interactions of EDT and stock price bubbles degree are considerably positive at 1% level. This confirms the following fact: as stock price bubbles keep rising, reducing effect on stock price crash risk through EDT decreases, which is consistent with H2.

Among control variables, regression coefficients of $NCSKEW_t$ and $DUVOL_t$ are considerably negative, which is in line with studies of Quan [50], Sun, and Zheng [20]. The regression coefficients of *RET*, *SIZE*, and stock price crash risks are significantly positive, agreeing with the study by Hutton et al. [30] and Xu et al. [58]. The regression coefficients of *DTURN* and *LEV* are negative, indicating that the higher the *DTURN* and *LEV*, the lower the stock price crash risk. Such consequences are similar to studies carried out by An and Zhang [58]; Callen and Fang [59]; and Wang et al. [21]. On the whole, control variables' empirical results are basically similar to the current research, illustrating this paper's conclusions are trustworthy.

*4.3. Analysis of Heterogeneity.* The business model, organizational structure, and competitive imitation environment of an enterprise are highly related to the nature of ownership and its main industry. To further analyze the different effectiveness of EDT reducing stock price crash risk, all subsamples are analyzed through categorical regression according to the company's ownership and industry. The outcomes are displayed in Tables 3 and 4 separately.

For different types of ownership, the regression coefficients of non-state-owned companies are quite higher than those of state-owned companies, which means that the digital transformation of non-state-owned companies makes better impact on diminishing stock price crash risks. State-owned enterprises are not entirely for business performance, so the reforms within organizational structure and business models are often subject to stronger administrative constraints. Meanwhile, considering that some key businesses in the state-owned enterprises requires a certain degree of confidentiality, the effect of digital transformation to improve information asymmetry inside and outside enterprises is limited. Non-state-owned enterprises usually face certain resource boundary constraints. Timely disclosure of the progress of digital transformation can help attract the interest of analysts and investors and achieve the purpose of ensuring the liquidity of capital market.

The regression coefficients of manufacturing and non-manufacturing industries are both significant at 1% level. However, absolute values of manufacturing enterprises' coefficients are significantly greater than those of non-manufacturing enterprises, indicating that there exists a better effect of reducing stock price crash risk through digital transformation in manufacturing enterprises. Digitalization is a crucial direction for the upgrading and rebuilding of manufacturing industries in China. Digital transformation can be introduced into all links in the value chain of manufacturing enterprises to improve enterprises' ability of processing data and increasing circulation efficiency of internal information. It also helps to reduce agency problems. Manufacturing enterprises with a certain level of digital transformation are considered to have stronger competitiveness [59] and are more likely to arouse attention of analysts and investors. In this way, they are subject to diminish companies' information asymmetry and ultimately diminish stock price crash risks.

## 5. Extended Study: Analysis of Influence Mechanism

The fourth part proves that the EDT reduces stock price crash risks, yet the mechanism behind is still unclear. According to the above analysis, EDT, on one hand, may alleviate the "principle-agent" problem by improving the investment efficiency and internal management capabilities

Table 2: EDT and stock price crash risks.

