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The Impact of Digital Transformation Disclosure Features in Annual Reports on the Cost of Debt Capital of A-Share Listed Companies in China

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ABSTRACT
This paper examines how digital transformation disclosure in annual reports affects the debt capital costs of Chinese A-share listed companies. The study defines four disclosure dimensions—quantity, quality, tone, and degree—and measures them through large-scale text analysis that integrates deep learning and natural language processing (NLP). Annual reports from 2013 to 2024 are programmatically extracted using Python, and a fixed-effects model is constructed in Stata for regression analysis to link disclosure with firms' debt capital costs. Empirical results show that richer, higher-quality, and greater-degree digital transformation disclosures are associated with significantly lower debt costs; tone also exerts an effect, but its role depends on the broader information environment. Two categories of moderating factors influence these relationships: the degree of digitalization reflected in analyst reports; the attention and digitalization intensity of media coverage. External information sources—especially analysts' interpretations and the depth of media coverage—further shape market perceptions, amplifying or weakening the impact of disclosure characteristics on the cost of debt capital. Robustness tests support the validity of the conclusions. Overall, the external information environment determines how information disclosure in listed companies' annual reports translates into lower debt capital costs. The study provides both theoretical grounding and practical guidance: enterprises can optimize debt financing by enhancing disclosure quality and extent, and actively engaging with analysts and the media to strengthen credible, digital-forward narratives.
KEYWORDS:Digital Transformation, Disclosure Characteristics, Debt Capital Cost, Text Analysis, Natural Language Processing (NLP)

Introduction

According to the China Enterprise Executive Tracking Survey Report (2021), the average financing cost of Chinese enterprises reaches as high as 8.33%, with the financing cost of small and medium-sized enterprises (SMEs) generally exceeding 10%. High financing costs erode corporate profit margins, suppress long-term investment intentions, and inadvertently increase systemic financial risks. The application of emerging technologies such as artificial intelligence, big data, cloud computing, and blockchain is reshaping corporate operating logic and financing models, providing technological support for mitigating information asymmetry and enhancing trust mechanisms in capital markets. In the United States, Amazon and Google have optimized their supply chains and financial disclosures through artificial intelligence and cloud platforms, significantly improving transparency and reducing capital costs (Mubarik & Khan, 2024). Germany's "Industry 4.0" strategy integrates enterprise resources through the Internet of Things (IoT) and blockchain, enabling manufacturing firms to obtain low-cost financing more easily (Azadi et al., 2024). Blockchain technology, by enhancing transaction transparency and reducing intermediary costs through decentralized ledgers, lowers financing risks and trust costs (Omokhoa et al., 2024). Existing studies have shown that digital transformation helps reduce corporate financing risks and capital costs by improving information transparency and governance quality (Che et al., 2023; Fan Hongzhong et al., 2022).

Previous research has explored the impact of corporate digital transformation on debt financing costs from the perspectives of operations or strategic change, but few studies have examined how the characteristics of digital transformation disclosures in annual reports influence creditors' perceptions of corporate risk, thereby affecting the cost of debt capital. Creditors usually rely on publicly disclosed information to assess a company's technological capability and future potential. Therefore, digital transformation information disclosed in annual reports may influence creditors' expectations of risk and return. From this perspective of information disclosure, this study investigates how various characteristics of digital transformation disclosures by Chinese A-share listed companies affect their cost of debt capital.From the perspective of information disclosure quantity, the word frequency and sentence frequency related to digital transformation in annual reports reflect the degree of corporate attention to digital transformation. The more frequently digital transformation is mentioned in annual reports, the more effectively it helps to reduce corporate debt financing costs (Wang & Cao, 2024). A higher disclosure quantity indicates that firms are more inclined to convey a positive image of digital transformation to the public, thereby influencing creditors' assessments of corporate risk and potential (Chen et al., 2025).

In addition to disclosure quantity, the quality of information is also crucial. Firms with higher information disclosure quality tend to have lower debt financing costs (Tao et al., 2023). High-quality disclosures generally demonstrate systematic and authentic corporate digital strategies, which help attract high-quality business partners and gain creditors' trust (Liu, 2025).

From the perspective of textual tone, the sentiment tendency (positive or negative) of digital transformation disclosures in annual reports reflects the attitudes and confidence of corporate management. Conveying confidence in digital transformation to shareholders and financial institutions helps enhance mutual trust among stakeholders (Wang, 2022), thereby reducing the cost of debt capital. By applying text mining and sentiment analysis methods, the emotional tendencies reflected in media coverage can also be quantified, further strengthening the confidence of management and shareholders (Dong, 2024).

In terms of the degree dimension, the proportion of digital transformation intangible assets to total intangible assets reflects the actual depth and intensity of corporate digital investment (Song, 2022). A higher proportion indicates more substantial resource commitment to digital transformation, and such substantive efforts may further influence creditors' assessments of repayment ability and risk levels, leading to lower debt capital costs (Su, 2024).

As one of the most information-rich qualitative texts in listed companies' annual reports, digital transformation disclosure serves as an important source for understanding corporate operations and forecasting future development. This paper constructs and analyzes four dimensions—quantity, quality, tone, and degree—of digital transformation disclosures. The reasons for selecting these dimensions are as follows: first, tone, as an emotional tendency feature in corporate information disclosure, has a significant impact on investors' psychological perceptions and judgments (Rennekamp, 2012). Meanwhile, corporate textual disclosures are often subject to impression management and information manipulation by management (Yuan & Li, 2022). Therefore, high-quality information disclosure not only constrains managerial strategic disclosure behaviors (Sun Tong & Xue Shuang, 2019) but also provides investors with more decision-useful information (Barron et al., 1999; Lambert et al., 2007). Second, most existing studies examine textual characteristics from a single dimension, whereas multidimensional textual disclosure indicators offer more accurate measurement (Li Chenggang et al., 2023). It is thus necessary to comprehensively examine digital transformation disclosures from multiple textual dimensions, as the "quantity" feature of existing studies only captures surface-level characteristics and fails to identify incremental information in disclosure. Based on this, this paper conducts an in-depth analysis from four dimensions—disclosure quantity, quality, tone, and degree—to comprehensively reveal how digital transformation disclosures in annual reports affect corporate debt costs.

