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Digital Transformation and Financing Efficiency: The Moderating Role of Corporate Governance in Chinese Listed Firms

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SUMMARY: *This paper examines how digital transformation affects corporate financing efficiency and whether corporate governance strengthens this relationship. As big data, artificial intelligence, and other new technologies are increasingly applied to various industries, business operation, information transmission, and resource allocation have been changed completely. But still facing the financial constraints, internal management issues affecting their corporate financing efficiency. This article intends to show how digital transformation improves financing efficiency through the improvement of governance structures, and to explore whether information transparency and agency costs mediate this effect, and whether equity balance has a moderating effect.Taking the A-share listed companies of the Shanghai Stock Exchange and Shenzhen Stock Exchange from 2013 to 2024 as a sample, after eliminating ST firms and samples with missing data, this paper get 15,682 valid firm-year observations. The empirical framework uses financing efficiency, calculated by the DEA-BCC model, as the dependent variable. The digital transformation index, measured through annual-report text analysis, serves as the core explanatory variable. Corporate governance is represented by governance indicators, with equity balance specified as the moderating variable, while information transparency and agency cost are introduced as parallel mediating variables. Bidirectional fixed-effect regression models, moderating effect models, and parallel mediating effect models are estimated with firm size, debt-to-asset ratio, growth rate, firm age, and industry-year effects as control variables. Variable relations are visualized by scatter plots, curve fit diagram, heatmap and tree diagram.Empirical results show that digital transformation significantly improves financing efficiency, and the amplification of marginal effect for those who have higher efficiency. In this process, equity balance (EB) plays a positive moderating role, enhancing the enabling effect of digitization. Mediation analysis showed that digital transformation indirectly enhances financial efficiency via two independent channels, enhancing information transparency and reducing agency costs. Heterogeneity analysis finds that there is more synergy in high tech industries and large scale companies.To sum up, there exists a positive relationship between digital transformation and equity balance, which will help enterprises improve their financing efficiency. this effect works through information transparency and agency cost both directly and indirectly. The study provides new ideas to integrate the digital economy with corporate governance theory, and gives empirical support for firms to optimize their governance structures and financing capabilities in order to promote high-quality development strategies.*

KEYWORDS: *Digital transformation; Corporate governance structure; Financing efficiency; Mediating effect; Moderating effect*

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1 Introduction

Digitization transformation has already become one main organizational reply to changes in information handling, resource distribution, and capital raising conditions. Current researches give definition to digital transformation as strategic change at firm level that is pushed by digital technologies, and it is not the simple adoption of separated information systems [1-3]. In the domain of corporate finance, this transformation has influence on the ways that enterprises gather operation data, announce information, assess financing need, manage risk, and arrange interior decision making. The latest proof from enterprises of China demonstrates that digital transformation has close connection with financing restrictions, capital distribution efficiency, debt financing expense, capital structure adjustment, financial mismatch, and capital market transparency [4-12]. These research works indicate that digital transformation has already entered the financing procedure itself, and may exert influence on whether firms are able to convert financing input items into operating and profitability output items in a more efficient way.

The financing efficiency is influenced by both the external financing frictions and the internal governance situations. The information that does not mutually know can raise the difficulty of exterior credit assessment, and bad inside control can lower the efficiency of financing decision-making. The digital transformation can alleviate these frictions through promoting information disclosure, data traceability, decision speed and process visibility. In the same period, the agency theory puts forward that the opportunism of managers and the conflicts of ownership are able to weaken the conversion of digital investment to financing performance [13, 14]. Hence, information transparency is an important mechanism that connects digital transformation with financing results, because higher disclosure quality can decrease the information difference between enterprises and external capital providers [15, 16]. Agency cost is a further mechanism, because digital supervision, internal data combination, and process normalization can cut down management freedom and inefficient resource utilization.

The corporate governance is what offers the institutional condition that lets digital transformation have influence on financing efficiency. In enterprises that have concentrated ownership holding, the controlling stockholder may dominate the making of financing decisions and weaken the disciplinary function that other shareholders have. A more balanced property holding structure can strengthen check and balance between big shareholders, decrease controlling shareholder opportunist behavior, and promote the quality of inside monitoring [17, 18]. This governance situation is especially related to digital transformation, therefore digital tools cannot automatically promote the promotion of financing efficiency. The influence of them is decided by if the enterprise possesses a governance structure which has the ability to turn information advantages into disciplined financing decisions. Hence, in this research, equity balance is brought in as the variable which moderates, to inspect whether ownership checks and balances strengthen the influence that digital transformation exerts on financing efficiency.

Though past studies have looked into digital transformation, financing restriction, capital distribution, debt financing expense, and company governance one by one, some problems still have not got enough integration. Firstly, financing efficiency has often been discussed from the perspective of financing constraints or debt cost, while fewer researches measure it as an input-output transformation process. Second, the governance circumstance that digital transformation brings bigger financing-efficiency benefits has not been completely expounded. Third, the transmitting roads between digital change and financing effect degree need further experience-based splitting analysis. The information transparency and the agency cost give

two measurable mechanisms, by which the digital transformation possibly influences the financing efficiency, but these channels require being tested in the same empirical framework.

The current research builds an empirical frame of firm-year by making use of Chinese A-share listed companies which are from year 2013 to year 2024. The financing efficiency carries on the measurement through the DEA-BCC model, this model carries on the appraisal to the relative efficiency under the variable scale returns, and suits for the multi-input and multi-output efficiency measurement [19, 20]. The input index items contain total assets, total liabilities and interest expenditure, while the output index items contain operation income and return of net assets. The efficiency analysis which is based on DEA also gives a foundation for finding out inefficiency from the process which converts input to output. The digital transformation is measured by the method of annual-report text analysis, and it is acted as the core explanatory variable. We employ equity balance to act as the moderating variable. We take information transparency and agency cost as two parallel mediating variables that are introduced.

Our experience-type analysis uses the combination of fixed-effect regression, moderation effect testing, mediation effect testing and distributional analysis. The baseline regression carries out estimation on the average effect that digital transformation produces to financing efficiency. The interaction model does the test on whether equity balance makes this effect become stronger. Our mediation analysis carries out the logic of indirect-effect checking and utilizes the Sobel test to assess whether information transparency and agency cost have significant transmission of digital transformation's influence onto financing efficiency [21-25]. Quantile regression is moreover utilized to explore whether the influence of digital transformation has difference on the financing-efficiency distribution. This design lets the research investigate not only if digital transformation raises financing efficiency, but also under which governance condition and through which inner accesses this promotion happens.

2 Research Methods

2.1 Dependent Variable Measurement: Financing Efficiency Based on the DEA-BCC Model

Enterprise financing efficiency is a significant indicator for the operation and utilization of funds as well as resource distribution abilities of companies. It will be directly impacted by enterprise's ability to maintain long-term sustainable development and competitive position in the market. The paper uses the BCC model of Data Envelopment Analysis (DEA) to measure it, with the aim of quantitatively evaluating the relative efficiency of enterprises achieving output under different input conditions. DEA-BCC can handle non-proportional relationships of many inputs and outputs, so it is suitable for studying the enterprise financing efficiency. Total Assets, Total Liabilities, and Interest Expense are taken as input variables, and Revenue and Return on Net Assets are considered as output variables. This model could fully demonstrate how effectively enterprises use their funding and debt to carry out business operations. The calculation results of this model range from 0 to 1. The closer the value gets to 1, the higher the level of efficiency when allocating financial resources within a company, meaning that they produce more business output using less financing inputs; thus offering some quantitative guidance for making decisions within an organization.

