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RESEARCH ON THE IMPACT OF MANAGERIAL CAPABILITIES ON THE DIGITAL TRANSFORMATION OF ENTERPRISES

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Abstract. Digitalization has brought profound changes to enterprises. As the main decision maker of firm, manager has an important impact on the digital transformation of enterprises that cannot be ignored. Based on the perspective of managerial heterogeneity, we tested the impact of managerial ability on the digital transformation of enterprises in China context. The results showed that managerial ability has a significant positive impact on the digital transformation of enterprises, that is, the stronger the managerial ability, the higher digitalization of firm. The mechanism study confirmed that managerial ability can overcome strategic inertia and improve capital allocation efficiency, then promote digital transformation of firm. Further research showed that the younger the top management team, the more significant the positive effect is; Independent directors can provide resources and play a consulting role to promote the impact of managerial ability on the digital transformation of firm; The older the firm is, the stronger the organizational inertia is, which can impede the impact of managerial ability on the digital transformation of firm. This study enriches the literature about executives, and has a certain practical significance for digitalization implement of enterprises.

Keywords: managerial ability, digital transformation, strategic inertia, capital allocation efficiency, DEA, TMT age, independent director, firm age.

JEL Classification: G34, G41, L21.

Introduction

According to the "White Paper on China's Digital Economy Development" (2021), digital technology is increasingly important. China's digital economy reached 39.2 trillion yuan in 2020, accounting for 38.6% of GDP and becoming a critical support for the high-quality development of the national economy. Despite the significant adverse effects of the COVID-19 outbreak on China and the global economy and society, digitalization played an irreplaceable role in monitoring and controlling the spread of the pandemic and helping the resumption

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of work and production. As the micro composition of the macro economy, firms play an essential role in implementing the "must-answer" question, contributing to their survival and long-term development. Therefore, exploring better ways to open up and promote the digital transformation of enterprises is of practical significance.

The literature has widely discussed the positive outcomes of digital transformation, such as reducing financing costs (Che et al., 2021), improving stock liquidity (Wu et al., 2021), promoting growth (Ni & Liu, 2021) and so on. Some case studies have explored the factors influencing enterprise digital transformation and the model and path of firm digital transformation, which mostly focused on the firm level (Gu & Zhang, 2020; Qi et al., 2021). However, the governance level of top management teams lacks sufficient attention. Managers are the main drivers and helmsmen of firm digital transformation, and their abilities play an essential role in the digitalization process (Lin et al., 2019). Based on this, we collected data from non-financial companies listed on China's A-share market spanning the period from 2011 to 2020, aiming to empirically examine the influence of managerial ability on digital transformation. The findings of our analysis affirm the positive impact of managerial ability in this context. Managers possessing high ability exhibit a propensity for risk-taking, efficient resource allocation, overcoming strategic inertia, enhancing capital allocation efficiency, and driving digital transformation initiatives. Additionally, our supplementary investigations reveal that this relationship is particularly pronounced among executive teams with a younger composition, firms with a higher presence of independent directors, and relatively younger companies.

This paper makes substantial contributions to both theory and practice in several ways. Firstly, it enriches the existing body of research on firm digitalization by examining more effective approaches to facilitate firm digital transformation, particularly from the lens of managerial heterogeneity, an area that has received comparatively less attention in the current literature. Secondly, it enhances the upper echelons theory by offering a more rigorous, precise, and comprehensive measurement of managerial heterogeneity. Thirdly, the paper provides an analysis of the mechanism through which managerial ability influences the digital transformation of enterprises, while considering the heterogeneity of its effects.

The structure of the paper is as follows: Section 1 provides a review of the relevant literature, develops research hypotheses, and offers theoretical analysis. Section 2 outlines the methodology and sample construction. In Section 3, the empirical analysis results, involving main regression, mechanism results, and heterogeneity results. Section 4 delves in to robustness checks. Finally, the last Section concludes the paper and discusses its limitations.

1. Theoretical analysis and research hypothesis

1.1. Managerial ability and digital transformation

Digital transformation is widely recognized as a crucial strategy for businesses in the current era of the digital economy. Extensive research, encompassing both qualitative and quantitative approaches, has been conducted to investigate this phenomenon. Qualitative research has focused on exploring the connotative, fundamental, and procedural aspects (Vial, 2019), while quantitative research has examined the impact of digital transformation on various

business outcomes, including financing costs (Che et al., 2021), stock liquidity (Wu et al., 2021), external transaction costs, and the level of professional division of labor within enterprises (Yuan et al., 2021). Numerous studies have consistently emphasized the imperative nature and beneficial outcomes of digital transformation. However, scant attention has been given to the influential factors that play a significant role in its implementation and success.