| | (1) $NCSKEW_{t+1}$ | (2) $NCSKEW_{t+1}$ | (3) $NCSKEW_{t+1}$ | (4) $DUVOL_{t+1}$ | (5) $DUVOL_{t+1}$ | (6) $DUVOL_{t+1}$ |
|---|---|---|---|---|---|---|
| $DCG_t$ | −0.177*** | −0.172*** | −0.203*** | −0.109*** | −0.101*** | −0.124*** |
| | (0.031) | (0.031) | (0.034) | (0.021) | (0.021) | (0.023) |
| $DCG_t \times PB_t$ | | | 0.008*** | | | 0.006*** |
| | | | (0.003) | | | (0.002) |
| $PB_t$ | | | 0.000 | | | 0.000 |
| | | | (0.001) | | | (0.001) |
| $NCSKEW_t/DUVOL_t$ | −0.139*** | −0.132*** | −0.134*** | −0.141*** | −0.134*** | −0.136*** |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| $RET_t$ | | 6.546*** | 6.355*** | | 4.589*** | 4.437*** |
| | | (1.353) | (1.312) | | (0.992) | (0.955) |
| $SIGMA_t$ | | −1.222** | −1.339** | | −1.301*** | −1.387*** |
| | | (0.554) | (0.557) | | (0.381) | (0.383) |
| $DTURN_t$ | | −0.049** | −0.046** | | −0.039** | −0.037** |
| | | (0.023) | (0.023) | | (0.016) | (0.016) |
| $Tobin\_Q_t$ | | 0.078 | −0.031 | | 0.015 | −0.079 |
| | | (0.106) | (0.118) | | (0.075) | (0.085) |
| $BM_t$ | | −0.665*** | −0.699*** | | −0.415*** | −0.444*** |
| | | (0.094) | (0.094) | | (0.062) | (0.062) |
| $SIZE_t$ | | 0.121*** | 0.126*** | | 0.052** | 0.055** |
| | | (0.032) | (0.032) | | (0.022) | (0.022) |
| $ROA_t$ | | −0.048 | −0.047 | | −0.050 | −0.047 |
| | | (0.181) | (0.181) | | (0.123) | (0.123) |
| $LEV_t$ | | −0.328*** | −0.318*** | | -0.240*** | −0.231*** |
| | | (0.108) | (0.109) | | (0.074) | (0.074) |
| $AbsACC_t$ | | 0.176 | 0.174 | | 0.141** | 0.140** |
| | | (0.113) | (0.113) | | (0.067) | (0.068) |
| Constant | −0.271*** | −0.134 | −0.106 | −0.156*** | 0.063 | 0.086 |
| | (0.019) | (0.145) | (0.144) | (0.013) | (0.098) | (0.097) |
| *Year, Ind* | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 10986 | 10986 | 10986 | 10986 | 10986 | 10986 |
| *Adj-$R^2$* | 0.071 | 0.091 | 0.092 | 0.076 | 0.094 | 0.095 |

*Note.* ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively. The numbers in parentheses are robust standard errors. Year represents the time dummy variable, and Ind represents the industry dummy variables.

Table 3: Analysis of heterogeneity: based on the nature of business ownership.

| | State-owned companies | | Non-state-owned companies | |
|---|---|---|---|---|
| | (1) $NCSKEW_{t+1}$ | (2) $DUVOL_{t+1}$ | (3) $NCSKEW_{t+1}$ | (4) $DUVOL_{t+1}$ |
| $DCG_t$ | −0.175** | −0.083 | −0.155*** | −0.093*** |
| | (0.083) | (0.054) | (0.034) | (0.023) |
| $NCSKEW_t/DUVOL_t$ | −0.119*** | −0.120*** | −0.149*** | −0.151*** |
| | (0.018) | (0.018) | (0.014) | (0.014) |
| *Controls, Year, Ind* | Yes | Yes | Yes | Yes |
| Obs | 4084 | 4084 | 6902 | 6902 |
| *Adj-$R^2$* | 0.076 | 0.077 | 0.105 | 0.113 |

Table 4: Analysis of heterogeneity: based on industry categories.

| | Manufacturing industries | | Nonmanufacturing industries | |
|---|---|---|---|---|
| | (1) $NCSKEW_{t+1}$ | (2) $DUVOL_{t+1}$ | (3) $NCSKEW_{t+1}$ | (4) $DUVOL_{t+1}$ |
| $DCG_t$ | −0.235*** | −0.137*** | −0.139*** | −0.087*** |
| | (0.052) | (0.036) | (0.038) | (0.025) |
| $NCSKEW_t/DUVOL_t$ | −0.142*** | −0.140*** | −0.124*** | −0.128*** |
| | (0.014) | (0.014) | (0.018) | (0.018) |
| *Controls, Year* | Yes | Yes | Yes | Yes |
| Obs | 6834 | 6834 | 4152 | 4152 |
| *Adj-$R^2$* | 0.108 | 0.117 | 0.073 | 0.067 |

of the enterprise and finally reduce stock price crash risks. On the other hand, it could reduce such risks by attracting more attention from media, analysts, and investors, decreasing analyst forecast errors and reducing the information asymmetry inside and outside enterprises. Based on this, the paper from the perspective of agency problems and information asymmetry further investigates the mechanism of EDT to reduce stock price crash risk.