The digital transformation information disclosed in annual reports not only reflects a firm's technological investment and strategic orientation but also conveys important signals about its future development potential and risk status to external stakeholders. However, whether these signals can be effectively recognized and interpreted by the market—and subsequently influence creditors' risk assessments—depends on the external information environment in which the firm operates. Analyst reports and media coverage serve as "information amplifiers" in capital markets. Through analysis, interpretation, and dissemination of corporate digitalization progress, they shape investors' and creditors' overall perceptions of the firm.

When analysts pay more attention to a firm's digital strategy in research reports, or when the media actively promote a firm's digital image, the degree of digitalization in the external information environment strengthens the signaling effect of annual report disclosures (Cheng, 2024). The higher the digitalization level of analyst reports, the more easily the positive signals conveyed by a firm's digital transformation disclosures are perceived and amplified by the market (Liu, 2025). The development of digital media magnifies investor sentiment in capital markets, enhances the authenticity of disclosed information, optimizes the granularity of information, and improves the efficiency of information transmission (He et al., 2025), thereby potentially reducing information asymmetry and

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influencing the cost of debt capital. Based on this, this paper introduces the degree of analyst report digitalization and media-reported digitalization as moderating variables to explore the role of the external information environment in the relationship between corporate digital disclosure and the cost of debt capital.

To further verify the above theoretical analysis, this study selects Chinese A-share listed companies as research samples and uses annual reports from 2013 to 2024, focusing on digital transformation disclosures in annual reports and examining their impact on the cost of debt capital. Compared with other capital markets, China's A-share market is characterized by a higher degree of information asymmetry and an underdeveloped external monitoring mechanism, making corporate disclosure content play a particularly critical role in financing decisions. Therefore, using Chinese A-share listed companies as the research sample enables a more targeted examination of the economic consequences of digital transformation disclosure on debt financing.

This study aims to employ a multidimensional quantitative approach to extract digital transformation disclosure characteristics from corporate annual reports and quantify their performance across four dimensions—quantity, quality, tone, and degree—to systematically examine their impact on the cost of debt capital. Meanwhile, it incorporates analyst report digitalization and media-reported digitalization as moderating variables to explore whether the external information environment strengthens the market effects of digital transformation disclosure characteristics. This paper not only extends the research on the economic consequences of digital transformation from the perspective of information disclosure but also provides new empirical evidence for understanding the transmission mechanism of corporate digital strategies in capital markets.

The Relationship Between the Disclosure Quantity of Digital Transformation in Annual Reports and the Debt Financing Cost of Chinese A-Share Listed Companies

The quantity of digital transformation disclosure reflects corporate information transparency and management's willingness to communicate with external stakeholders (Wang et al., 2023). Firms that disclose more digitalization-related information (e.g., word frequency, sentence frequency) in annual reports can effectively reduce information asymmetry between management and creditors, allowing creditors to more accurately assess corporate risk and operational stability, thereby lowering financing costs (Wang & Cao, 2024).

H1: There is a significant relationship between Quantity and CODC.

The Relationship Between the Disclosure Quality of Digital Transformation in Annual Reports and the cost of debt capital of Chinese A-Share Listed Companies

The quality of disclosure reflects the logical consistency and content coherence of corporate information expression. Textual consistency plays a crucial role in the evaluation of information quality (Wang et al., 2023). Conjunctions are essential in enhancing cohesion between sentences and providing organizational cues within the text. Semantic cohesion can be used to measure the logical consistency and internal coherence of textual expressions (Li & Ma, 2022). High-quality digital transformation disclosures are typically characterized by semantic clarity and logical rigor, which enhance the credibility and reliability of information, help capital market participants more accurately assess a company's future cash flows, and thereby reduce the cost of debt capital (Xie, 2018).H2: There is a significant relationship between Quality and CODC.

The Relationship Between the Disclosure Tone of Digital Transformation in Annual Reports and the cost of debt capital of Chinese A-Share Listed Companies

The disclosure tone reflects management's attitude and confidence toward the firm's digital transformation (Yu et al., 2024). Tone and voice directly embody the managerial mindset, as optimistic managers tend to use positive and confident language in their disclosures (Lai & Yan, 2024). Such a positive signal helps alleviate creditors' concerns about the firm's operational risks and improves the firm's credit standing, thereby influencing the cost of debt capital (He, 2025).H3: There is a significant relationship between Tone and CODC.

The Relationship Between the Degree of Digital Transformation Disclosure in Annual Reports and the cost of debt capital of Chinese A-Share Listed Companies

The degree of disclosure reflects a firm's actual investment and resource commitment in the field of digitalization (Li, 2024). A higher disclosure degree, measured by the proportion of "digital intangible assets to total intangible assets," indicates greater investment in technology and innovation, demonstrating the substantive nature and sustainability of the firm's digital strategy (Kou, 2024). Such genuine resource investment enhances creditors' trust, thereby reducing financing costs (Wang, 2025).H4: There is a significant relationship between Degree and CODC.

The Moderating Role of Media-Reported Digitalization

The media serve as an important channel for corporate information dissemination. When the media report more frequently on a firm's digital transformation, the firm's digital disclosure information can be transmitted to the public and financial markets more efficiently and extensively. Most investors can obtain information about listed companies through the media at the earliest possible time, which enhances the verifiability of information disclosure (Li et al., 2024). The digitalized media environment improves information accessibility and transmission speed, helping to further reduce information asymmetry and amplify the signaling effect of corporate disclosure characteristics (Li et al., 2025). Therefore, the digital media environment may alter the relationship between digital disclosure characteristics and the cost of debt capital.

H5a: There is a significant relationship between Quantity and CODC, moderated by MRD.
H5b: There is a significant relationship between Quality and CODC, moderated by MRD.
H5c: There is a significant relationship between Tone and CODC, moderated by MRD.
H5d: There is a significant relationship between Degree and CODC, moderated by MRD.