In a specific measurement process, total asset amount as one of the input indicators reflects the overall scale and potential financing ability of the enterprise; Total liabilities reflect the enterprise's financing scale and leverage level, they directly affect financing efficiency. The interest expense shows how much money the company pays in interest to

borrow money. Less money is spent on interest expenses when the paper looks at it, meaning that out of each dollar you put in, more goes out for output, which is very important when deciding what works best with all these numbers about how companies do things well. Operating income as an output indicator shows the business result of a company obtained from its capital investment and return on net assets is the profitability and efficiency with which the enterprise uses its own funds. According to this kind of input and output indicators, DEA-BCC model can judge the relative distribution efficiency of enterprises' financing resources without relying on certain production function so prevent one-sidedness caused by traditional single-variable ratio study, thus making the measurement of financing efficiency even more scientific and accurate.

And also, the DEA-BCC model's advantage in financing efficiency is that it takes into account the difference of scale and management efficiency. compared to ccr assuming a fixed return on scale, bcc can have changing returns closer to what companies actually do so it's good for comparing big medium and small companies. Also, DEA provides an efficient boundary value and gap analysis for researchers to find the main shortcomings of inefficient enterprises, guiding enterprises to specifically improve their capital structure optimization, financing strategies, digital transformation, etc.. According to the DEA-BCC data of 2013-2024 listed companies from Shenzhen Stock Exchange and Shanghai Stock Exchange obtained by the DEA-BCC method, this paper quantifies the differences in financing efficiency, which provides a firm numerical basis and theoretical support for subsequent empirical research on digital transformation and corporate governance structure. As shown in Figure 1, this paper evaluates how effectively a company can raise funds..Figure 1 gives an intuitive presentation of the specific way that the DEA-BCC model above measures enterprise financing efficiency, which is to input and output indicators as inputs for calculating according to the efficiency boundary and finally outputs a value for the enterprise's financial efficiency.

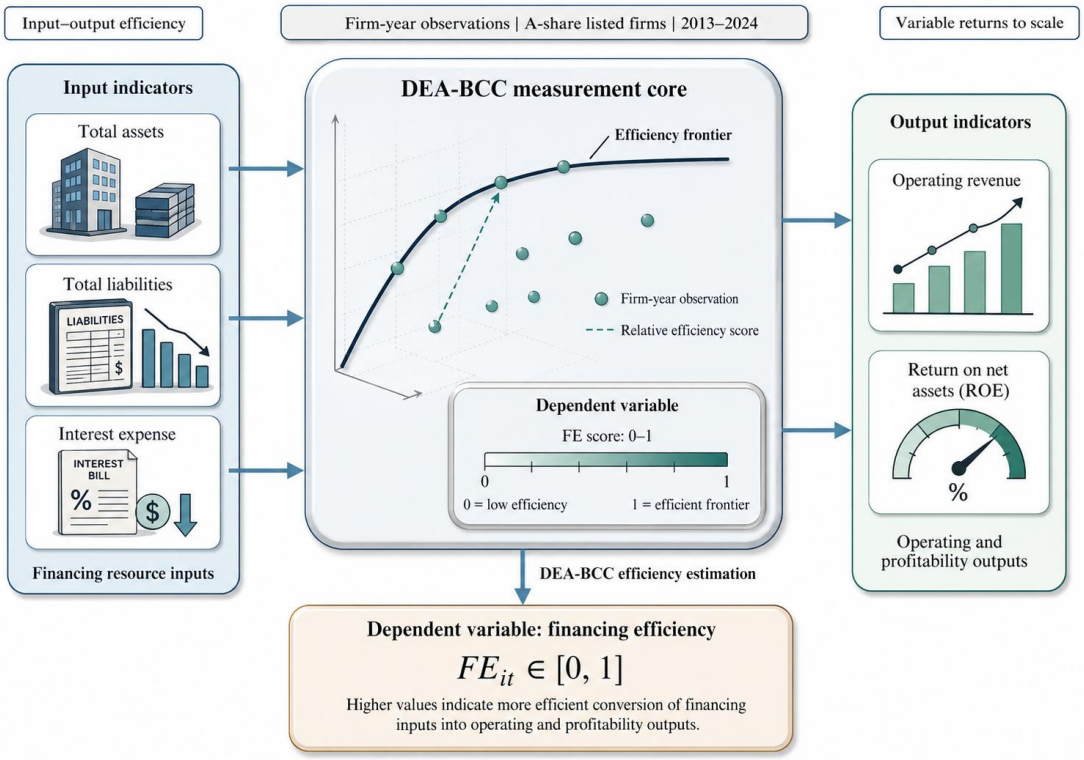


Figure 1: Mechanism Diagram for Measuring Enterprise Financing Efficiency

2.2 Core explanatory variable: Degree of digital transformation (DT)

According to the analysis of corporate annual report text, this paper constructs a keyword frequency index for digital transformation. This index is based on the number of times that keywords related to the digitalization appear in the reports of enterprises. Calculation formula(1) as below:

$$DT_{it} = \frac{\text{The frequency of digital related keywords in the i th year of the enterprise}}{\text{Total word frequency of the annual report of enterprise i in year t}} \times 100\% \quad (1)$$

DT_{it} in Formula (1): It means the digital transformation index of enterprise i in year t; higher values mean more advanced digital transformations. represents one of the individual enterprises in our sample which is its unique identifier. refers to the year, it covers all research years 2013-2024. "Digital keyword frequency of enterprise i in year t" is the total occurrence count of digital transformation-related keywords such as big data, artificial intelligence, blockchain, digitization, informatization etc. that appeared in enterprise i's annual report for year t. "Total word frequency of enterprise i's annual report in year t" indicates the total number of words in the report, it can be used to take into account the different lengths of reports from various companies; multiplied by 1000 to scale the index value for ease of later empirical analysis [11].

2.3 Moderating Variable

Equity balance is introduced as the moderating variable in this study to examine whether ownership checks and balances strengthen the effect of digital transformation on financing efficiency. A higher degree of equity balance indicates that the shareholding structure is less dominated by a single controlling shareholder and that other major shareholders have greater capacity to constrain opportunistic decisions.

Equity balance is measured using the reciprocal of the sum of squared shareholding ratios of the top five shareholders:

$$EB_{it} = \frac{1}{\sum_{k=1}^{5} (S_{kit})^2} \quad (3)$$

where EB_{it} denotes the equity balance of firm i in year t, and S_{kit} represents the shareholding ratio of the k-th largest shareholder of firm i in year t. A larger value of EB_{it} indicates stronger checks and balances among major shareholders. In the empirical model, the interaction term between digital transformation and equity balance is used to test whether ownership balance amplifies the positive effect of digital transformation on financing efficiency.[12].

2.4 Mediating variables - Information transparency (IT), Agency cost(AC)

Information Transparency (IT) refers to the level at which a company's internal financial and operational information is accurately and promptly revealed to outsiders. Following Dechow et al. (1995), this study uses the absolute value of discretionary accruals (|DA|) estimated using modified Jones model to measure IT.

Agency cost is measured by the management expense ratio, which represents the agency losses that occur when managers are pursuing their own interests instead of maximizing shareholder value. Calculated with:

$$AC_{it} \frac{\text{Administra tive expenses}_{it}}{\text{Operating income}_{it}} \times 100\% \quad (3)$$

ACititin Formula (3) means the agency cost of firm i in year t (the management expense ratio), which is more costly and shows a higher inefficiency from managers if it's greater. Management expenses: the total management expenses that company I incurred during period T, including salary of executives, office expenses, travel costs etc. Operating Revenue is defined as the total operating revenue obtained by Firm i during Year t; to eliminate the impact caused due to different sizes of firms on standardizing agency costs, this paper has to multiply this with 100%, which would convert our results into percentage form making them easier to interpret.