Promoting digital transformation is a crucial endeavor, and it demands recognition of its intricate and all-encompassing nature at the company level. This top-down organizational change brings forth various risks and challenges for. The process necessitates continuous communication, adjustment, optimization, and iterative cycles to attain the desired outcome for the firm businesses (Gray & Rumpe, 2017; Hopkins et al., 2013). Consequently, the successful implementation and advancement of enterprise digital transformation heavily rely on the unwavering support and active engagement of top-level managers.

Managers play a vital role in enterprise management and bear the responsibility of making critical business decisions. According to the upper echelons theory, a manager's cognitive abilities, perceptions, and values exert significant influence on a company's behavior (Hambrick & Mason, 1984). Scholars have extensively explored managers' demographic characteristics and psychological cognitive preferences to assess their personal cognition, abilities and the resulting impact on corporate outcomes. However, it is crucial to integrate demographic characteristics into managerial ability to understand their influence on various fields, so managerial ability is the key component, which can enable managers to effectively integrate internal and external information and make reliable estimates of future developments. Managerial ability encompasses the manager's cognitive level and their ability to deal with complex affairs, effectively utilizing the company's resources to improve efficiency and create value.

Managerial ability can significantly impact the digital strategy in various aspects. Firstly, from a decision-making perspective, digital transformation must overcome strategic inertia, which entails making changes, often accompanied by risk and uncertainty, thereby highlighting the crucial role of managerial ability in implementing digital transformation (Lyu et al., 2016). High managerial abilities mean strong risk-bearing and controlling (He et al., 2016), help managers to deeply understand the environment and industry development trends, then make informed decisions. Managerial ability facilitates perceiving and embracing change, exploring new avenues, and transcending conventional boundaries (Demerjian et al., 2013). Secondly, from a resource perspective, resource plays a pivotal role in the process of digitalization. Digital transformation necessitates the adoption of new digital technologies, requiring firms to possess adequate human, material, financial, and other essential resources, as well as the dynamic capability to coordinate them. Managerial ability is necessary resources, it means high level of information collection and analysis, which can not only ensure the stability of daily operations but also promote steady transformation. High-ability managers possess profound experience and knowledge structures, coupled with familiarity with the firm and sensitivity to changes. They effectively mobilized the firm to obtain and reallocates resources, such as cultivating digital talents and forming scientific digital teams (North et al., 2020). Conversely, if managers lack situational judgment and fail to grasp industry changes, blindly following investment trends may lead the enterprise into a financial crisis. Moreover, capable managers are capable of delivering strong business performance and often enjoy a

favorable market reputation (Wiklund & Shepherd, 2003). This positive reputation serves as a powerful signal to external investors, attracting greater social capital investment into enterprises, bolstering the available funds, and solidifying the necessary capital investment for corporate transformation.

Based on the above analysis, the following hypotheses are proposed:

H1: Managerial ability plays a positive role in promoting the digital transformation of enterprises, that is, the higher the managerial ability is, the higher the degree of digital transformation of enterprises is.

1.2. Mediating effects of strategic inertia and capital allocation

As previously discussed, digital transformation requires overcoming strategic inertia, which occurs when managers fail to timely perceive and understand changes in the external environment. This leads to enterprises developing a reliance on established paths and commitments when formulating strategic goals and solutions, often resulting in the replication of previously successful strategies and the allocation of resources primarily in the current market rather than exploring new market opportunities (Yeow et al., 2018). Managerial ability plays a vital role in driving strategic changes, breaking free from path dependence, and ultimately enhancing firm digitalization.

Managers play a crucial role in allocating enterprise funds, as they are responsible for determining the direction of capital allocation based on the business activities of the company. Given the resource-intensive nature of digital transformation, firms often seek external resources such as technology, manpower, and capital to support and successfully execute their digital initiatives while ensuring uninterrupted business operations. Effective capital allocation is thus vital in providing the necessary support for the digital transformation of enterprises. In this regard, managerial ability plays a significant role in enhancing the efficiency of firm capital allocation.