*5.1. Enterprise Digital Transformation and Agency Problems.* The "Agency Theory" holds the opinion that executives hiding negative news and taking excessive risks are essential explanations for stock price crash risks. By improving

management efficiency and internal management capacity, the EDT helps to reduce the manipulable space of earnings management, to alleviate the "principle-agent" problem, as well as to improve both decision-making ability and investment efficiency. Taking the method from Gao and Wang [53] as a reference, the agency costs of enterprises in this paper are measured by the ratio of management expense (*ADE*). The larger *ADE*, the higher agency cost. Dibo Internal Control Index is selected as a proxy variable of internal management capability (*DIB*) [27, 50]. The larger *DIB*, the stronger governance capability. Referring to the existing research [54], the governance effect of management is measured by two indicators, real earnings management (*Earnings*) and investment efficiency (*INV_E*). *Earnings* are calculated by the model from Roychowdhury [55]. The higher *Earnings*, the higher degree of real earnings management. *INV_E* is calculated by the model from Richardson [56]. The higher *INV_E*, the lower investment efficiency of enterprises.

According to Table 5, the EDT significantly reduces *ADE* and improves *DIB*. The EDT reduces accounting manipulation to some extent in the management level, but has no significant impact on *INV_E*. These findings all indicate that through improving executive capacity and reducing accounting manipulation, digital transformation can alleviate agency problems and thus further reduce stock price crash risks. "Agency Theory" about EDT diminishing stock price crash risks is valid.

*5.2. Enterprise Digital Transformation and Information Asymmetry.* According to the "Information Theory", the main explanation for the risk of specific share price crash in enterprises is the information asymmetry inside and outside enterprises. By improving data mining and processing capabilities of enterprises, the EDT helps the market timely understand the production and operation state of enterprises and attract the attention of analysts, so as to reduce analysts' wrong prediction and to alleviate the information asymmetry inside and outside enterprises. Referring to the method from Huang and Guo [57], media attention (*News*) is measured in this paper by the logarithm of annual media reports of listed enterprises and analysts' attention (*Analyst*) by tracking the number of institutions of a listed enterprise. The further analysis in this paper investigates the change of information transfer efficiency in the capital market by the absolute deviation of analyst forecast (*FERR*) and stock price synchronization (*SYNCH*). According to the analysis of Tan et al. [58], the level of EDT is available information for all analysts, and the relative deviation predicted by the analysts will not change significantly. Therefore, absolute deviation is adopted in this paper to measure the prediction deviation, and the specific calculation methods are shown in (6). This study calculate stock price synchronization from the model in Durnev et al. [59]. To obtain the normal distribution of $R^2$, logarithmic processing is performed in this paper.

The measuring method of *FERR* is specifically explained here as

Table 5: Analysis of mechanism: agency problems.

| | (1) *ADE* | (2) *DIB* | (3) *Earnings* | (4) *INV_E* |
|---|---|---|---|---|
| $DCG_t$ | −0.013*** | 0.082** | −0.014* | 0.005 |
| | (0.003) | (0.040) | (0.008) | (0.003) |
| *Controls, Year, Ind* | Yes | Yes | Yes | Yes |
| Obs | 10986 | 10986 | 10628 | 10176 |
| *Adj-$R^2$* | 0.193 | 0.158 | 0.051 | 0.040 |

Table 6: Analysis of mechanism: information asymmetry.

