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Smarter and Prosperous: Digital Transformation and Enterprise Performance

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Abstract: Using manually constructed enterprise digital data from 2012 to 2020, this paper innovatively constructs an enterprise digitalization index to explore its impact on enterprise performance and discusses the potential channels of digitalization on enterprise performance. The findings show that (1) digitalization has a significant positive effect on firm performance, and this finding holds after a series of robustness tests. (2) Digitalization improves firm performance by reducing external management costs and strengthening internal controls. The mediating effects model tests the potential impact mechanism of digitalization on firm performance. (3) The effect of digitalization on the performance of state-owned enterprises is greater than for non-state-owned enterprises. The results of the heterogeneity analysis provide policy recommendations for the development of digital transformation of enterprises. Overall, this study provides new insights into the relationship between digitalization and firm performance.

Keywords: digitalization; firm performance; mediating model; external management costs; internal controls

1. Introduction

In recent years, the rapid expansion of China's digitalization has garnered significant attention [1]. Digitalization has garnered widespread recognition as a pivotal catalyst for fostering novel digital enterprises, endowing companies with substantial prospects to optimize resource allocation, efficiently control expenses, and pursue sustainable growth [2,3]. Accordingly, digitalization has become an essential aspect of firms' operations, as highlighted in the 14th Five-Year Development Report, emphasizing the need to accelerate digitalization and promote relevant upgrading [4]. The digital revolution holds immense promise for fostering economic growth and enhancing performance while aligning with the United Nations' Sustainable Development Goals (SDGs) [5]. Digitalization is using technology to radically improve a business's performance or scope and change its operations [6]. It enables firms to access innovative ways of sales or productivity, value creation, and novel forms of customer interaction [7], providing manifold benefits for firms.

One of the most significant advantages of digitalization is that it facilitates direct communication between firms and customers, allowing firms to collect customer feedback on products more conveniently and at a lower cost. Such feedback enables firms to upgrade their products to be more targeted, enhancing their competitiveness in the market. Furthermore, digitalization promotes data exchange among firms, enabling them to understand the market and their competitors comprehensively. Digitalization also enables firms to establish efficient management systems and scientific organizational frameworks, making it wise to adopt digitalization in a rapidly changing business environment.

According to public information, more than 80% of firms in China have implemented digitalization, while 15.2% of firms are planning to digitize. The growing interest in digitalization has spurred increasing research on its impact on firm development. Digitalization

engenders prospects for interregional specialization and cooperation among companies, fostering sustainable business development. For example, Ilvonen et al. (2018) [8] demonstrated that digitalization promotes the restructuring of firm production forms. Hinings et al. (2018) [9] proved that digitalization leads to novel digital organizational forms, reducing transaction costs and time. Carmela et al. (2020) [10] found that digitalization confers enduring economic and social sustainability advantages upon companies operating within the agri-food industry.

Extant literature analyzing digitalization's effects mainly focuses on firm profits, operational efficiency, innovation ability, and organizational performance [11–14]. Even though the research on the relationship between enterprise digitalization and enterprise performance is now a hot topic [15,16], few researchers have constructed a comprehensive study on the link between firms' digitalization and performance. One of the primary reasons for this is the absence of an authoritative index for measuring firms' digitalization. Therefore, this paper manually constructs a dataset for measuring firms' digitalization. The construction process comprises three steps. First, we select digitalization-related keywords based on existing literature using Python. Second, this paper conducts a frequency analysis of digitalization keywords in annual reports of Chinese-listed firms from 2012 to 2020. Third, we construct a firm's digitalization index, primarily based on the frequency of digitalization in annual reports obtained in the second step.

At the same time, existing studies do not agree on the impact of digital transformation on firm performance and its mechanisms. For example, Curran (2018) [17] argued that applying traditional digital technologies has no significant impact on firm performance. Moretti and Biancardi (2020) [18] proposed that digital technologies improve the quality of products and services, reshape the value creation mechanisms of stakeholders in traditional business models, and improve firm performance. It has been shown that the digital transformation of brick-and-mortar firms can reduce costs, increase efficiency, and encourage innovation, thereby improving business performance. [19,20] For example, Kohtamäki et al. (2020) [21] suggest that digital transformation helps improve the efficiency of business operations and contributes significantly to business performance. Ode and Ayavoo (2020) [22] argue that digital transformation facilitates the promotion of innovation, providing incremental contributions to value discovery and value creation

Therefore, we match the constructed digitalization indicators with the data of listed companies from 2012 to 2020 to study the impact of digitalization on corporate performance. To further understand the pathways of the impact of digitalization on firm performance, this paper also discusses the mechanisms of the impact of digitalization on firm performance. In addition, a series of robustness tests and heterogeneity analyses are conducted. The conclusions of this paper contribute to the existing literature on digitalization and firm performance and provide insights into how digitalization can improve firm performance.