Based on the above analysis, the following hypotheses are proposed:

H2: The higher the managerial ability is, the lower the firm strategic inertia and higher the capital allocation efficiency.

1.3. Heterogeneous effects of managerial ability

To gain further insights in to the impact of managerial ability, we extend our analysis to consider the heterogeneous effects at different level within the organization.

Firstly, let us consider the impact at the top management team (TMT) level. The adventurousness of an executive team tends to be higher when the team is younger, as age can be associated with a decline in cognitive abilities and a decrease in flexibility, making individuals more resistant to change (Tanikawa & Jung, 2016). Conversely, older executives may exhibit less physical energy and sensitivity to new ideas, leading to a tendency to avoid risks and make conservative strategic decisions (Taylor, 1975; Wu & Guan, 2015). Their focus often lies in ensuring the security of decision-making, which can limit their willingness to pursue risky opportunities (Bantel & Jackson, 1989; Barker III & Mueller, 2022). Given that digital

transformation entails a highly complex, long-term, and comprehensive process that requires sustained commitment and investment, a younger management team can bring more energy and agility to address the challenges inherent in the digital transformation journey. Moreover, a younger managerial team tends to encounter fewer barriers to the utilization of their managerial ability, facilitating the implementation of digital transformation practices within the organization. Based on these considerations, we propose the following hypothesis:

H3a: The TMT age negatively moderate the effect of managerial ability on firm digital transformation.

Secondly, at the board level, independent directors possess high personal reputation, extensive external networks, and significant expertise in specific fields. These qualities enable them to contribute to the decision-making process by providing management with informed and effective recommendations (Hillman & Dalziel, 2003). By offering professional and objective insights during board meetings, independent directors can enhance the quality of decision-making within the organization. Moreover, their broad network connections can open up valuable external resource channels for enterprises, facilitating the deployment of decisions and fulfilling the resource requirements associated with digital transformation initiatives. Additionally, independent directors play a crucial role in supervising and mitigating agency conflicts, thereby safeguarding shareholder interests and increasing shareholder wealth (Fama & Jensen, 1983). Their independent monitoring also helps ensure the proper utilization of managerial ability, fostering the advancement of digital transformation within the organization. In light of these considerations, we propose the following hypothesis:

H3b: Independent directors positively moderate the effect of managerial ability on firm digital transformation.

Lastly, at the firm level, as firms mature, they often become more inclined to adhere to established practices and limit exploratory behavior, resulting in a tendency to exhibit rigid patterns of behavior that hinder effective action (Li & Yi, 2010). Older firms tend to rely on past models for resource integration and utilization, which can lead to inefficient resource allocation. Consequently, managers face greater challenges in driving digital transformation within such firms. Moreover, the impact of managerial ability on the promotion of digital transformation is significantly diminished. Given these considerations, we propose the following hypothesis:

H3c: Firm age negatively moderate the effect of managerial ability on firm digital transformation.

2. Methodology

2.1. Data and sample

To clarify the methodology, it is important to first explain the research population, which in this study refers to all listed firms on the Shanghai Stock Exchange and Shenzhen Stock Exchange in China. The period of analysis spans from 2011 to 2020. Excluded from the

research population are firms in the financial and banking sectors, as they tend to possess distinctive capital and governance structures. To construct the initial research sample, firm-year observations were retrieved from the Chinese Stock Market Accounting Research (CSMAR) database. Subsequently, any observations with missing variables were eliminated, and winsorization was applied at the 1% level on both ends to minimize the influence of outliers. Following these adjustments, the final sample consisted of 9,170 firm-year observations, representing 2,174 companies.

2.2. Variables

2.2.1. Dependent variable

Digital Transformation. The degree of firm digital transformation is the dependent variable in this study. We adopt the method used by Wu et al. (2021) and measure the digital transformation level based on the frequency of words related to digital technology application in the firm's annual report. A higher frequency of these words indicates greater digital investment. We use the natural logarithm of the number plus one to construct an index of firm digitalization. In our robustness test, we analyze the number directly for the negative binomial and Tobit regression models.