| | (1) News | (2) Analyst | (3) FERR | (4) SYNCH |
|---|---|---|---|---|
| $DCG_t$ | −0.068 | 0.100*** | −0.607*** | 0.007 |
| | (0.047) | (0.028) | (0.211) | (0.007) |
| *Controls, Year, Ind* | Yes | Yes | Yes | Yes |
| Obs | 4563 | 10986 | 10953 | 10765 |
| *Adj-$R^2$* | 0.572 | 0.172 | 0.046 | 0.332 |

$$FERR_{i,j,t} = \frac{\left|FEPS_{i,j,t} - EPS_{i,t}\right|}{\left|EPS_{i,t}\right|}. \quad (6)$$

In (6), $i$ represents enterprise, $t$ represents time, and $j$ represents analyst group. *FEPS* represents analysts' expected earnings per share, and *EPS* represents an enterprise's actual earnings per share for the year. The greater the *FERR*, the more significant the absolute deviation of analyst forecasts.

According to Table 6, enterprise digital transformation (EDT) significantly improves *Analyst* and reduces *FERR*. The effect of EDT on *News* and *SYNCH* is not significant. These findings suggest that digital transformation help those enterprises under transformation to arouse more attention from the market, especially the analysts' attention. With the analysts' interpretation of some specific enterprise information, the EDT can reduce the absolute deviation of analysts' forecasts, alleviating companies' information asymmetry, then finally diminishing stock price crash risks. "Information Theory" about EDT diminishing stock price crash risks is valid.

## 6. Robustness Test

*6.1. Endogenous Problems.* This paper adopts one-period-ahead dependent variables and uses fixed effect models to control the potential endogenous problems to some extent. However, there may still be reverse causality problems and omitted variables in this study. To make the conclusion more reliable, this paper uses the 2SLS method and DID model to further eliminate the influence of endogenous problems.

In order to solve the potential reverse causality problem, the lag first-order degree of digital transformation (*L.DCG*) and the proxy variable (*DCG_IV*) are adopted as the two instrumental variables for the degree of enterprise digital transformation (*DCG*) to carry out the two-stage least square method. The proxy variable (*DCG_IV*) is constructed as follows. According to studies of Kim et al. [29], Wang et al. [21], and Meng et al. [23], this study adopts the mean value of digital transformation degree of other enterprises in each

Table 7: Endogenous problems: 2SLS.

| | First stage | Second stage | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | $DCG_t$ | $NCSKEW_{t+1}$ | $DUVOL_{t+1}$ |
| $DCG_t$ | | −0.453*** | −0.301*** |
| | | (−6.615) | (−6.402) |
| $DCG\_IV_t$ | 0.355*** | | |
| | (0.052) | | |
| $L.DCG_t$ | 0.510*** | | |
| | (0.039) | | |
| *Controls* | Yes | Yes | Yes |
| Obs | 7738 | 7738 | 7738 |
| *Adj-*$R^2$ | 0.439 | 0.076 | 0.080 |
| F-value | 172.06 | | |
| Underidentification test (Kleibergen-Paap rk LM statistic) | | 137.542*** | 137.49*** |
| Weak instrumental variable test (Kleibergen-Paap rk Wald F statistic) | | 172.06*** | 171.921*** |
| Overidentification test (Hansen *J* statistic *P*-value) | | 0.0657 | 0.0517 |

*Note.* Weak instrumental variable test *** indicates that Kleibergen-Paap rk Wald F statistic exceeds all critical values, including 15% and 25%.

Table 8: Endogenous problems: DID.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | $NCSKEW_{t+1}$ | $DUVOL_{t+1}$ | $NCSKEW_{t+1}$ | $DUVOL_{t+1}$ |
| $Time_t \times Treat_t$ | −0.108*** | −0.058** | | |
| | (0.040) | (0.027) | | |
| $Time_t \times Treat_t \times DCG_t$ | | | −0.193*** | −0.122*** |
| | | | (0.022) | (0.015) |
| *Controls, Year, Ind* | Yes | Yes | Yes | Yes |
| Observations | 10986 | 10986 | 10986 | 10986 |
| *Adj-*$R^2$ | 0.089 | 0.092 | 0.097 | 0.100 |

industry except the target enterprise as its proxy variable (*DCG_IV*). Enterprises in the same industry have similar industry characteristics and competitive environment, and the degree of their digital transformation is relatively close. The instrumental variables are correlated with the explanatory variables, meeting the instrument relevance restriction accordingly. However, there is no evidence to prove that other enterprises in the same field are subject to the same effect of digital transformation degree affecting its stock price crash risk. The instrument exogeneity restriction is met accordingly.