The Moderating Role of Analyst Report Digitalization

Finally, analysts play the role of professional interpreters and information disseminators in the capital market (Sun, 2025). When analysts issue more reports related to a firm's digital transformation, they can more effectively collect, analyze, and disseminate information concerning the firm's digital transformation (Liu et al., 2025). Analysts' professional reports enhance the market's understanding and trust in corporate digital disclosures, thereby strengthening the impact of digital disclosure characteristics on the cost of debt capital (Yuan, 2024).

H6a: There is a significant relationship between Quantity and CODC, moderated by ARD.
H6b: There is a significant relationship between Quality and CODC, moderated by ARD.
H6c: There is a significant relationship between Tone and CODC, moderated by ARD.
H6d: There is a significant relationship between Degree and CODC, moderated by ARD.

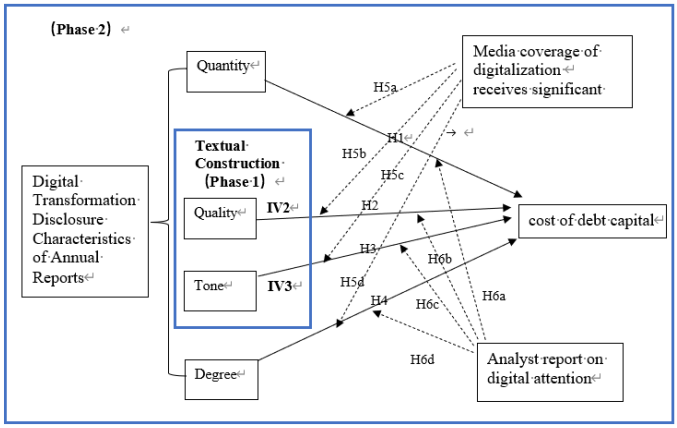

Figure1.Hypothetical framework (Source: Created by Ma Yuxin)

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Methods and Methodology

Sample and Data Sources: This paper selects non-financial listed companies in China's A-share market from 2013 to 2024 as the research sample, covering the Main Board, ChiNext Board, and STAR Market. The financial industry is excluded because financial institutions differ significantly in terms of capital structure, regulatory frameworks, and information disclosure requirements, making their cost of debt capital incomparable with that of other industries.

The study uses secondary data, consisting of both financial information and textual information. Financial and firm characteristic data are obtained from the CSMAR and CNRDS databases, while textual data are sourced from the annual report PDF files disclosed by listed companies on CNINFO. To ensure sample quality, companies designated as *ST/*ST, as well as those with missing financial data or unavailable annual report texts, are excluded. The final sample consists of approximately 3,600 listed companies and about 21,000 firm-year observations, forming an unbalanced panel dataset. All continuous variables are Winsorized at the top and bottom 1% levels to mitigate the influence of extreme values.

Measurement of Variables: To comprehensively characterize the features of digital transformation disclosure in the annual reports of listed companies, this paper adopts natural language processing (NLP) methods to extract semantic, emotional, and structural features from textual data, thereby constructing a multidimensional disclosure measurement system. Compared with traditional approaches that rely on disclosure length or manual judgment, NLP techniques can capture the semantic logic behind language in large-scale text samples, more accurately reflecting management's authentic expressions and attitudes toward digital transformation disclosure. Specifically, this paper defines and quantifies the characteristics of digital disclosure from four dimensions: quantity, quality, tone, and degree.

(1) Disclosure Quantity (Digital_Quantity) Disclosure quantity reflects the breadth of digitalization-related content disclosed in annual reports. This paper measures it using the sentence frequency method. Based on the CNRDS platform's dictionary of digital transformation keywords (a total of 161 keywords), the number of sentences in the annual report containing at least one keyword is counted. A higher sentence frequency indicates greater attention by the company to digitalization topics in its information disclosure.

(2) Disclosure Quality (Digital_Quality) To measure the coherence and readability of disclosure content, this paper employs a semantic cohesion index based on the Word2Vec model. It extracts sentences containing digitalization-related keywords, aligning with recent research in the NLP field. Tabari and Johnson (2023) quantified textual cohesion using lexical repetition and semantic network structures, verifying that semantic-level cohesion is an important dimension for evaluating text quality, thus providing solid theoretical support for this study's approach. A higher level of semantic cohesion indicates clearer and more logically consistent disclosure language, implying higher text quality.

(3) Disclosure Tone (Digital_Tone) Disclosure tone reflects the emotional inclination of management in digital strategy disclosure. This paper adopts the FinBERT model (Nan Hu, 2023; Huang et al., 2022) to classify the sentiment of sentences related to digital transformation in annual reports. The model categorizes sentences as positive, negative, or neutral and assigns them positive, negative, or zero values, respectively. The weighted average is then calculated to obtain the firm-level annual tone indicator. A higher value indicates a more positive and confident tone in digital disclosure. FinBERT identifies emotional tendencies based on contextual semantics, providing higher accuracy than traditional dictionary-based methods.

(4) Disclosure Degree (Digital_Degree) Disclosure degree reflects the firm's actual investment in the field of digitalization. This paper measures it as the proportion of digitalization-related intangible assets to total intangible assets reported in the firm's financial statement notes. Using a Python program, contents associated with keywords such as "information systems," "data platforms," "intelligent manufacturing," and "cloud computing" are identified, and their proportions are calculated. A higher ratio indicates a greater level of investment in digital infrastructure.

The dependent variable of this study is the cost of debt capital (CODC), measured as the ratio of financial expenses to total liabilities at the end of the period, following the approach of Pittman and Fortin (2004).The moderating variables include media-reported digitalization (MRD) and analyst report digitalization (ARD), both measured as the natural logarithm of the frequency of digitalization-related keywords appearing in relevant media reports or analyst reports on the CNRDS platform.The control variables include firm size (Size) and return on equity (ROE). In addition, firm and year fixed effects are controlled for in the model to eliminate biases caused by unobservable factors.