2.2.2. Independent variable

Managerial Ability. Managerial ability can be evaluated through the assessment of firm efficiency, which comprises firm-specific and manager-specific efficiency drivers (Demerjian et al., 2011). To ensure a more accurate measure, we adopt Demerjian's method, which involves adjusting a DEA-generated firm efficiency measure by eliminating influential firm-specific characteristics that may either support or impede management's endeavors. The calculation process, as outlined in previous studies (Zhang et al., 2021; Yao et al., 2020), is as follows:

We begin by evaluating the production efficiency of the firm using model (1). We consider each firm-year as a decision-making unit (DMU) and employ DEA analysis to determine the efficiency value of the firm. The model focuses on revenue as the sole output measure, while considering net property, plant and equipment (PPE), net research and development (R&D), goodwill, other intangible assets (intangible), cost of goods sold (CoGS), and the current period value of selling, general and administrative costs (SG&A) as input measures.

$$\max\theta = Sales / (v\_1 PPE + v\_2 Net\ R\&D + v\_3 Goodwill + v\_4 Intangible + v\_5 CoGS + v\_6 SG\&A). \quad (1)$$

In addition, we recognize that firm productivity is influenced by a combination of firm-specific and manager-specific factors. To separate the effects of these factors, we conduct a regression analysis, regressing total firm efficiency on six firm characteristics that are known to impact firm efficiency. This analysis enables us to distinguish between firm efficiency and managerial ability within the overall measure of total firm efficiency. To estimate this relationship, we employ the Tobit regression model (2), taking industry into account and controlling for year fixed effects. The residual obtained from this regression serves as the measure of managerial ability (MA).

$$\theta = \alpha\_0 + \alpha\_1 Size + \alpha\_2 Marketshare + \alpha\_3 Age + \alpha\_4 CF + \alpha\_5 FCI + \alpha\_6 HHI + \alpha\_7 Year + \varepsilon. \quad (2)$$

Here, Size is the natural logarithm of the total assets, Market share is the proportion of the company's operating income in the industry, Age is the company's listing years (plus 1 and then natural logarithm), *CF* is a dummy variable (1 if the free cash flow is positive, 0 otherwise), *FCI* is a dummy variable (1 if the firm engages in overseas operations, 0 otherwise), and *HHI* is the company's diversified operation level (the sum of the squares of the revenue of each industry divided by the total revenue).

2.2.3. Mediation variables

To assess the level of strategic inertia within an enterprise, we employ the fluctuation in the annual allocation of strategic resources as a measure. Specifically, the magnitude of strategic inertia is determined by the extent of fluctuation in the allocation of strategic resources over the course of a year. A small degree of fluctuation indicates a high level of strategic inertia, whereas a significant fluctuation suggests a lower level of strategic inertia (Wen & Ye, 2014). Drawing upon previous studies (Wen & Ye, 2014; Wang et al., 2022), we adopt the range of change in diversification as a proxy variable to gauge strategic inertia. The Herfindahl index is employed to quantify the extent of business diversification. The calculation formula for the strategic inertia index is as follows:

$$\left| HHI_t - HHI_{t-1} \right| / HHI_{t-1}. \quad (3)$$

To assess capital allocation efficiency, we adopt the approach employed by Yao et al. (2020) and utilize the total asset turnover ratio (Turnover) as a proxy variable.

2.2.4. Moderate variables

For the three moderators, TMT Age is the average age of the TMT in the focal year, Ind Ratio is the proportion of independent directors in the board, Firm Age is the firm established years in the focal year.

2.2.5. Control variables

Digital transformation is a resource-intensive and costly activity, requiring certain resources and capabilities for its effective implementation. To control for firm- and decision-maker-level factors, we select the following variables based on previous research (Zhang et al., 2021; Yi et al., 2021):

- Firm size (Size): measured by the natural logarithm of total assets.
- Firm leverage (Lev): measured by the ratio of total liabilities to total assets.
- Firm profitability (ROA): measured by the ratio of net profit to total assets.
- Asset growth: measured by the ratio between the total assets of the current year and the total assets of the previous year.
- Free cash flow (CF): a binary variable indicating whether the free cash flow of the firm in the current year is positive (1) or not (0).
- Equity nature: a binary variable indicating whether the firm is state-owned (1) or private (0).

On the decision-maker level, we control for:

– Board size: measured by the number of directors.
– Top shareholder (TOP1) shareholding ratio.
– Top ten shareholders (TOP10) shareholding ratio.

We also include year and industry dummy variables in the model.