According to column (1) of Table 7, the two instrumental variables are not weak (F-value>10), and the two are significantly positively related to the core explanatory variable *DCG* at 1% level. According to columns (2) and (3), the instrumental variables pass the underidentification test and there is no overidentification problem, which proves this study's instrumental variables are reasonable. With endogenous problems controlled, the enterprise digital transformation (*DCG*) and stock price crash risks still meet the significant negative correlation, proving the conclusions of this paper are robust and unlikely to be interfered by reverse causality problems.

Considering that it is an excellent quasinatural experiment for enterprises to promote digital transformation in batches, this paper chooses a multiperiod double-difference model to further solve the potential problem of omitted variables. Based on related research [12], after twice calculus of differences between the Treatment Group and the Control Group before and after the transformation, the DID model can effectively eliminate the biased error caused by internal differences and the time trend irrelevant to the experimental group within enterprises, so that to obtain the "net effect" on stock price crash risks through EDT. This paper constructs the following models to test the effect on stock price crash risks through EDT.

$$\begin{aligned} \text{Crash}_{i,t+1} &= \alpha_0 + \alpha_1 \text{Time}_{i.t} + \alpha_2 \text{Treat}_{i,t} + \alpha_3 \text{Time}_{i,t} \\ &\quad \times \text{Treat}_{i,t} + \gamma \text{Controls} + \varepsilon_{i,t+1}, \\ \text{Crash}_{i,t+1} &= \theta_0 + \theta_1 \text{Time}_{i,t} \times \text{Treat}_{i,t} \times DCG_{i,t} \\ &\quad + \gamma \text{Controls} + \text{Ind} + \text{Year} + \varepsilon_{i,t+1}. \end{aligned} \tag{7}$$

In the above formulas, Treat represents the individual dummy variable. *Treat* = 1 represents the enterprises that have carried out digital transformation from 2013 to 2020, and *Treat* = 0 represents the enterprises that have not carried out digital transformation. *Time* represents the dummy variable of time, which takes 1 as the value from the first year of digital transformation of an enterprise. Otherwise, it takes 0 as the value. Considering that individual enterprise and time dummy variables may ignore the influence brought by the degree of EDT, this paper introduces the DID model (Table 8) with moderating effect to estimate the impact. $\alpha_3$

Table 9: Robustness test: longer forecast windows.

| | (1) $NCSKEW_{t+1}$ | (2) $DUVOL_{t+1}$ | (3) $NCSKEW_{t+1}$ | (4) $DUVOL_{t+1}$ | (5) $NCSKEW_{t+1}$ | (6) $DUVOL_{t+1}$ |
|---|---|---|---|---|---|---|
| $L.DCG_t$ | −0.215*** | −0.141*** | | | | |
| | (0.040) | (0.027) | | | | |
| $DCG_t$ | | | −0.219*** | −0.153*** | −0.234*** | −0.152*** |
| | | | (0.047) | (0.033) | (0.071) | (0.050) |
| *Controls, Year, Ind* | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs | 7985 | 7985 | 6283 | 6283 | 4698 | 4698 |
| *Adj-$R^2$* | 0.11 | 0.114 | 0.095 | 0.098 | 0.087 | 0.095 |

Table 10: Robustness test: change the calculation method of stock price crash risk.