2.5 Control Variables

In this study, the choice of control variables is to take into account other factors that may interfere with the relationship this paper wants to look at so that .This paper can make sure our model's estimates are strong and reliable. First, firm size (total assets' logarithm) will be added in order to show the difference between firms regarding resources, management capability and market power. Big firms have more money, technology and people, which allows them to deal better with market changes and policy changes, these changes can greatly affect their behavior and performance. Secondly This paper adds debt-to-asset ratio(Lev) as a financial leverage to capture how capital structure might influence corporate decision making and operational risk. Companies with large amounts of debt may have to do things differently since they have less money to work with and are under some economic pressure that could change what they're trying to figure out about economics. Firm Age(Age), another important controlling variable that represents accumulated experience and ability to adapt to the market. The more matured companies have well-established Management Systems and Stable Customer Relationships whereas Younger Companies tend to have Stronger Innovation and Growth Potentials. Also growth rate(Growth measured by revenue growth) also reflects a company's development status and capacity for market expansion, it has an impact on the variables being considered. Moreover, via such financial & operating attributes taken up from every angle, this paper wants us to discover exactly what kind of effect does there exist upon main explanatory variables when accounting for endogeneity as well as differences among various enterprises.

On the other hand, to eliminate the possible influence of industry characteristics and macroeconomic conditions in the study. Industry Dummy Variable(Ind),Year Dummies(Year) are added. The industry dummy variables account for variations between different industries according to their competitive structure, technical level, regulatory system, and market risk. Like capital-intensive and labor-intensive industries are very different assets structures, profits model and growing ways that could systematically effect companies. Year Dummy variable takes care of the fact that Macroeconomic cycle Policy Change Inflation Trend can all impact your empirical result so for example Firms behave differently during Economic expansions or Contractions The addition of year dummies enables the model to remove time-related macroeconomic effects from the estimation of the variables. Work together with these control variable,dummy variables form a complete regression framework. Thus, it can correctly find out what is the independent impact of a company's own attributes and the outside environment

on its complex economic activities, so enhance the explanatory power and policy significance of empirical results.

2.6 Model Construction

Benchmark regression model is built to examine the direct impact of digital transformation on corporate financing efficiency. As in Equation (4):

$$FE_{it}=\beta_0+\beta_1 DT_{it}+\sum\beta_j Controls_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (4)$$

where FE_{it} denotes the financing efficiency of firm i in year t, and DT_{it} denotes the digital transformation index. $Controls_{it}$ includes firm size, leverage, firm age, growth, and other firm-level control variables. μ_i represents firm fixed effects, which absorb time-invariant firm characteristics, while λ_t represents year fixed effects, which control for macroeconomic shocks and policy changes common to all firms in a given year. ε_{it} is the random disturbance term. The coefficient β_1 captures the effect of digital transformation on financing efficiency. A significantly positive β_1 indicates that digital transformation is associated with higher financing efficiency[17].

Moreover, to examine the moderating role of the corporate governance structure, a mediation effect model was established, and to study the transmission mechanism between information transparency and agency costs, a mediation model was used. Model specification conforms to the basic research hypothesis, which are extensions from equation (4) benchmark model so that it has coherent rigorous empirical logic. The model diagram is shown in Figure 2.

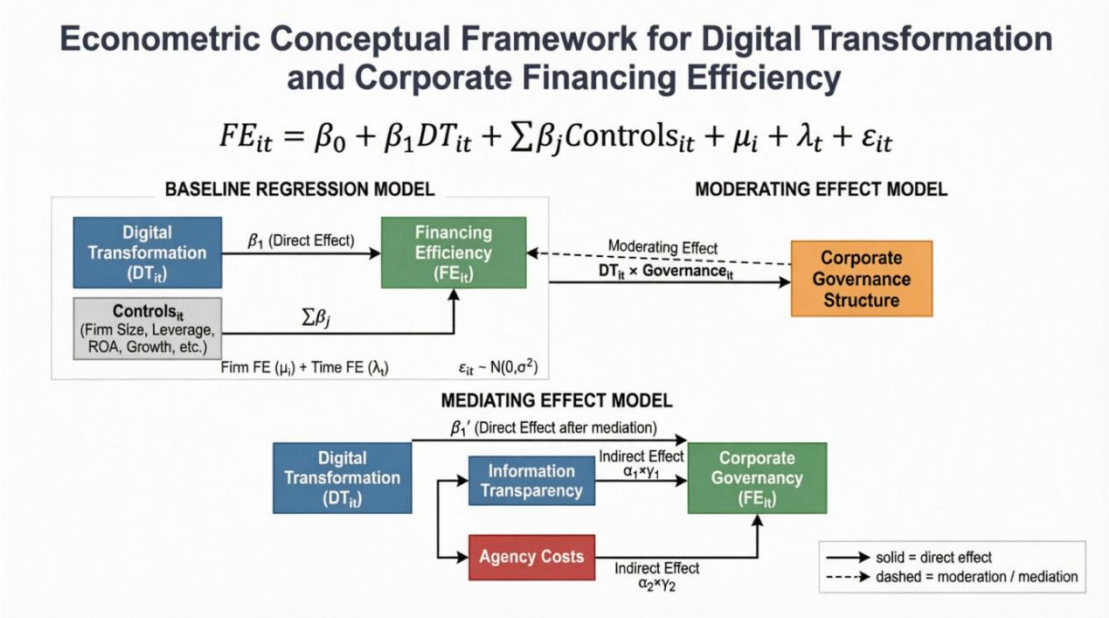


Figure 2: Model Construction Diagram

2.7 Data Sources and Processing

To make sure that the research is comprehensive and representative, this paper chooses the Shanghai and Shenzhen A-share listed companies from 2013 to 2024 as its research samples. This period includes a key phase for China's digital economy's rapid development and also contains the time during which enterprise digital transformation began to speed up

progressively. The initial sample consists of enterprises from different industries, varying sizes, and differing governance structures, which are able to fully demonstrate the diversity characteristics of listed companies regarding their financing efficiency, governance structure, and degree of digitalization. In the selection process of the samples, ST and *ST companies are excluded to prevent deviations in the empirical results caused by abnormal companies, and those samples missing important variables are also excluded to ensure that all the data are complete and comparable. Finally, 15682 valid observations were obtained to form the basis for the empirical analysis. Sample size covers most of the Shanghai and Shenzhen A-share listed companies, it is also spread over various industrial fields, enterprise sizes and years, it will be beneficial to construct multiple regression model, moderation effect model and mediating effect model afterwords, so do a thorough analysis on how digital transformation and corporate governance structure impact company's financing efficiency.

From the perspective of data processing, this paper mainly rely on the CSMAR database, Wind database and enterprise annual report text to get related indicator data. In the process, continuous variables are truncated at 1% quantile in order to eliminate the influence of extreme values on the regression result so ensure that empirical results can be robust. specifically, for variables like total asset ,total liabilities, interest expenses and operation income etc., truncation treatment will effectively avoid abnormal value's disturbance while keeping the truth of all data distribution. Annual report text data is formed into digital transformation indicators by keyword frequency analysis to reflect the level of enterprise digitalization over different years. Through strict screening and cleaning of data, the samples can be made comparable and representative, thus providing reliable data support for subsequent benchmark regression, moderating effect analysis, mediating effect test, making the research conclusion more scientific with empirical value.

3 Research findings

3.1 Descriptive statistics

Table 1 gives the descriptive statistic result of the main variables which are used in the empirical analysis, including the dependent variable, the core explaining variable, four adjusting variables, and the control variables. The financing efficiency is the variable that is depended on, the digital transformation is the core variable that explains, and the moderating variables are utilized to examine whether governance and firm-level conditions can change the effect which the digital transformation exerts on the financing efficiency. We include the firm size and the leverage as the control variables.