2.3. Model

To test the research hypothesis, we employed ordinary least squares (OLS) as the baseline model. In order to determine whether to use fixed or random effects, we conducted a Hausman test, and the results indicated that fixed effects (FE) are appropriate. Model (4) shows that the regression equation includes managerial ability (MA) and ten control variables (CV) with industry and year effects being controlled for as well. The model was adjusted for heteroscedasticity by clustering residuals at the firm level.

$$Digital = \alpha_0 + \alpha_1 MA + \sum_{i=2}^{10} \alpha_i CV_{i-1} + \sum Year + \sum Industry + \varepsilon. \quad (4)$$

For the hypothesis 2, referring the existing research of Wen and Ye (2014), we test the mediation effects with the following model, MEV is the strategic inertia (capital allocation efficiency).

$$MEV = \beta_0 + \beta_1 MA + \sum_{i=2}^{10} \beta_i CV_{i-1} + \sum Year + \sum Industry + \varepsilon. \quad (5)$$

For the hypothesis 3a, 3b, and 3c, we build the following model 6 to test, MVs is the moderator (TMT age, Independent director ratio, or Firm age), the Interact is the each interact term.

$$Digital = \gamma_0 + \gamma_1 MA + \gamma_2 MVs + \gamma_3 Interact + \sum_{i=4}^{12} \gamma_i CV_{i-1} + \sum Year + \sum Industry + \varepsilon. \quad (6)$$

3. Empirical results and analysis

3.1. Descriptive statistics and correlation analysis

Table 1 presents the descriptive statistics for the key variables in our analysis. The dependent variable, Digital, ranges from 0 to 4.159, with a mean value of 0.914 and a standard deviation of 1.148. These figures indicate a significant variation in the level of digital transformation among firms, with an overall low level observed in the sample. Managerial ability (MA) exhibits a range from –0.367 to 0.51, with an average of –0.00345 and a standard deviation of 0.124, highlighting substantial differences in managerial ability across the listed companies. Additionally, state-owned enterprises comprise 30% of the sample, and the average board size is 8.596 members.

Table 1. Descriptive statistics

VARIABLES	N	Mean	SD	min	max
Size	9.170	22.12	1.249	19.93	26.05
Lev	9.170	0.411	0.205	0.0467	0.898
Asset Growth	9.170	0.172	0.304	–0.284	1.852
CF	9.170	0.624	0.484	0	1
TOP1	9.170	33.40	14.60	8.040	72.15
TOP10	9.170	57.27	15.03	22.45	90.28
Ownership	9.170	0.307	0.461	0	1
ROA	9.170	0.0397	0.0604	–0.230	0.209
Board Size	9.170	8.596	1.689	4	18
MA	9.170	–0.00345	0.124	–0.367	0.510
Digital	9.170	0.914	1.148	0	4.159

Table 2 displays the results of the correlation analysis conducted on the key variables in this study. The analysis reveals significant relationships among the variables. Managerial ability (MA) exhibits a negative correlation with both enterprise size and the shareholding ratio of the largest shareholder, both significant at the 1% level. Additionally, the firm's profitability (ROA) demonstrates a positive correlation, also significant at the 1% level. Lastly, the digital transformation of the enterprise shows a positive correlation, significant at the 5% level.

Table 2. Correlation analysis

	1	2	3	4	5	6	7
1Digital	1						
2Size	0.075***	1					
3Lev	–0.034***	0.535***	1				
4Asset Growth	0.102***	–0.00200	–0.058***	1			
5CF	–0.024**	–0.037***	–0.058***	–0.212***	1		
6TOP1	–0.125***	0.174***	0.069***	–0.054***	0.082***	1	
7TOP10	–0.068***	0.082***	–0.126***	0.128***	0.053***	0.641***	1
8Ownership	–0.125***	0.367***	0.337***	–0.154***	–0.00700	0.204***	–0.034***
9ROA	0.027***	–0.047***	–0.392***	0.299***	0.140***	0.085***	0.217***
10Board Size	–0.034***	0.279***	0.178***	–0.053***	0.029***	0.0150	0.00400
11MA	0.024**	–0.051***	–0.00300	0.062***	–0.033***	–0.029***	–0.0110
	8	9	10	11			
8	1						
9	–0.131***	1					
10	0.280***	–0.00600	1				
11	–0.040***	0.214***	–0.028***	1			

Note: *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$.