Data Analysis and Model Specification: The text mining and variable construction in this paper are primarily conducted using Python, while the econometric analysis is performed with Stata 19.To examine the impact of digital transformation disclosure characteristics on firms' cost of debt capital, this paper follows the approach of Kim et al. (2017) and constructs a two-way fixed effects panel model. To mitigate potential endogeneity issues, the core explanatory variables and control variables are lagged by one period. Robust standard errors are employed for parameter estimation to correct for heteroscedasticity. The model is specified as follows:

$$CODC_{i,t+1} = \alpha_0 + \alpha_1 Dig\_Disclosure_{i,t} + \alpha_2 Controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

Here, $CODC_{i,t+1}$represents the cost of debt capital of firm $i$in year $t+1$, and $Dig_Disclosure_{i,t}$denotes the digital transformation disclosure characteristics of firm $i$in year t. $\mu_i$and $\lambda_t$represent the firm and year fixed effects, respectively. Compared with previous approaches that relied on manual judgment or disclosure length statistics, this paper applies natural language processing (NLP) techniques to quantify digital transformation information disclosure characteristics at the semantic level, achieving a shift from "literal counting" to "semantic understanding." By integrating machine learning models (Word2Vec and FinBERT) with financial data, a four-dimensional indicator system encompassing breadth, depth, sentiment, and substantive investment is constructed. This not only improves the quantitative precision of disclosure characteristics but also provides a more detailed and replicable analytical framework for studying the economic consequences of digital strategy disclosure.

Results

Descriptive Statistics & Correlation

Table 1 Descriptive Statistics

Variable	N	Mean	SD	P25	P50	P75	Min	Max
Tone	21,204	9.5245	11.5323	2.2462	5.5800	12.0336	-0.6672	62.6417
Quality	21,204	21.4266	6.5786	17.0740	20.6856	24.6925	9.1476	46.7180
Quantity	21,204	3.2740	1.0445	2.5649	3.2581	3.9703	0.0000	6.6000
Degree	21,204	-3.4132	1.8512	-4.5458	-3.3520	-2.1968	-9.2103	0.0001
CODC	21,204	0.0033	0.0313	-0.0052	0.0077	0.0206	-0.1778	0.0679
MRD	21,204	3.2894	1.5297	2.1972	3.2189	4.2767	0.6931	12.3421
ARD	13,173	2.0340	1.2634	1.0986	2.0794	3.0445	0.0000	5.3519
Size	21,204	3.1053	0.0562	3.0646	3.0987	3.1393	2.9730	3.2753
ROE	21,204	0.0668	0.1315	0.0315	0.0764	0.1262	-1.1740	0.4151

Table 1 presents the descriptive statistical results of the main research variables in this paper, including the quantity (Quantity), quality (Quality), tone (Tone), and degree (Degree) of digital transformation disclosure, as well as the cost of debt capital (CODC), media-reported digitalization (MRD), analyst report digitalization (ARD), and control variables (firm size Size and return on equity ROE). From the statistical results, the means and standard deviations of the variables vary considerably, reflecting significant heterogeneity among sample firms in terms of digital disclosure and financing characteristics. Specifically, the mean value of disclosure quantity (Quantity) is 3.274 with a standard deviation of 1.044, indicating that most firms include a certain degree of digital information disclosure in their annual reports, but the breadth of disclosure differs substantially. The mean value of disclosure quality (Quality) is 21.4266 with a standard deviation of 6.5786, suggesting that firms differ significantly in the semantic coherence and readability of their texts. The mean value of disclosure tone (Tone) is 9.5245, with a relatively high standard deviation (11.5323), showing large variations in managerial tone across firms' digital disclosures. The mean value of disclosure degree (Degree) is –3.4132 with a standard deviation of 1.8512, indicating that the proportion of digital intangible assets remains relatively low for most firms.

Regarding the external information environment variables, the mean value of media-reported digitalization (MRD) is 3.2894, while that of analyst report digitalization (ARD) is 2.0340, suggesting that although the overall level of digitalization in external communication channels is relatively high, there are still certain disparities. Among the control variables, firm size (Size) is relatively concentrated, with a standard deviation of only 0.0562, whereas return on equity (ROE) shows greater volatility, indicating substantial differences in profitability across firms. To mitigate the influence of extreme values, the variables of disclosure

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Vol. 36 Issue 1, 2026, Pages 5714-5722

quality and tone are Winsorized (tail-trimmed). Since data on analyst report digitalization are available only from 2015 onward, its sample size (13,173) is slightly smaller than that of other variables (21,204).

Table 2 Correlation coefficients and p-values between variables

	CODC	Quantity	Quality	Tone	Degree	MRD	ARD	DSC	SIZE	ROE
CODC	1.0000									
Quantity	-0.0801*** (0.0000)	1.0000								
Quality	-0.0498*** (0.0000)	0.1664*** (0.0000)	1.0000							
Tone	-0.0867*** (0.0000)	0.7395*** (0.0000)	0.0849*** (0.0000)	1.0000						
Degree	-0.1198*** (0.0000)	0.3866*** (0.0000)	0.0667*** (0.0000)	0.3026*** (0.0000)	1.0000					
MRD	-0.0552*** (0.0000)	0.2904*** (0.0000)	0.0585*** (0.0000)	0.2404*** (0.0000)	0.1430*** (0.0000)	1.0000				
ARD	-0.0241*** (0.0057)	0.0868*** (0.0000)	-0.0054 (0.5353)	0.0374*** (0.0000)	0.0454*** (0.0000)	0.2486*** (0.0000)	1.0000			
SIZE	0.2118*** (0.0000)	0.0205*** (0.0024)	0.0407*** (0.0000)	-0.0053 (0.4348)	-0.0995*** (0.0000)	0.2966*** (0.0000)	0.2976*** (0.0000)	0.0340*** (0.0000)	1.0000	
ROE	-0.1761*** (0.0000)	-0.0283*** (0.0000)	-0.0459*** (0.0000)	-0.0267*** (0.0001)	-0.0205*** (0.0024)	0.0668*** (0.0000)	0.2893*** (0.0000)	0.0420*** (0.0000)	0.0718*** (0.0000)	1.0000

Table 2 presents the Pearson correlation coefficients and their significance levels among the main variables. The results show that the quantity, quality, and tone of digital disclosure are all significantly and negatively correlated with the cost of debt capital (CODC) ($p < 0.01$), indicating that the more sufficient the disclosure, the clearer the content, and the more positive the tone, the lower the cost of debt financing. This finding is consistent with the theoretical expectations of this paper. The disclosure degree (Degree) also shows a significant negative correlation with CODC, suggesting that the more a firm invests in digitalization, the lower its credit financing risk premium.