This study may have the following two marginal contributions. First, we propose a new digitalization index to measure the digitalization level of the enterprise comprehensively, thus minimizing the bias that may arise from using a single index. Although the available literature provides a variety of indicators to indicate digital development, using a single indicator can lead to potential bias. Secondly, this paper analyzes the influence of digitalization on enterprise performance, and discusses the influence channels of digitalization on enterprise performance from the perspective of reducing external transaction costs and strengthening internal control. Although existing literature has explored the influence of various factors on enterprise performance at the theoretical level, such as Martinez-Caro et al. (2020) and Duman and Akdemir (2021) [23,24], our study is a helpful supplement to the influence and mechanism of digitalization on enterprise performance from an empirical perspective.

The paper is organized as follows. Section 2 presents the literature review of digitalization measurement in firms and digital factors that may affect firm performance. Section 3 introduces the research background and hypothesis. Section 4 provides the model and data. Section 5 discusses the empirical results. Section 6 sheds light on further analyses. Section 7 presents the conclusion and implications.

2. Literature Review

2.1. The Measurement of Digitalization in Firms

Most of the existing literature on digitalization measurement is at the national level, and the main methods used include input–output accounting, SNA accounting, and satellite account accounting. International digitalization indices, such as the Digital Economy and Society Index (DESI), the index constructed by the Organization for Economic Co-operation and Development (OECD), and the Information and Communications Technologies (ICT) Development Index of the United Nations International Telecommunication Union (ITU) have been developed. In particular, DESI clarifies the situation regarding developing digitalization and the digital public service sector in EU countries. The index constructed by the OECD contains 38 digitalization indicators and provides international comparability. The IDI can fully reflect and compare ICT developments in different countries and at different times. China's independently constructed digitalization indices include the Xinhua Group China City Digital Economy Index, the China Academy of Information and Communication Research DEI Index System, and the China Digital Economy Index of Sadie Consulting. These indices are widely used at the national level [25–29].

However, there is a shortage of indices at the firm level, and analysis methods are diverse. Much of the literature focuses on analyzing the impact of digital technology on business performance in a particular segment. Some parts of the literature use case studies, others employ production functions, and others use strategic analysis. For instance, Bajari et al. (2019) [30] constructed a production function to measure the impact of big data on firm performance, while Khayer et al. (2020) [31] used the technology–organization–environment framework based on Fred Fiedler's contingency theory to assess how cloud computing affects small and medium enterprises' performance. Wamba-Taguimdje et al. (2020) [32] analyzed the influence of artificial intelligence on firm performance by reviewing 500 case studies from IBM, AWS, and Universal Robots websites. Carmela Annosi et al. (2020) [10] conducted an exhaustive literature review encompassing 94 peer-reviewed articles in the English language, focusing on business subject areas. Employing a meticulous "eye-balled approach", they scrutinized the articles to identify consistent themes suitable for comprehensive textual analysis and created numerical indices. There is a lack of suitable measurements to construct a study on firms' digitalization and firm performance at the firm level, and even the existing firm-level indicators are focused only on a specific measurement, which cannot reflect the full picture of firms' digitalization.

2.2. Digital Factors That May Affect Firm Performance

The impact of digitalization technologies, such as big data, intelligent manufacturing, artificial intelligence, and the Internet of Things, on firm performance, has been extensively investigated in the literature [30,31,33,34]. The consensus among researchers is that these technologies confer several benefits to firms, which enhance their performance in multiple dimensions. For instance, Maroufkhani et al. (2019) [35] contend that big data enable firms to leverage business analytics to gain a competitive advantage in the market. Similarly, Belvedere et al. (2013) [36] found that information and communication technology (ICT) enables industrial enterprises, especially those involved in long-lifecycle products, to embrace new business models based on real-time data utilization and rapid processing capabilities. Also, Mithas et al. (2011) [37] demonstrate that IT capability facilitates firms in developing customer, process, and performance management capabilities, which contribute to firm performance. Khayer et al. (2020) [31] propose that cloud computing provides a platform for firms to access networks, servers, applications, and services, improving the firm's core competencies and enhancing firm performance. Furthermore, Wamba et al. (2017) [33] posit that artificial intelligence encompasses a broad spectrum of technologies, such as machine translation, chatbots, and self-learning algorithms, which benefit firms by improving their financial, marketing, and administrative functions. Martín-Peña et al. (2019) [38] discovered that increasing the synergy between service-oriented and digital approaches can enhance business performance. Hautala-Kankaanpää (2022) [39] found that digitalization