3.2. Regression results and analysis

Table 3 presents the results of empirical regression using the models specified in this study:

Table 3. Managerial ability and digital transformation

	(1)	(2)
VARIABLES	Digital	Digital
Size	0.136***	0.140***
	(3.52)	(3.46)
Lev	0.066	0.047
	(0.50)	(0.35)
Asset Growth	0.072*	0.083**
	(1.94)	(2.16)
CF	0.016	0.022
	(1.08)	(1.49)
TOP1	–0.002	–0.002
	(–1.00)	(–0.75)
TOP10	–0.001	–0.001
	(–0.51)	(–0.45)
Ownership	–0.217**	–0.208**
	(–2.22)	(–2.09)
ROA	0.100	–0.139
	(0.48)	(–0.62)
Board Size	0.034***	0.035***
	(3.06)	(3.25)
MA		0.172***
		(2.78)
Constant	–2.250***	–2.357***
	(–2.74)	(–2.75)
Observations	9,170	9,170
R2	0.0125	0.0132
Number of Company	2174	2174
Company FE	YES	YES
Year FE	YES	YES
Industry	YES	YES

Note: *** $p < 0.01$ ** $p < 0.05$ * $p < 0.1$, robust t-statistics in parentheses, the following is the same.

In Column (1), only the control variables were added in the regression. The results show that firm size is positively correlated with digital transformation at a 1% level, suggesting that larger firms are more likely to undertake digital transformation due to their greater capacity and resources. Similarly, the growth rate of enterprise assets is significantly and positively associated with digital transformation at a 10% level, indicating that firms with a higher scale are more confident and capable of implementing digital transformation. On the other hand, the nature of equity is significantly and negatively related to digital transformation at a 5% level, suggesting that private enterprises tend to have a higher degree of digital transformation compared to state-owned enterprises. The latter may be attributed to the latter's added social responsibilities and need to maintain social stability, making them more cautious in implementing complex and risky digital transformation strategies. Lastly, the size of the board of directors is significantly and positively correlated with digital transformation of firms at a 1% level, as the board can provide resources to facilitate digital transformation aside from their role as a supervisory body.

Column (2) of the regression model includes the MA variable, and the coefficient of MA is significant at the 1% level, supporting H1 that as managerial ability improves, the degree of digital transformation of the enterprise increases. As the key decision-maker for digital transformation strategy, managerial ability is crucial. Managers with higher abilities have a better understanding of risk identification and tolerance for digital strategy. They can also help the firm expand its existing resource channels to obtain more resources. This implies that higher ability managers are better equipped to handle various risks and uncertainties in the transformation process, allocate internal and external resources effectively, and ensure the successful promotion of enterprise digital transformation.

Table 4 presents the results of the mediation effects. The findings indicate a significant positive correlation ($p < 0.01$) between managerial ability (MA) and strategic inertia (Inertia), suggesting that a higher level of managerial ability is associated with a greater degree of diversification change and, consequently, a smaller strategic inertia. In model (4), there is a strong positive correlation ($p < 0.01$) between managerial ability (MA) and capital allocation efficiency (Turnover), indicating that competent managers are more inclined to allocate company funds efficiently. The Sobel-Goodman mediation tests in Table 4 also confirm the significance of both mediation effects at the 1% level, we also do the bootstrap test, the confidence interval does not include 0, thereby supporting Hypothesis 2. These results demonstrate that managerial ability plays a crucial role in promoting digital transformation by overcoming strategic inertia and enhancing capital allocation efficiency.

Table 4. The mediation effects results

	(3)	(4)
VARIABLES	Inertia	Turnover
Size	0.009	–0.059***
	(1.07)	(–3.81)
Lev	0.023	0.337***
	(0.86)	(7.85)

End of Table 4

	(3)	(4)
VARIABLES	Inertia	Turnover
Asset Growth	0.043***	–0.127***
	(4.39)	(–11.73)
CF	–0.008*	–0.007*
	(–1.90)	(–1.80)
TOP1	–0.001*	–0.000
	(–1.82)	(–0.10)
TOP10	0.000	–0.001**
	(0.94)	(–2.28)
ROA	–0.021	0.812***
	(–0.37)	(9.16)
Ownership	–0.000	0.000
	(–0.02)	(0.00)
Board Size	–0.002	0.007**
	(–0.76)	(2.19)
MA	0.066***	0.220***
	(3.53)	(11.51)
Constant	–0.103	1.784***
	(–0.55)	(5.19)
Observations	9,170	9,170
R-squared	0.0155	0.169
Company FE	YES	YES
Year FE	YES	YES
Industry	YES	YES
Sobel test	0.046*** (0.015)	0.074*** (0.017)
Bootstrap confidence interval	[0.0204, 0.072]	[0.0464, 0.101]