Among the independent variables, disclosure quantity (Quantity) and tone (Tone) exhibit the highest correlation ($r = 0.7395$, $p < 0.01$), reflecting that firms tend to use more positive language when actively disclosing digitalization information. Although the correlations of disclosure quality (Quality) with quantity and tone are significant, the coefficients are relatively low, indicating that disclosure richness and readability are not completely synchronized. Media-reported digitalization (MRD) shows a significant positive correlation with all disclosure characteristics, suggesting a certain synergy between the external digital communication environment and firms' internal disclosure behaviors. The positive correlations of analyst report digitalization (ARD) with disclosure quantity and tone also support this conclusion.

Table 3 Results of multicollinearity diagnosis

Variable	VIF	1/VIF
Quantity_M	4.17	0.239530
Quality_M	1.40	0.711945
Tone_M	6.11	0.163590
Degree_M	2.44	0.409091
MRD_M	1.30	0.766971
ARD_M	1.27	0.785262
DSC_M	1.27	0.788200
SIZE	1.23	0.812637
ROE	1.11	0.903379
Quantity_MRD	3.04	0.328783
Quality_MRD	1.16	0.861955
Tone_MRD	3.22	0.310858
Degree_MRD	1.32	0.756807
Quantity_ARD	2.53	0.394845
Quality_ARD	1.13	0.888482
Tone_ARD	2.29	0.436100
Degree_ARD	1.25	0.797046
Quantity_DSC	4.38	0.228417
Quality_DSC	1.24	0.809533
Tone_DSC	6.23	0.160549
Degree_DSC	2.02	0.495014
Mean VIF	2.39	

To test for multicollinearity, this paper calculates the Variance Inflation Factor (VIF) for each variable Table 3, and the results are shown in the table. All variables have VIF values less than 10, with an average value of 2.39, which is far below the commonly used thresholds (10 or 5), indicating that the model does not suffer from serious multicollinearity problems.Overall, the results of the descriptive statistics and correlation analysis are consistent with theoretical expectations, providing reliable data support for the subsequent regression analysis.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
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Vol. 36 Issue 1, 2026, Pages 5714-5722

Baseline Regression Results

Table 4 Summary of Hypothesis Testing

Hypothesis development	Sig	P-value	Hypothesis	Result
H1: There is a significant relationship between Quantity and CODC.	0.0235	0.523	H1	Not Supported
H2: There is a significant relationship between Quality and CODC.	-0.0060**	0.018	H2	Supported
H3: There is a significant relationship between Tone and CODC.	0.0088***	0.000	H3	Supported
H4: There is a significant relationship between Degree and CODC.	-0.0803***	0.000	H4	Supported

Table 4 summarizes the regression analysis results of hypotheses H1–H4 in this paper. The results show that the four variables representing digital transformation disclosure characteristics exhibit certain differences in both the direction and significance of their effects on the cost of debt capital (CODC).

The regression coefficient of disclosure quantity is –0.0235, with a P-value of 0.523, which does not reach statistical significance ($p > 0.05$), indicating that the quantity of digital disclosure has no significant impact on the cost of debt capital, and the null hypothesis H1 cannot be rejected. This suggests that simply increasing the length or frequency of disclosures does not effectively reduce corporate financing costs, as the expansion of information volume at the quantitative level may fail to convey more valuable signals to creditors.

The regression coefficient of disclosure quality is –0.0060, with a P-value of 0.018, which is significantly negative at the 5% level, supporting hypothesis H2. This indicates that the higher the semantic coherence and readability of digital transformation information in annual reports, the lower the cost of debt capital. In other words, the logic and clarity of disclosure content can effectively enhance creditors' understanding of the firm's digital strategy, thereby reducing their perceived risk.

The regression coefficient of disclosure tone is 0.0088, with a P-value of 0.000, which is significantly positive at the 1% level, supporting hypothesis H3. This result indicates that the more positive the tone, the higher the firm's cost of debt capital. Although this finding contrasts with some prior literature, it may reflect creditors' cautious attitude toward overly optimistic managerial language, perceiving it as potential "tone management" or signal manipulation, which leads to an increase in required risk premiums.

The regression coefficient of disclosure degree is –0.0803, with a P-value of 0.000, which is significantly negative at the 1% level, supporting hypothesis H4. This result shows that the greater the firm's actual investment in digital-related intangible assets, the lower its cost of debt capital, indicating that substantive digital transformation enhances external financiers' confidence in the firm's long-term competitiveness and operational stability.

The regression results indicate that the quality, tone, and degree of digital disclosure all have significant effects on the cost of debt capital, with the negative relationships of quality and degree being the most robust. In contrast, mere disclosure quantity does not play a substantive role, reflecting that the quality of digital information disclosure exerts a stronger influence than its quantity on capital market assessments of corporate credit risk.

Regarding the control variables, the coefficient of firm size (ln_Size) is 10.3605 and significantly positive at the 1% level, suggesting that larger firms have higher costs of debt capital, possibly due to their more complex financing structures and higher leverage ratios. The coefficient of return on equity (ROE) is –2.2835, also significantly negative at the 1% level, indicating that firms with higher profitability face lower debt financing costs, consistent with the predictions of information asymmetry and risk premium theories. Overall, the directions of the control variable results align with theoretical expectations, further validating the rationality of the model specification.

The intercept term (_cons), though statistically significant, merely reflects the constant component of the model and has no substantive economic meaning; therefore, it is not discussed further in this paper.