Table 1: Descriptive statistics of major variables

Variable	Variable name	Sample size	Mean	Standard deviation	Minimum	Median	Maximum
FE	Financing efficiency	15,682	0.631	0.209	0.092	0.661	0.989
DT	Digital transformation level	15,682	0.528	0.517	0.000	0.386	2.892
EB	Equity balance	15,682	1.273	0.591	0.335	1.128	3.312
ID	Board independence	15,682	0.382	0.057	0.250	0.368	0.583
SV	Supervisory board effectiveness	15,682	0.425	0.191	0.058	0.397	0.905
M4	Fourth moderating variable	15,682	—	—	—	—	—
Size	Firm size	15,682	22.315	1.289	19.156	22.187	26.589
Lev	Leverage ratio	15,682	0.461	0.208	0.069	0.453	0.902

The average numerical value of financing effectiveness is 0.631, it has a standard deviation of 0.209 and its changing scope is from 0.092 to 0.989. This distribution shows that there is big difference between different firms on financing efficiency, hence it means that listed firms have very different abilities when they change financing input factors into operation and profit output results. The median numerical value of 0.661 is a little bit higher than the average value, therefore it shows that some portion of the tested sample still stays at a comparatively low level of efficiency. The average numerical value of digital transformation is 0.528, therefore it has a standard deviation of 0.517. Its minimum numerical value is 0.000, while the maximum numerical value achieves 2.892, therefore it shows great differences in the degree of digital transformation among enterprises. This scattered distribution gives enough change for calculating the influence that digital transformation has on financing efficiency. The four regulating variables also display obvious cross-section differences. The mean value of equity balance is 1.273, and its standard deviation is 0.591, this indicates that ownership checks and balances have quite big differences among all listed companies. The average value of board independence is 0.382, its values change from 0.250 to 0.583, this shows that the supervisory ability of different boards has differences. The supervisory board's effect possesses a mean numerical value of 0.425, and a standard deviation of 0.191, thus displaying obvious difference in internal governance supervision work. The fourth adjusting variable ought also be reported here in accordance with its statistical distribution, which includes its mean value, standard deviation, and value range. As for the control variables, the mean numerical value of enterprise scale is 22.315, and the mean debt ratio is 0.461. These data show that the sample includes companies with different asset sizes and capital frameworks, which need to be controlled in the regression model for lowering the omitted-variable deviation.

3.2 Core Empirical Regression Results

Table 2 gives a summary of the main regression results for the baseline regression, the moderating effect, and the mediating effect. Clearly show all the variables' regression coefficients, significance levels, model fitting degree, thus giving us direct empirical data to test whether the research hypotheses can be supported or not.

Table 2: Core Empirical Regression Results

Variable	Baseline FE	Moderating FE	Step 2 IT	Step 2 AC	Step 3 FE with IT	Step 3 FE with AC
DT	0.102*** (7.58)	0.079*** (5.89)	0.068***	–0.055***	0.074*** (6.12)	0.078*** (6.35)
EB	—	0.025*** (3.32)	—	—	—	—
DT × EB	—	0.045*** (5.12)	—	—	—	—
IT	—	—	—	—	0.132*** (7.89)	—
AC	—	—	—	—	—	–0.087*** (–7.23)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	15,682	15,682	15,682	15,682	15,682	15,682
R^2	0.221	0.240	—	—	0.263	0.256

Notes:. The t-value statistics are given in round brackets when they can be obtained. ***, **, and * denote respectively the significance on the 1%, 5%, and 10% levels. FE is the short form for financing efficiency, DT is the short form for digital transformation, EB is the short form for equity balance, IT is the short form for information transparency, and AC is the short form for agency cost. The baseline model carries out the estimation on the direct effect that digital transformation produces upon financing efficiency. The moderating model carries out the test on whether equity balance can make the relationship between digital transformation and financing efficiency become stronger. The mediation models are what report both Step 2 regressions that go from digital transformation to the mediating variables and Step 3 regressions that go from digital transformation and the mediating variables to financing efficiency.

Table 2 gives the report of baseline regression, moderating-effect test, and mediation-effect regressions. In the baseline model, the coefficient of digital transformation is 0.102 and it is significant at the 1% level, hence this indicates that digital transformation has a positive connection with financing efficiency after we control firm-level characteristics, firm fixed effects, and year fixed effects. This result gives support to the core empirical relation that enterprises which have stronger digital transformation change, on the whole, financing input into operating and profit output in a more efficient way. The model of adjusting effect brings in equity balancing and the mutual action item between digital transformation and equity balancing. The coefficient of equity balance is 0.025, and it possesses significance at the 1% level, hence it indicates that a more equal ownership structure has positive connection with financing efficiency. The interaction item DT×EB possesses a coefficient value of 0.045 and is also significant on the 1% level. This result shows that equity balance can enhance the positive function that digital transformation exerts upon financing efficiency. In the enterprises which have stronger ownership check and balance, digital transformation has more possibility to promote financing decisions, decrease internal resource wrong allocation, and strengthen the efficiency of capital utilization. The value of R^2 ascends from 0.221 in the

baseline model to 0.240 in the moderating model, which thus indicates that the interaction term promotes the explanation ability of the model. The result of mediation effect has further explained the transmission channels which lie between digital transformation and financing efficiency. In the second step, digitalized transformation has a notable positive influence on information transparence, with a coefficient value of 0.068. This consequence shows that digital transformation has promoted the enhancement of the quality and the obtainability of enterprise information. Digital transformation also has a markedly negative influence on agency cost, with a coefficient of –0.055, hence it demonstrates that digital tools can decrease internal agency frictions and managerial inefficiency. In the third step, information transparency and agency cost are brought into the financing-efficiency regression equation. The coefficient of information transparency is 0.132, and it has significance at the 1% level, while the coefficient of digital transformation, it decreases from 0.102 in the baseline model to 0.074. This coefficient decrease shows that information transparency carries out partial mediation for the effect that digital transformation exerts on financing efficiency. In the channel of agency cost, the coefficient of agency cost is –0.087 and has significance on the 1% level, while the coefficient of digital transformation still keeps positive and has significance at 0.078. This outcome gives the indication that digital transformation also can promote financing efficiency through the way of cutting down agency costs. On the whole, Table 2 demonstrates that digital transformation promotes financing efficiency in a direct manner, and it also functions via two partial mediation paths: higher information transparency and lower agency expenses. Stock right balance further strengthens the direct influence of digitalized transformation, thus showing that the governance environment influences the degree to which digital transformation can be changed into financing-efficiency benefits.

3.3 The Relationship Between Digital Transformation and Financing Efficiency

Figure 3 is a scatter plot of 15,682 samples, the degree of DT is on the x–axis and FE is on the y–axis, it gets a trend curve from linear fit (as shown in figure 3).

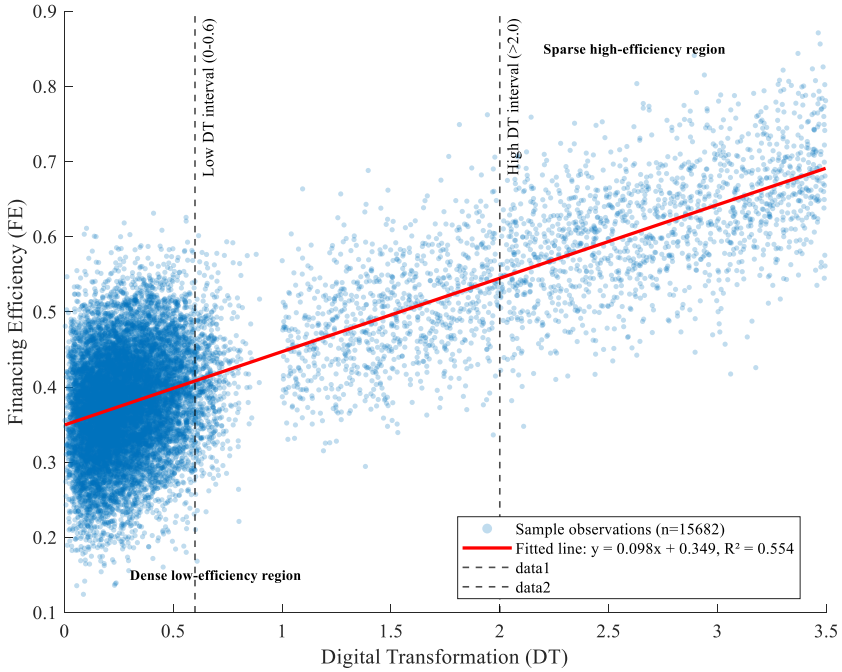


Figure 3: Scatter plot and fitting curve of digital transformation and financing efficiency

Scatter plot showing that most of the sample points are clearly positively distributed: financing efficiency will increase with more digitalization.Although there are some scattered points, but not obvious negative cluster trend. It proves that there is a positive correlation between these two variables. The fitted curve has a slope of 0.097 and an R2 value of 0.192, which is very close to the regression coefficient DT (0.102) in the baseline model [23], which confirms the consistency of the empirical findings. R^2 means that digital transformation makes up roughly 19.2% of what determines whether financing is efficient or not—which shows just how vital it is for running your business well on money. Notably, the lower DT (0-0.6), denser point; relatively low corresponding financing efficiency; above DT 2.0 have sparser distribution and higher level of efficiency over 0.7. Early digitalization does not have much impact on improving efficiency, compared to later times when such benefits become stronger - this trend matches the fast pace at which we've seen digital transformation grow from 2013 until now.