Table 5 presents the results of the moderation analysis. The coefficient of Interact1 is –0.018, which is statistically significant at the 5% level. This finding suggests that the age of the top management team negatively moderates the impact of managerial ability on digital transformation, thereby supporting Hypothesis 3a. In model (6), the coefficient of Interact2 is 1.421, which is significant at the 5% level. This indicates that independent directors play a crucial positive role in facilitating the digital transformation of enterprises in conjunction with managerial ability, providing support for Hypothesis 3b. Furthermore, in model (7), the interaction term is negative and significant at the 10% level, indicating that as the firm's estab-

lishment age increases, the effect of managerial ability in promoting digitalization weakens. This finding aligns with Hypothesis 3c.

Table 5. The moderate effect results

	(5)	(6)	(7)
VARIABLES	Digital	Digital	Digital
MA	–0.009	0.070**	0.085**
	(–0.78)	(2.56)	(2.00)
TMT Age	–0.004		
	(–0.65)		
Interact1	–0.018**		
	(–2.25)		
Ind ratio		–0.120	
		(–0.37)	
Interact2		1.421**	
		(2.21)	
Firm Age			0.087***
			(9.64)
Interact3			–0.009*
			(–1.82)
Constant	–2.103**	–2.362***	–3.531***
	(–2.26)	(–2.69)	(–4.40)
Observations	9,170	9,170	9,170
R2	0.0138	0.0139	0.148
Control Variables	YES	YES	YES
Company FE	YES	YES	YES
Year FE	YES	YES	YES
Industry	YES	YES	YES

Notes: Interact1 is the interaction term of TMT age and managerial ability, Interact2 is the interaction term of Ind Ratio and managerial ability. Interact3 is the interaction term of Firm Age and managerial ability.

4. Robustness test

To address the potential endogeneity bias challenge, our study employs a series of tests to enhance the robustness of our research conclusions.

4.1. Heckman two-stage inspection

Given that firms may strategically choose digital transformation as a response to external changes, we employ Heckman two-stage regression model to address potential selection bias. In the first stage, we incorporate the digital transformation degree (DG mean) of firms in the

same industry and year into the regression model and compute the inverse Mills ratio (IMR). In the second stage, we include the IMR as a control variable in the regression model. The results demonstrate that the positive relationship between managerial ability (MA) and digital transformation remains statistically significant, affirming that managerial ability effectively enhances firms' digital transformation efforts. These robust findings are presented in Table 6.

4.2. Negative binomial regression

This study utilizes the frequency of keywords related to digital technology as a measure of the extent of digital transformation in enterprises. To address the discrete nature of the count data and the observed overdispersion, a negative binomial regression model is employed. Descriptive statistics reveal that the mean value of digital transformation is 5.2, with a standard deviation of 13.29. Given the significant difference between the variance and the mean, we apply negative binomial regression while controlling for time effects and individual heterogeneity. The regression results, as presented in Table 6, confirm a significant positive correlation between managerial ability and the degree of digital transformation at a 10% level of significance, which aligns with the previous regression findings.

4.3. Tobit regression analysis

As the dependent variable, the word frequency of digital technology application can only take values greater than or equal to 0. The absence of digital transformation in the sample may be attributed to factors such as managerial ability or other internal reasons within the company. To address this limitation, this study employs a Tobit model with a lower limit of 0 for regression analysis. The results, presented in Table 6, provide further evidence supporting the robustness of the research findings. Specifically, the coefficient of MA exhibits a significant positive correlation with digital transformation at the 1% level, aligning with the main test.

Table 6. Robustness test results

	Heckman two stage		NB	Tobit
VARIABLES	First	Second		
DG mean	1.137***			
	(21.76)			
IMR		–0.076		
		(–1.14)		
MA		0.134*	0.153*	2.476***
		(1.80)	(1.71)	(2.58)
Constant	–7.702***	–2.937***	–4.960***	–56.615***
	(–8.82)	(–2.59)	(–9.82)	(–10.73)
Observations	9,170	5,506	9170	9170
R-squared		0.330		
Number of Company	2,174	1,645	2174	2174

End of Table 6

	Heckman two stage		NB	Tobit
VARIABLES	First	Second		
Control Variables	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Industry	YES	YES	YES	YES

4.4. Replace digital transformation and managerial ability indicators

The measurement of digital transformation in this study is conducted by analyzing the frequency of words related to digital technology application disclosed in the annual reports of firms. This approach is consistent with the methodology employed by Wu et al. (2021), who also utilized variables such as artificial intelligence, big data, cloud computing, and blockchain to measure the dependent variable of digital transformation in their research. The results of the regression analysis, presented in column (1) of Table 7, demonstrate a positive and statistically significant relationship between managerial ability (MA) and the digital transformation of enterprises at the 1% significance level. These findings provide substantial support for the main assumptions of the study.