| | (1) $NCSKEW\_CAP_{t+1}$ | (2) $DUVOL\_CAP_{t+1}$ | (3) $NCSKEW\_N_{t+1}$ | (4) $DUVOL\_N_{t+1}$ |
|---|---|---|---|---|
| $DCG_t$ | −0.102** | −0.046 | −0.141*** | −0.083*** |
| | (0.044) | (0.028) | (0.045) | (0.027) |
| $NCSKEW_t/DUVOL_t$ | −0.184*** | −0.191*** | −0.170*** | −0.185*** |
| | (0.014) | (0.013) | (0.014) | (0.014) |
| *Controls, Year, Ind* | Yes | Yes | Yes | Yes |
| Observations | 7660 | 7660 | 7660 | 7660 |
| *Adj-$R^2$* | 0.110 | 0.118 | 0.130 | 0.144 |

*Note.* Among control variables, $NCSKEW_t/DUVOL_t$ corresponds to the calculation method of the explained variables.

and $\theta_1$ reflect the change of risk before and after the implementation of digital transformation, which is the core parameter to be estimated in this section.

The main regression results of model (6) and (7) are displayed in columns (1)-(2) and (3)-(4), respectively. Two core coefficients $\alpha_3$ and $\theta_1$ are both negative at least 5% level, which indicates that after controlling endogenous problems, the degree of enterprise digital transformation (*DCG*) still significantly reduces stock price crash risks. It proves that the problem of omitted variables can unlikely interfere the robust and reliable conclusions of this paper.

*6.2. A Longer Forecast Window.* The forecast time window for stock price crash risks and EDT is expanded to help enterprises overcome the mutual causal influence between the EDT and stock price crash risks and to further investigate the long-term effect of digital transformation on stock price crash risks. In columns (1)-(2) of Table 9, the consequences of the EDT are treated in a lagging period and in columns (3)-(6) the results of stock price crash risk are dealt for 2–3 periods in advance.

The coefficient of EDT is significantly negative in both advanced and delayed treatment, and the absolute value of coefficient does not decrease with the extension of the forecast window. Enterprise digital transformation has a long-term inhibitory influence to stock price crash risks, which proves that conclusions of this study have relatively higher robustness.

*6.3. Different Calculation Methods of Stock Price Crash Risk.* Previously, average market return weighted by circulating market value is used to calculate stock price crash risks. In this part, the market average return weighted by total market value and the unweighted market average return rate are adopted to recalculate the risk. Both results are distinguished by subscripts CAP and N, respectively.

According to Table 10, stock price crash risks after EDT and different calculation methods are negatively correlated except *DUVOL_CAP*. The inhibitory effect of EDT on stock price crash risk does not change with the different calculation method, which proves that this paper's conclusions are relatively robust.

## 7. Conclusion

As the digital economy becomes increasingly important, digital transformation has become an inevitable trend for both survival and sustainable development of corporations. Taking capital market as a study perspective, this paper investigates the impact of digital transformation on stock price crash risks. Based on the data of Chinese A-share public enterprises between 2013 and 2020, the degrees of EDT have been measured by the word segmentation function of Jieba and text analysis of *Python*. Further, empirical tests were carried out to verify the influence direction and possible mechanism of the impact of EDT on stock price crash risks. Major conclusions are summarized in the following section.

EDT can significantly diminish stock price crash risks. As endogenous problems are solved, conclusions remain valid after robustness tests. In particular, the effect of EDT on reducing stock price crash risk declines as the level of the stock price bubble rises, and the effects are different in different ownership systems and industries. Further research in this study finds that EDT can improve internal management capabilities of the enterprise and meanwhile arouse more attention from the external market. Further, it reduces the stock price crash risks by alleviating the "principle-

agent" problem and reducing the information asymmetry inside and outside enterprises.

This paper sheds light on the following policies. China should actively grasp the opportunities of digital economy development and EDT to promote its enterprises in various industries to implement digital transformation at all levels through elaborating supportive policies for different segments and building demonstration enterprises. The purpose is to achieve high-quality development of enterprises. At the same time, regulatory authorities should standardize the disclosure system for EDT, enhance the accuracy and standardization of information disclosure, and improve the information interpretation capabilities of the capital market. For state-owned enterprises, the government should further promote its market-oriented reform and help strengthen its internal management capabilities, and it should empower them to play a more important role in promoting the innovation of Chinese enterprises and leading the digital transformation [53–55].

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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