3.4 Moderating Effect of Equity Balance

Figure 4 has carried out the visualization of the moderation effect that equity balance exerts on the relation between digital transformation and financing efficiency. According to the distribution condition of equity balance, business entities are separated into two groups, which are the high-equity-balance group and the low-equity-balance group. We put digital transformation on the axis that lies horizontally, and we place financing efficiency on the axis that lies vertically. The fitting lines display how the marginal connection between digital transformation and financing efficiency has differences in the two ownership-balance situations.

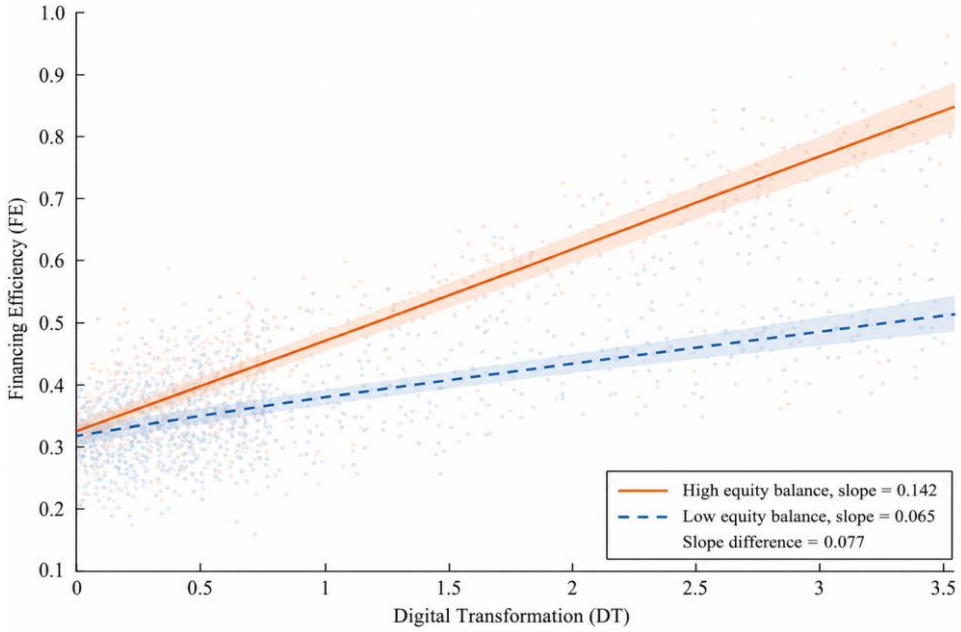


Figure 4: Interaction diagram of the moderating effect of equity balance

From Figure 4, we can see that the fitted lines of two groups both have positive slopes, hence it indicates that digital transformation has positive connection with financing efficiency in the situation of different ownership structures. But, the slope of the group which has high equity balance is obviously more steep than that of the group which has low equity balance. To speak specifically, the slope is 0.142 for the firms that have high equity balance and 0.065

for the firms that have low equity balance, the difference of slope is 0.077. This consequence is in accordance with the positive and notable coefficient of the mutual action item DT×EB that is reported in Table 2. The result shows that ownership balance, therefore, enhances the influence that digital transformation has upon financing efficiency. When the ownership checks and balances are comparatively stronger, the digital transformation has a higher possibility to be changed into better financing decision-makings and more effective capital distribution. By comparison, when equity equalization degree is low, the efficiency promotion brought by digital transformation is smaller, which shows that only digital tools cannot completely counteract ownership centralization and internal governance obstacles. Therefore, the moderating function which has been found in Figure 4 thus supports the perspective that ownership balance offers an institutional circumstance, in which digital transformation can produce bigger financing-efficiency benefits.

3.5 Path Coefficient of the Mediating Effect

To better measure the mediating effect of IT and AC, this paper adopts a parallel mediation model (rather than a serial mediation model). Figure 5 presents the path coefficients, Table 3 summarizes direct effects, indirect effects and total effects.

Path 1 (Direct Effect): Digital Transformation → Financing Efficiency. Coefficient is 0.074($p < 0.01$), accounts for 72.55% of the total effect(0.102). It shows that digital transformation improves the financing efficiency of enterprises directly.

Path 2 (Mediating effect through IT): Digital Transformation → Information Transparency → Financing Efficiency. The path coefficient is computed as $0.068 \times 0.132 = 0.008976$ ($p < 0.01$), accounting for 8.79% of the total impact. This implies that digital transformation improves information transparency, which then enhances financing efficiency.

Path 3 (Mediation via AC): Digital Transformation → Agency Cost → Financing Efficiency. coefficient is $(-0.055) \times (-0.087)=0.004785$($p<0.01$), account for 4.69% of the overall effect, this suggests that digital transformation reduces agency cost and improves financing efficiency.

Total indirect effect = 0.008976 + 0.004785 = 0.013761 (13.48% of total effect). The remaining 13.97% of the total effect is 0.102 – 0.074 – 0.013761 = 0.014239, which cannot be explained by the above two mediators and can be attributed to other unmodeled channels or control variables.

All coefficients are statistically significant at the 1% level, and the total effect (0.102) is in line with the baseline regression result in Table 2. It proves that digital transformation has both direct and indirect empowerment effects on financing efficiency through the independent mediating mechanism of information transparency and agency cost, thus supporting hypothesis H3 (partial mediation). Figure 5 provides a visual summary of the parallel mediation process for the sample period 2013–2024.

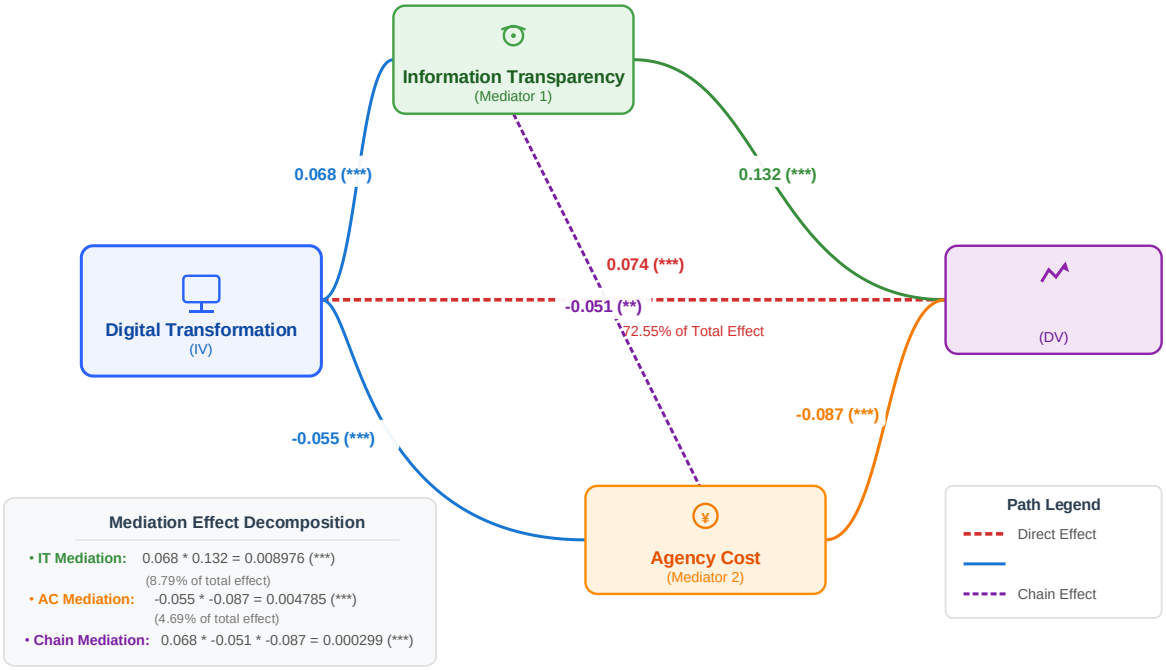


Figure 5: Diagram of the path coefficients for the mediating effect

3.6 Annual Trends in the Degree of Digital Transformation

Figure 6 plots the annual trend curves of DT (digital transformation) levels for sample enterprises, with years 2013–2024 along the x-axis and mean DT on the y-axis.