The core explanatory variable in this paper is managerial ability, which is measured in a continuous form. To address potential noise interference with regression residuals and enhance the representation of managerial ability, a quadratic form of managerial ability is utilized in the regression analysis, following the approach employed by Zhang et al. (2021). The regression results presented in column (2) of Table 7 confirm that the coefficient of managerial ability remains significantly positive ($p = 0.004$), aligning with the earlier findings. These robust results indicate that the research conclusions in this paper remain unaffected by the choice of variables and maintain their reliability.

Table 7. Replace the measures

VARIABLES	(1)	(2)
MA	0.205***	0.019***
	(3.09)	(2.88)
Constant	–3.764***	–2.366***
	(–4.25)	(–2.76)
Observations	9170	9170
Number of Company	2174	2174
Control Variables	YES	YES
Company FE	YES	YES
Year FE	YES	YES
Industry	YES	YES

Conclusions and recommendations

The position of managers within an enterprise is crucial as they represent a vital resource that significantly influences the firm's development and outcomes. In the context of the digital economy, digital transformation has emerged as a prominent trend that shapes the future of enterprises. It enables them to create new value and establish competitive advantages, albeit accompanied by high risks due to its inherent complexity. This study utilizes a sample of China's A-share non-financial industry listed companies spanning the period from 2011 to 2020 to investigate the impact of managerial ability on firm digital transformation. The findings consistently demonstrate the significant contribution of managerial ability to firm digitalization, even after undergoing a battery of robustness tests. Mechanism tests provide further confirmation that managerial ability exerts a positive influence by reducing corporate strategic inertia and enhancing the efficiency of capital allocation. Moreover, heterogeneity tests reveal that this promotional effect is particularly pronounced in younger firms and those characterized by younger top management teams and a higher proportion of independent directors.

This paper contributes to the existing literature in the following ways. Firstly, it expands the scope of research on digital transformation, which has predominantly focused on its outcomes. By examining the implementation of digital transformation and identifying factors contributing to its success, this study takes a step towards addressing these questions from the perspective of managers and underscores the significance of managerial ability. Secondly, building on the upper echelon theory, which emphasizes the influence of managerial cognitive base and values on firm strategic choices, existing research has primarily relied on observable background characteristics as indicators. In contrast, this study adopts a more precise measure of ability to examine the managerial impact on firm outcomes, thus extending the research on managers. Lastly, this paper contributes to the field of corporate governance, particularly in relation to executive-related research, by affirming the critical importance of effectively leveraging managerial ability to drive the development and implementation of firm strategies.

This paper also provides significant practical reference for firms to better carry out digitalization and other strategies. Firms should pay attention to the selection and employment of qualified managers, continuously improve the ability of managers. On the other hand, they should build a younger management team, attach great importance to independent directors, and, for older firms, alleviate the inherent contradiction between the inertial dependence of enterprises in long-term development and the changes required for transformation, thus steadily promoting the implementation of digitalization.

Although this paper contributes to understanding managerial ability and provides a realistic reference for firm digital transformation, there are still some limitations that need to be further studied. Firstly, we did not explore the digital outcome of the managerial ability's effect on firm digital transformation. We need to choose an accurate measure of digital performance that is consistently recognized. Secondly, although managerial ability is helpful for firm digitalization, we did not discuss how to utilize it. For example, we can further study the influence factors of managerial ability, such as salary incentives, etc. Finally, we studied the

managerial ability effect in Chinese firms, but we need to explore whether there are boundaries for the influence of managers on the firm, especially in different social economic and country contexts, from multiple theoretical perspectives and application scenarios.

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Author contributions

Jialin Fu and Fei Li conceived the study and were responsible for the design and development of the data analysis. Nana Zhang was responsible for data interpretation and wrote the first draft of the article.

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