Moderating Effects of MRD and ARD

Table 5 The Moderating Effects Hypothesis Testing

Hypothesis development	Sig	P-value	Hypothesis	Result
H5a: There is a significant relationship between Quantity and CODC, moderated by MRD.	-0.0118	0.315	H5a	Not Supported
H5b: There is a significant relationship between Quality and CODC, moderated by MRD.	0.0012	0.412	H5b	Not Supported
H5c: There is a significant relationship between Tone and CODC, moderated by MRD.	-0.0014*	0.091	H5c	Supported
H5d: There is a significant relationship between Degree and CODC, moderated by MRD.	0.0128*	0.074	H5d	Supported
H6a: There is a significant relationship between Quantity and CODC, moderated by ARD.	-0.0388**	0.049	H6a	Supported
H6b: There is a significant relationship between Quality and CODC, moderated by ARD.	-0.0047**	0.040	H6b	Supported
H6c: There is a significant relationship between Tone and CODC, moderated by ARD.	-0.0036**	0.024	H6c	Supported
H6d: There is a significant relationship between Degree and CODC, moderated by ARD.	-0.0127	0.241	H6d	Not Supported

Table 5 presents the test results of the moderating effects of media-reported digitalization (MRD) and analyst report digitalization (ARD) on the relationship between digital transformation disclosure characteristics and the cost of debt capital (CODC). The results show that the interaction terms of different dimensions

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 5714-5722

vary in both significance and direction, indicating that the influence mechanism of the external information environment on corporate digital disclosure is relatively complex.

From the perspective of the moderating effect of media-reported digitalization (MRD):

The regression coefficient of the interaction term between disclosure quantity and media-reported digitalization (Quantity_MRD_M) is –0.0118, with a P-value of 0.315, which is not significant. This indicates that media-reported digitalization does not significantly strengthen the effect of digital disclosure quantity on the cost of debt capital, and thus Hypothesis H5a is not supported.

The coefficient of the interaction term between disclosure quality and media-reported digitalization (Quality_MRD_M) is –0.0012, with a P-value of 0.412, which is also insignificant, indicating that Hypothesis H5b is not supported.

The coefficient of the interaction term between disclosure tone and media-reported digitalization (Tone_MRD_M) is –0.0014, with a P-value of 0.091, which is significantly negative at the 10% level, supporting Hypothesis H5c. This suggests that under a more mature media digitalization environment, a more positive managerial tone has a stronger effect in reducing the cost of debt capital, indicating that external media help enhance the transmission and risk mitigation function of positive tone information.

The coefficient of the interaction term between disclosure degree and media-reported digitalization (Degree_MRD_M) is 0.0128, with a P-value of 0.074, which is significant at the 10% level, supporting Hypothesis H5d. This means that when a company's digital investment is relatively high and receives more attention from digitalized media, the effect of its information disclosure on improving the cost of debt financing becomes more significant.

From the perspective of the moderating effect of analyst report digitalization (ARD):

The regression coefficient of the interaction term between disclosure quantity and analyst report digitalization (Quantity_ARD_M) is –0.0388, with a P-value of 0.049, which is significantly negative at the 5% level, supporting Hypothesis H6a. This indicates that when the level of digitalization in analyst reports is higher, the effect of digital disclosure quantity in reducing the cost of debt capital becomes stronger.

The coefficient of the interaction term between disclosure quality and analyst report digitalization (Quality_ARD_M) is –0.0047, with a P-value of 0.040, which is significantly negative at the 5% level, supporting Hypothesis H6b. This shows that the higher the degree of digitalization in analyst reports, the stronger the effect of high-quality disclosure in reducing corporate debt financing costs.

The coefficient of the interaction term between disclosure tone and analyst report digitalization (Tone_ARD_M) is –0.0036, with a P-value of 0.024, which is also significantly negative at the 5% level, supporting Hypothesis H6c. This indicates that analysts' enhanced ability to identify and interpret corporate disclosure tone in digital reports helps strengthen the market signaling effect of positive tone.

However, the coefficient of the interaction term between disclosure degree and analyst report digitalization (Degree_ARD_M) is –0.0127, with a P-value of 0.241, which is not significant, indicating that Hypothesis H6d is not supported. This suggests that the level of digitalization in analyst reports does not significantly moderate the relationship between corporate digital asset investment and the cost of debt capital.

The analysis of moderating effects shows that the external information environment plays a partial moderating role in the relationship between digital transformation disclosure and financing costs. Media digitalization mainly strengthens the effects of disclosure tone and degree, while analyst report digitalization significantly enhances the effects of disclosure quantity, quality, and tone. This indicates that the digitalization process of external information channels can improve the efficiency of information transmission, thereby amplifying the impact of corporate digital disclosure on capital market pricing.

Robustness & Endogeneity Tests

Table 6 Robustness test results

Variables	Coefficient	P-value	Consistent with the main test result
Quantity	-0.0844***	0.000	Inconsistent
Quality	-0.0018**	0.019	Consistent
Tone	0.0026***	0.000	Consistent
Degree	-0.0417***	0.000	Consistent
ln_size	3.9645***	0.000	Consistent
ROE	-1.5110***	0.000	Consistent
_cons	-10.5429***	0.000	Consistent
Observations	20233		
R-squared	0.6972		
Adj R-squared	0.6315		
stkcd	YES		
year	YES		

*** p<0.01, ** p<0.05, * p<0.1

From table 6, to verify the robustness of the research conclusions, this paper conducts multidimensional tests by changing the measurement methods of the core variables and modifying the model settings. Specifically, regarding the dependent variable, the cost of debt capital (CODC) in the baseline model, measured as "the ratio of financial expenses to total liabilities" (Cost1), is replaced by "the ratio of the sum of interest expenses, service charges, and other financial expenses to total liabilities" (Cost2), and the model is adjusted to a "current disclosure–current debt cost" setting to examine the immediate impact of disclosure behavior on current financing pricing. For the independent variables, alternative indicators are used to verify the four characteristics of digital transformation disclosure: disclosure quantity is replaced from sentence frequency to word frequency; disclosure quality is replaced from the semantic score of "containing at least one keyword" (Quality_1kw) to the semantic score of "containing at least two keywords" (Quality_2kw); disclosure tone is expanded from FinBERT scores analyzing only the Management Discussion and Analysis (MD&A) section to sentiment scores for the entire annual report text; disclosure degree is replaced from "the ratio of digital intangible assets to total intangible assets" to "the ratio of digital intangible assets to the sum of fixed and intangible assets."