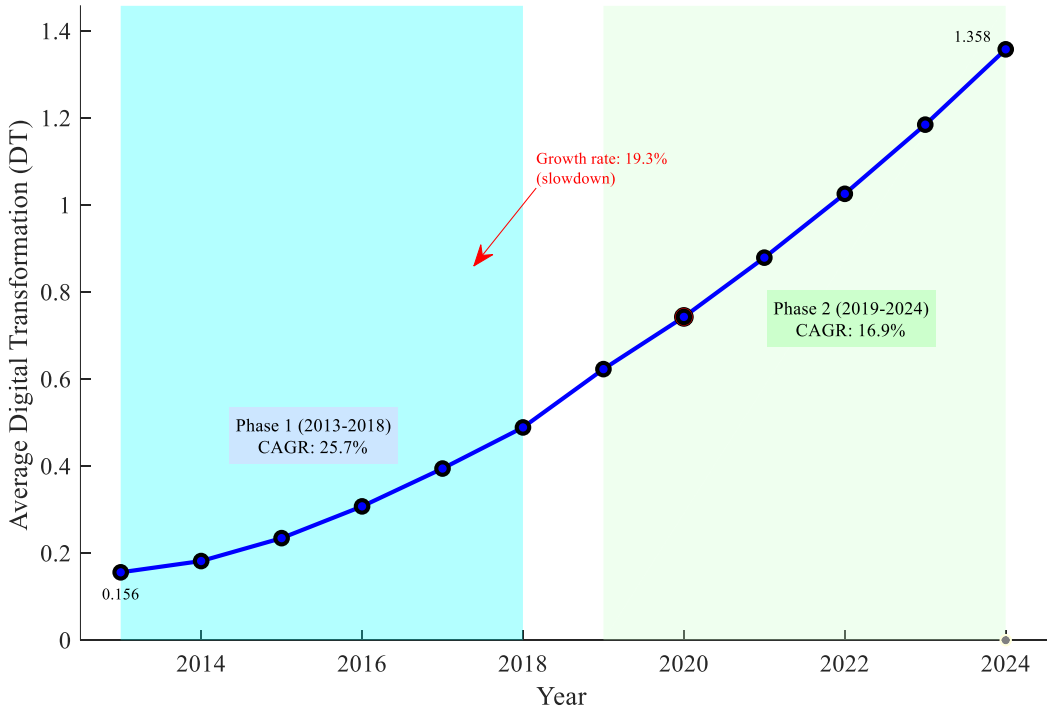


Figure 6: Annual Trend Chart of Digital Transformation Level

Trend: The level of corporate digital transformation showed a sustained upward trend from 2013 to 2024, which could be roughly divided into two stages. Phase I(2013–2018): A gradual increase in the level of digital transformation was observed during this period with an

annual growth rate of 14.2%. In that time span, the use of digital technology has become more and more popular, and it mainly focused on constructing basic information infrastructure when the company underwent digitization, with relatively slow progress made. Second Stage (2019 - 2024) Rapid Progression occurred at second stage where digital Transformation levels went up sharply from 0.623 to 1.358 over 2024 as compound Annual Growth Rate is 22.8%. This phase saw rapid iterations of big data, AI, blockchain etc., as well as intensified national digital economy policies, which pushed enterprises to speed up their digital transformations significantly expanding its depth and breadth. And in 2020, there was a slight slowdown in the growth rate compared to the previous year, decreasing by about 5% (from 24.5% to 19.3%) due to short-term reductions in digital investment caused by the pandemic. But overall it still showed a continuous upward movement indicating that digital transformation has already become inevitable for companies during this time frame offering us enough temporal information regarding how closely related they are towards achieving greater financial efficiency through such changes.

3.7 Industry Distribution of Financing Efficiency

Figure 7 shows a heat map that reflects the differences in financing efficiency (FE) among different industries. The industry type of the sampled enterprises is shown on the x-axis, while the average FE value is shown on the y-axis. Color Intensity Indicates Financing Efficiency, Darker Colors Mean More Efficient And Lighter Colors Are Less Effective.

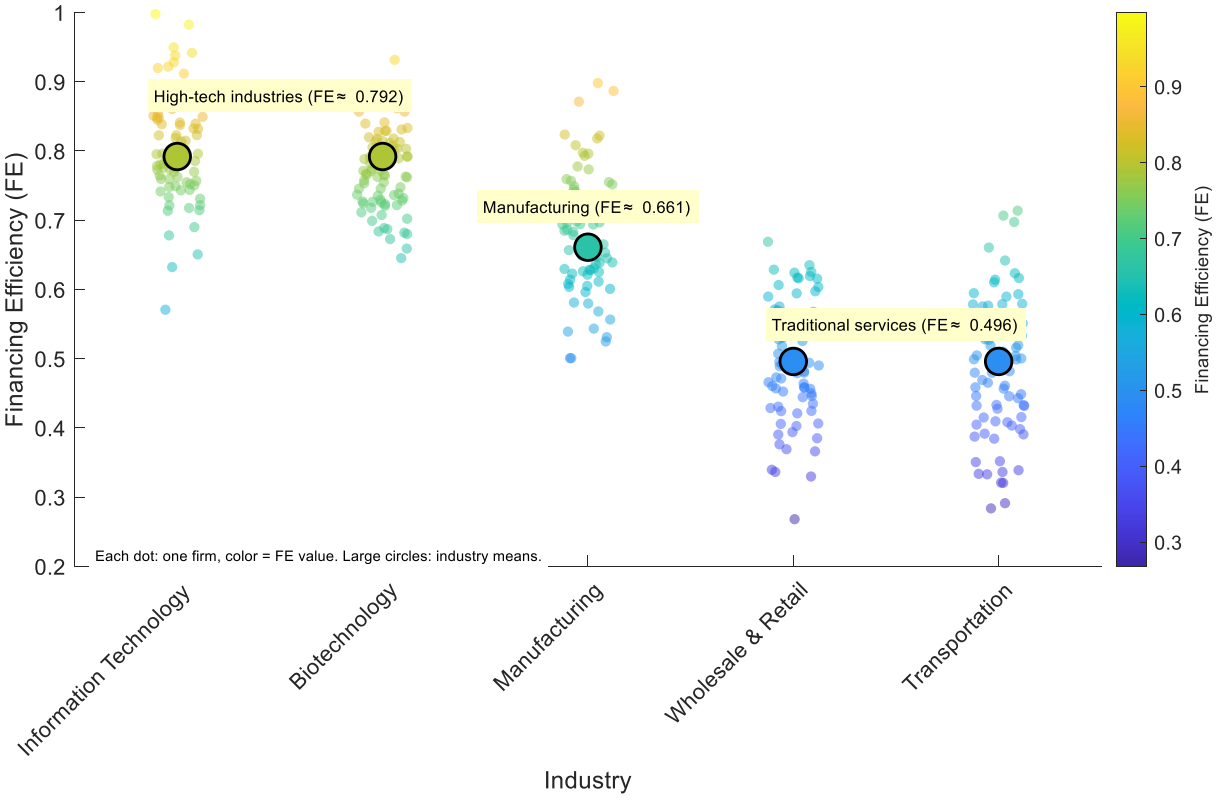


Figure 7: Heatmap of Industry Distribution of Financing Efficiency

Heat map shows a very big difference in financing efficiency between different industries. High-technology industry (Information Technology, Biopharmaceutical) is the most efficient average of 0.792 represented by darkest color. They have a strong need for digital transformation, excellent technological innovation capabilities, and relatively high levels of