The test results show that the sign direction and significance of the core explanatory variables remain generally consistent under different measurement scales and time settings. Only disclosure quantity is insignificant in the baseline model but shows a significant negative relationship in the robustness tests. This indicates that the impact of digital transformation disclosure characteristics on the cost of debt capital is robust and reliable, and that under the current-period setting, there exists an obvious immediate effect, which may be reflected through mechanisms such as credit rating adjustment, short-term financing negotiation, and debt covenant constraint. Overall, the conclusions of this paper do not depend on the specific measurement methods of variables. The core results remain consistent across multiple alternative settings, further verifying the validity and robustness of the research conclusions.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 5714-5722

Discussion

After systematically analyzing the results of the baseline regression, moderating effects, and robustness tests, it can be observed that the characteristics of digital transformation disclosure in corporate annual reports exert differentiated effects on the cost of debt capital across various dimensions. Overall, disclosure quality and degree play a significant role in reducing financing costs, while tone exhibits a positive impact, reflecting the market's cautious response to "optimistic expressions." Meanwhile, media-reported digitalization (MRD) and analyst report digitalization (ARD) act as moderators in this relationship to varying degrees, further revealing the transmission mechanism between corporate disclosure and debt pricing under different external information environments.

The Relationship Between Digital Transformation Disclosure Quantity and the Cost of Debt Capital (CODC) is Insignificant

The findings indicate that the quantity of digital transformation disclosure does not exhibit a statistically significant relationship with the cost of debt capital, suggesting that the volume of disclosure itself is not a key determinant of financing costs. This implies that capital markets prioritize the content quality and economic substance of information rather than the breadth or length of disclosure. Excessive quantitative disclosure without substantive content may create an "information noise" effect, making it difficult for creditors to accurately assess the firm's true risk level and thereby weakening the alleviating effect of disclosure on financing constraints. This result aligns with the core proposition of information asymmetry theory: an increase in the amount of information does not necessarily reduce information asymmetry; only high-quality and verifiable information can effectively improve market expectations. Firms should avoid merely pursuing an increase in disclosure volume and instead focus on enhancing the logic, coherence, and substance of disclosure content, ensuring that digital transformation information truly reflects strategic execution and technological capability. This, in turn, can foster creditor trust and reduce financing costs more effectively.

Significant Negative Correlation Between Digital Transformation Disclosure Quality and the Cost of Debt Capital (CODC)

Empirical results support Hypothesis H2, indicating that higher quality in digital transformation disclosure is associated with a lower cost of debt capital. High-quality disclosures maintain semantic coherence and clarity, enabling external investors and creditors to better understand a firm's digital strategy, technology investment, and operational performance, thereby reducing cognitive bias and risk premiums. This finding is consistent with information asymmetry theory and information transparency theory, both of which posit that high-quality information transmission enhances market trust and improves financing efficiency. Firms should strengthen the structure and readability management of digital disclosure content in annual reports, presenting digital investments, outcomes, and financial impacts in a data-driven and modularized manner. Doing so enhances the transparency and professionalism of disclosures, thereby lowering financing costs and improving market reputation.

Significant Positive Correlation Between Digital Transformation Disclosure Tone and the Cost of Debt Capital (CODC)

Results support Hypothesis H3, showing that the more positive the disclosure tone, the higher the firm's cost of debt capital. This suggests that the capital market may interpret overly optimistic or exaggerated language as a signal of managerial impression management, leading to an increase in required risk premiums. The conclusion implies that emotional expression can amplify market sensitivity to uncertainty. Creditors tend to adopt a conservative stance toward "overly optimistic" expressions to guard against potential risks of information manipulation. Firms should maintain a neutral and rational tone when disclosing digital transformation information, grounding disclosures in facts and data rather than excessive optimism, to prevent market misinterpretation and stabilize financing costs.

Significant Negative Correlation Between Digital Transformation Disclosure Degree and the Cost of Debt Capital (CODC)

Hypothesis H4 receives strong support. A higher degree of digital transformation disclosure—reflected by a greater proportion of digital investment in intangible assets—is associated with a lower cost of debt capital. This indicates that the capital market values firms with substantive digital investments, as such disclosures directly signal technological capability, innovation strength, and future growth potential, thereby reducing uncertainty in external risk assessment. This conclusion aligns with information transparency theory and signaling theory, suggesting that the more specific and data-supported the disclosure, the easier it is for the market to identify its intrinsic value. Firms should proactively disclose concrete information such as digital assets, R&D expenditure, and intelligent system development, ensuring consistency in measurement standards, and transmit their digital capabilities through hard information to lower capital costs and mitigate creditors' prudential pricing.

Moderating Effect of Media-Reported Digitalization (MRD)

Empirical results partially support Hypothesis H5. Media-reported digitalization significantly moderates the relationship between tone and the cost of debt capital (H5c: supported) and exhibits a marginally significant negative moderating effect on disclosure degree (H5d: marginally supported). This suggests that media digitalization can, to some extent, mitigate the risk premium effect of an optimistic tone while reinforcing the market's recognition of substantive investment. Media coverage provides an external verification mechanism in information dissemination, helping creditors and investors better understand corporate transformation progress and reducing excessive interpretation or misjudgment. Firms should actively leverage digital media channels for transparent and objective information communication, enhancing external supervision and trust through multi-level media disclosures, thereby weakening the adverse financing effects induced by emotional tones.

Moderating Effect of Analyst Report Digitalization (ARD)

Findings support Hypotheses H6a, H6b, and H6c, indicating that analyst report digitalization significantly moderates the effects of disclosure quantity, quality, and tone on the cost of debt capital, while showing no significant moderating effect on disclosure degree (H6d). The negative moderating effect of ARD suggests that analysts' digital interpretation and dissemination enhance market information processing efficiency, reduce noise effects, and enable creditors to assess firm risk more accurately. This finding is consistent with Naqvi et al. (2021), which highlights the critical role of analyst reports in mitigating information asymmetry and improving risk perception. Firms should proactively strengthen communication and collaboration with analysts by providing structured and quantifiable digital data, enabling analysts to interpret transformation information more comprehensively. Such efforts help improve market expectations and stabilize debt pricing.