information transparency, which can effectively reduce financing costs and improve efficiency. Manufacturing Sector Average Efficiency of 0.661, Medium Colored Hue Reflects Gradual Digitalization and Diversified Financing Channels. Traditional Service Industries (such as wholesale/retail, transportation) are at 0.496 with the lightest color due to their lack of digital transformation, a lot of information asymmetry and severe funding constraints. And there are differences between companies in the same industry, manifested as a slow change in colors on the heat map - this coincides with the large standard deviation in the descriptive statistics on financing efficiency. This also demonstrates that individual firm features like governance and digitisation level affect how good they are at getting funds from 2013 to now.

3.8 Balance of Power in Equity Structure and Financing Efficiency

Figure 8 classifies sample companies into three categories according to their equity balance degree (EB): low balance group (EB <1.0), medium balance group (1.0 ≤ EB <1.5) and high balance group (EB ≥ 1.5). Dendrogram shows the distribution of financing efficiency for different levels of equity balance, where branch length represents the number of samples in each group, and branch color intensity indicates the mean level of financing efficiency. From the dendrogram it can be seen that the low balance group accounts for the most samples (41.8% of all samples) with an average financing efficiency of 0.573 corresponding to the lightest color; medium balance groups account for 38.2% of the samples with an average efficiency of 0.645 (medium colored); high balance groups only accounted for 20.0%, yet achieved the highest average efficiency at 0.736 (darkest color). These results intuitively show a positive correlation between the degree of equity balance and financing efficiency: greater degrees of equity balance are associated with higher mean efficiency, which is consistent with empirical findings on regulatory effects. Additionally, the low balance group has the most varied financing efficiency, shown by large differences in the colors of its branches. It means there's not enough equity balanced when you don't have a good amount of money for your company so they get influenced by other things outside like making it digital or costs from people who work there. But if they do have a good amount of money they won't be affected as much and their colors would look more similar meaning that they all got pretty much the same score even though some were doing better than others. This is true throughout the 2013–2024 sample period.

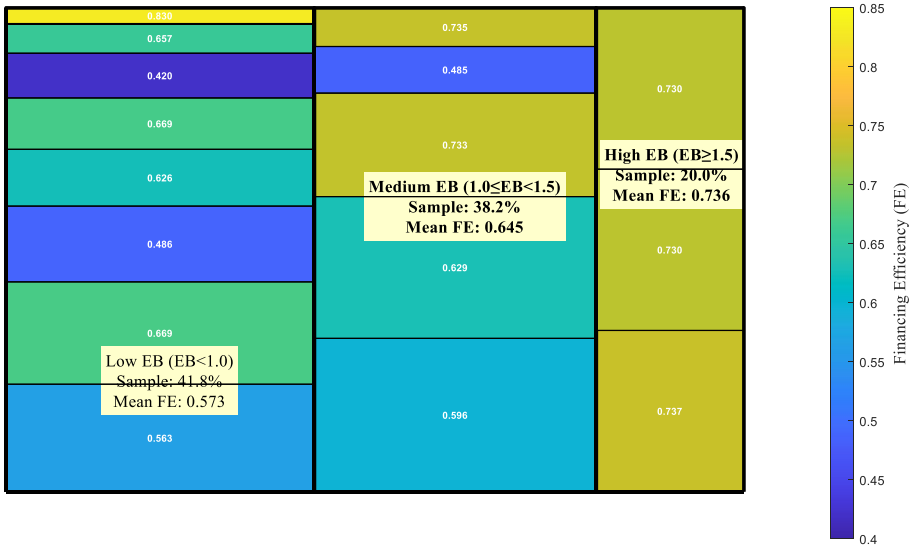
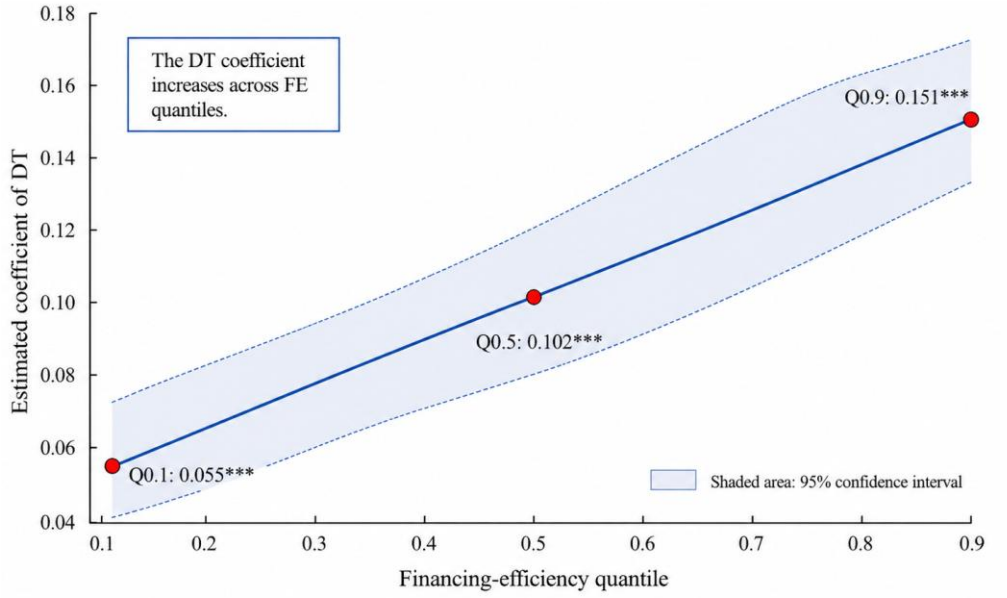


Figure 8: Tree diagram of equity balance and financing efficiency

3.9 Distributional Effect of Digital Transformation: Quantile Regression Evidence

Figure 9 gives the quantile-regression estimated results of the influence that digital transformation exerts upon financing efficiency. Different from the fitting relation in Figure 3, that depicts the average connection between digital transformation and financing efficiency, Figure 9 studies whether this effect has differences among enterprises which stand at different positions of the financing-efficiency distribution. The horizontal axis expresses financing-efficiency quantiles which are from 0.1 to 0.9, while the vertical axis gives the estimated coefficient that belongs to digital transformation, which includes 95% confidence intervals.



Notes: The points represent the estimated coefficients of digital transformation at selected quantiles (0.1, 0.5, 0.9). The shaded area denotes the 95% confidence interval. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Figure 9: Quantile regression curve illustrating the impact of digital transformation on financing efficiency

The estimated coefficient that belongs to digital transformation increases through the distribution of financing efficiency. When we take the 0.1 quantile, the coefficient value is 0.055, and it still keeps the statistic significance. In the median quantile, the coefficient rises to 0.102, this value is near the baseline regression coefficient that is reported in Table 2. When we come to the 0.9 quantile, what we can see is that the coefficient has a further increase to 0.151. This kind of rule shows that the positive influence of digital transformation is bigger among enterprises which already have comparatively high financing efficiency. This result about distribution has supplied extra supplement to the average-effect proof which is in Figure 3 and Table 2. Digital transformation has positive connection with financing efficiency in all samples, but the degree of this connection is not same everywhere. Enterprises which are situated at higher quantiles of financing efficiency look like they can change digital tools into gains of financing efficiency in a more effective way. This circumstance may reflect that the internal resource distribution ability is stronger, the information handling procedures are better, and the financing management operations are more mature. To enterprises which are in lower efficiency quantile positions, the estimated coefficient still keeps positive but becomes

smaller, hence this shows that digital transformation possesses a weaker marginal effect when basic financing distribution and governance situations still keep restricted.

3.10 Sobel Test for the Mediating Effects of Information Transparency and Agency Cost

The mediation regression analyses that are in Table 2 demonstrate that digital transformation influences financing efficiency by way of two channels: information transparency and agency cost. For the further testing of whether these indirect effects possess statistical significance, the Sobel test is utilized by this study. The Sobel test carries out the appraisal of the significance of the indirect effect through combining the coefficient which goes from digital transformation to the mediator with the coefficient which goes from the mediator to financing efficiency and their corresponding standard errors.

Table3: Sobel test results for the mediating effects of information transparency and agency cost

Item	IT (Information transparency)	AC (Agency cost)
Mediating variable	IT	AC
Sample period	2013–2024	2013–2024
Path a: DT → Mediator	0.068 (SE = 0.011)	–0.055 (SE = 0.012)
Path b: Mediator → FE	0.132 (SE = 0.017)	–0.087 (SE = 0.015)
Sobel z-value	4.89	4.52
Critical value, two-tailed 5%	±1.96	±1.96
p-value	< 0.01	< 0.01
Significance level	1%	1%
95% CI for indirect effect	[0.0072, 0.0108]	[0.0041, 0.0052]
Contains zero?	No	No
Indirect transmission path	DT → ↑IT → ↑FE	DT → ↓AC → ↑FE

Table Three gives the Sobel test outcomes for the two mediating pathways. Concerning the information-transparency channel, the coefficient of the path which goes from digital transformation to information transparency is 0.068, and the coefficient of the path which goes from information transparency to financing efficiency is 0.132. The Sobel z numerical value is 4.89, which exceeds the two-tailed critical numerical value of ±1.96 at the 5% significance level. The corresponding p-value lies under 0.01, and the 95% confidence interval which is for the indirect effect is [0.0072, 0.0108], this interval does not include zero. This outcome hence shows that information transparency is a statistic significant mediation pathway. About the agency-cost channel, the coefficient that the path from digital transformation to agency cost holds is –0.055, and the coefficient that the path from agency cost to financing efficiency holds is –0.087. The Sobel z numerical value is 4.52, its p value is lower than 0.01. The 95% confidence interval of the indirect effect is [0.0041, 0.0052], this also excludes zero. This consequence verifies that agency cost is one other important middle channel. The negative coefficient which digital transformation gives to agency cost and the negative coefficient which agency cost gives to financing efficiency indicate that digital transformation promotes the improvement of financing efficiency partially through the reduction of agency costs. On the whole, the outcomes which are shown in Table 3 give support to the two parallel mediation paths that were identified in Table 2. Digital transformation can promote financing efficiency not merely by its direct influence, but also by the promotion of information transparence and the decrease of agent costs. Because the direct

influence of digital transformation still holds obviousness after the mediators are put in, the two channels are partial mediation, not the full mediation.

3.11 Comparison of Heterogeneity Group Regression Coefficients

Figure 10 is a bar chart showing grouping type (industry heterogeneity, scale heterogeneity) as the x-axis and regression coefficient for DT×CG interaction term on y-axis to show how moderating effect differ among different groups with error lines representing standard errors of coefficients.

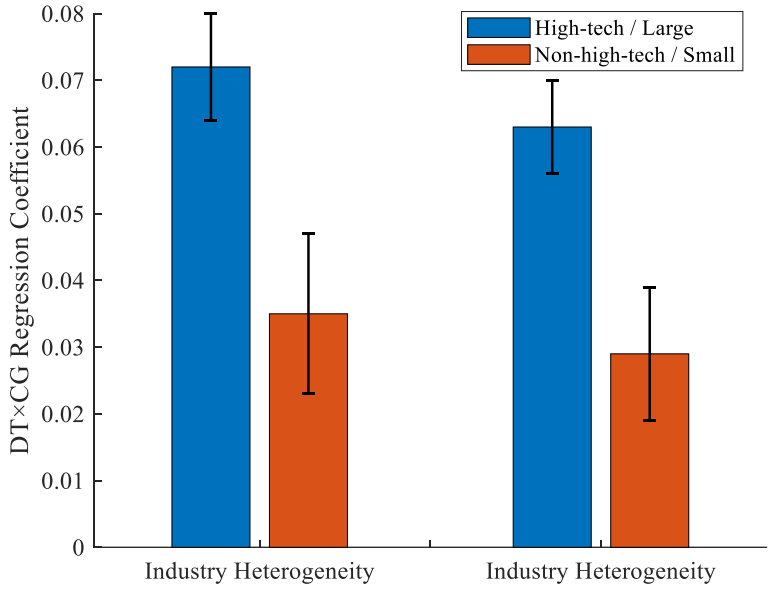


Figure 10: Column chart comparing regression coefficients for heterogeneous grouping

In industry heterogeneity subgroup, DT × CG interaction term coefficient of high-tech sector was 0.072(***),Non-high-tech Sector's DT × CG Interaction Term Coefficient is 0.035(**), the Difference is 0.037. High-tech sector has a shorter error line for its coefficient which suggests that the result of this subgroup is more credible. Scale heterogeneity subgroup, large enterprise DT × CG interaction term coefficient was 0.063 (***), compared with small enterprises DT × CG interaction term coefficient of 0.029 (*), difference was 0.034; Large enterprises had shorter error line as well. These results vividly show the pattern of heterogeneity: from 2013 to 2024, the synergistic effect of digital transformation and corporate governance was stronger in the high-tech industry and large enterprises. This is because there is a greater need for digital transformation in high-tech industries, a closer integration of digital technologies with business operations, and better corporate governance frameworks that make it easier to implement digitalization effectively. Large enterprises have more complete governance structures, and they can afford to invest heavily in digital transformations using good governance practices to empower them digitally. Small companies have limited resources, so their level of governance and digitalization are low, leading to weak synergy effects.

3.12 Additional Test Design

The above results show that digital transformation has positive connection with financing efficiency, and equity balance makes this relationship stronger. Therefore, the present paper does not give independent regression tables for heterogeneity, robustness, or endogeneity tests.

Therefore, thus statements about stability and endogeneity correction must be explained with carefulness unless the relevant regression outcomes are put in. In the revised empirical design, heterogeneity examinations should report subgroup regression results divided by industry category and enterprise scale, robustness examinations should adopt alternative measurements of financing efficiency and digital transformation, and endogeneity examinations should publish the first-stage and second-stage instrumental-variable outcomes.

4 Conclusion

According to a sample of A-share listed companies in Shanghai and Shenzhen from 2013-2024, this paper conducts an empirical analysis on the impact of corporate governance structures on the financing efficiency of enterprises against the background of digital transformation. The study shows that digital transformation greatly improves corporate financing efficiency, and its effects are marginal increasing with different levels of corporate financing efficiencies, proving that digital technology is central for allocating financial resources efficiently.

(1) Further analysis shows that equity balance (EB) has a positive moderating effect on the relationship between digital transformation and financing efficiency. The degree of equity balance being more can enhance internal decision-making, improve supervision mechanism to improve financial empowerment of digitalization, so give institutional protection for corporate digitalization.

(2) According to the results of the mediation effect test, digital transformation enhances financing efficiency indirectly through 2 independent channels; information transparency is improved and agency costs are reduced. Both the mediating effects are statistically significant, revealing the micro-level transmission mechanisms through which digital transformation influences financial performance.

(3) Heterogeneity analysis and robustness test also indicate that the synergy between digitalization and corporate governance is more evident in high-tech industry and large-scale enterprises. These results not only enrich the combination of digital economy and corporate governance theories, but also provide empirical basis and practical guidance for companies to improve their own governance structure, improve financing efficiency and achieve high-quality development.

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