Conclusion

This paper, based on a sample of China's A-share listed companies, systematically examines the impact of digital transformation disclosure characteristics on firms' cost of debt capital (CODC) from the perspective of annual report texts.Empirical results indicate that both the quality and degree of digital transformation disclosure are significantly and negatively correlated with the cost of debt capital, implying that high-quality and substantive digital disclosure effectively reduces corporate financing costs. In contrast, the tone of disclosure exhibits a significant positive relationship, suggesting that overly optimistic emotional expressions may be interpreted by the market as a signal of "managerial over-optimism," prompting creditors to raise risk premiums. The quantity of disclosure is statistically insignificant in the baseline model but shows a certain degree of negative significance under contemporaneous specifications and alternative measures, implying that the breadth of disclosure still exerts some influence when temporal alignment and definitional adjustments are considered. Overall, the market tends to respond positively to digitalization-related information that is high-quality, verifiable, and reflects substantive investment, while remaining cautious toward rhetorical or sentiment-driven content.

Further analysis reveals that the external information environment plays a significant moderating role in the relationship between corporate disclosure and cost of capital.Media-reported digitalization (MRD) mitigates the adverse effect of overly optimistic tones and, to some extent, amplifies the positive signaling effect of substantive disclosure. Meanwhile, analyst report digitalization (ARD) significantly strengthens the explanatory power of disclosure quantity, quality, and tone, enhancing the market's understanding and responsiveness to digital information. The combined effect of MRD and ARD improves the transmission mechanism of corporate information, thereby enhancing creditors' risk perception and the efficiency of capital pricing. Robustness tests confirm that the sign and significance of key variables remain consistent across alternative CODC measures, contemporaneous versus lagged specifications, and model variations, indicating the robustness and reliability of the findings. Moreover, stronger significance in contemporaneous models reflects the capital market's immediate response to firms' digital information.

This study extends the literature on digital transformation by incorporating a capital market perspective and, for the first time, systematically reveals the transmission mechanism of digital disclosure through the chain of "strategic implementation—market perception—financing pricing" from the viewpoint of debt financing costs.Theoretically, this research enriches the application of information asymmetry theory, signaling theory, and sentiment bias theory in debt pricing, providing new evidence for understanding the economic consequences of non-financial information in capital markets. Practically, the findings suggest that firms should adhere to the principle of "quality over quantity," disclosing digital transformation progress in a data-driven, structured, and verifiable manner while avoiding overly optimistic or ambiguous statements. Meanwhile, regulatory authorities should improve the standard system for digital information disclosure, and

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financial institutions should incorporate disclosure quality and tone into credit assessment models, jointly promoting higher information transparency and more efficient resource allocation in capital markets.

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MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages 5714-5722

Appendix I. Keywords of Digital Transformation Disclosure in Annual Reports（161 Keywords）

Networking	Virtual Manufacturing	Differential Privacy Technology	Cloud Ecosystem
Identity Authentication	Online and Offline Integration	Smart Wearables	Biometric Technology
Information Integration	Internet Plus	Smart Grid	Automated Monitoring
Cyber-Physical Systems	Consumer to Business (C2B)	Internet of Things (IoT)	Autonomous Driving
Intelligent Control	Mobile Internet	Ontology-based Modeling	Intelligent Data Analytics
Massive Concurrency	Open Banking	Smart Factory	Intelligent Fault Diagnosis
System Integration	Mobile Payment	Intelligent Manufacturing	Integrated Solutions
Green Computing	NFC Payment	E-Commerce	Smart Terminals
Virtual Reality (VR)	Information Management	Cloud Computing	Smart Transportation
Intelligent Connectivity	Smart Logistics	Deep Learning	Mixed Reality (MR)
Industrial Communication	Digital Intelligence	Smart Environmental Protection	Intelligent Customer Service
Autonomous Driving	Digital Technology	Internet Model	Mobile Internet
Investment Decision Support System	Cloud Platform	Data Management	Semantic Search
Smart Financial Contract	Intelligent Warehousing	Industrial Intelligence	Digital Currency
Natural Language Processing (NLP)	Lifecycle Management	Smart Home	Internet Solutions
Business Intelligence	Virtualization	Intelligent Systems	Brain-like Computing
Data Control	Speech Recognition	Integrated Systems	Network Connectivity
Online to Offline (O2O)	Data Visualization	Quantitative Finance	Stream Computing
Smart Banking	Digital Terminals	Internet Applications	Networked Information Sharing
Information Software	Information Networks	Industrial Cloud	Smart Devices
Automated Production	Business to Consumer (B2C)	Smart Agriculture	Big Data
Digital Finance	Digital Communication	EB Data Storage	Intelligent Technology
E-Commerce	Internet Healthcare	Automated Detection	Machine Learning
Mobile Internet	Cognitive Computing	Data Center	Unmanned Retail
Financial Technology (FinTech)	Future Factory	Blockchain	Digitalization
Internet Technology	Smart Marketing	Information Center	Smart Mobility
Digital Marketing	Mobile Intelligence	Automated Monitoring	Image Understanding
Graph Computing	Smart Cultural Tourism	Distributed Computing	Data Network
Digital Control	Informatization	Cloud Service	Augmented Reality (AR)
Smart Manufacturing	Internet Plus	Online to Offline	Integrated Control
Internet Platform	Third-Party Payment	Smart Healthcare	High-end Intelligence
Manufacturing Execution System (MES)	Intelligent Investment Advisory	Heterogeneous Data	Converged Architecture
Information Systems	Data Mining	Intelligent Robots	Information Terminals
Smart Energy	Internet Thinking	Smart Payment	Industrial Internet
Data Science	Mobile Internet	Internet Business	Multi-Party Secure Computing
Internet Finance	Big Data Plus	Industrial Internet	Consumer to Consumer (C2C)
Credit Information	Internet Marketing	Financial Technology	Facial Recognition
Digital Network	Internet Ecosystem	Industrial Information	Internet Business Model
Business to Business (B2B)	Data Platform	Intelligent Chip / Smart Chip	Smart City
Digital Twin	Intelligent Scheduling	Industrial Big Data	Cloud Native
Intelligent Algorithm			