can enhance business performance by improving the supply chain capabilities of the company, specifically the ability to integrate digital resources with business operations. Sedera et al. (2016) [40] believe that digital platforms can assist in establishing platforms such as the Internet of Things (IoT), integration platforms, and supply chain platforms. These platforms enable the integration of production and logistics control, data management, applications and processes among companies, thereby enhancing operational efficiency.

Nevertheless, although the literature extensively examines the effects of discrete digital technologies on corporate performance, a subset delves into the confluence of digitalization and corporate performance by constructing digital indices. While these studies offer valuable insights, there remains a necessity to develop tailored indices and engage in pertinent discussions that cater specifically to the examination of Chinese A-share listed companies for a more comprehensive understanding. Thus, a research gap in the literature calls for an investigation into the relationship between digitalization and firm performance at the firm level [32].

3. Theoretical Analysis and Research Hypothesis

In the 21st century, the rapid development of information technology has given rise to a systematic revolution in digital technology, encompassing the Internet, big data, and artificial intelligence. Digitalization has emerged as a platform allowing firms to collaborate globally, offering significant growth potential for businesses and society [41]. Public data suggest that in 2021, China's digital economy attained an overall size of 45.5 trillion yuan, accounting for 39.8% of its GDP. Against this backdrop, it is evident that the digitalization of firms will be a vital strategy for Chinese firms in the coming years. Hence, it is crucial for firms to ascertain whether digitalization enhances firm performance and how best to achieve this objective.

3.1. Theoretical Analysis: Why Can Digitalization Help Firms Promote Firm Performance?

The proliferation of digital transformation significantly impacts a growing number of enterprises, exerting profound influence on their decision-making processes. Drawing upon the institutional isomorphism theory advanced by DiMaggio and Powell (1983) [42], enterprises aspire to acquire legitimacy and stability within specific industry and social contexts by adopting and emulating established institutional norms and practices. Against the backdrop of China's concerted efforts in promoting digital transformation policies, enterprises seek to adapt to the contemporary business landscape shaped by digitalization. Consequently, they embrace and implement new institutional elements that align with the prevailing digitalization trends observed in their respective industries and markets. Notably, during their digital transformation journey, enterprises introduce digital tools and technologies as novel institutional components, fostering congruence with the evolving market environment, and ultimately striving for enhanced external recognition and acceptance. Simultaneously, guided by the transaction cost theory, enterprises endeavor to reformulate their market relationships by addressing both external transaction costs and internal control costs, thereby concurrently pursuing the twin objectives of advancing firm performance [7].

As previously explored in studies by Wokurka et al. (2017), Duerr et al. (2018), and Martínez-Caro et al. (2020) [23,43,44], digitalization offers several advantages for enterprises. Firstly, it can help reduce operational costs arising from information asymmetry in external transactions. Additionally, digital technologies such as cloud computing and big data provide enterprises with a wealth of researchable data, enhancing transactional efficiency. With the aid of these technologies, businesses can access timely information about consumer demands, enabling them to update and upgrade their products more promptly. Moreover, digital technologies can overcome certain limitations imposed by regional cultures, language barriers, and national differences, opening up new possibilities for traditional firms. From the perspective of internal control costs, digitalization can help overcome the boundaries of "information silos" within an organization. All

business units can share and utilize data through digital platforms, promoting efficiency. Furthermore, digitalization can assist enterprises in formulating sound strategic plans to adapt to evolving market conditions. Based on these considerations, this study posits the following hypothesis:

Hypothesis 1. *Digitalization can significantly promote firm performance.*

3.2. Theoretical Analysis: How Can Digitalization Help Companies Improve Their External Competitiveness?

Digitalization has a profound impact on firms' external transaction costs, and its effects are multifaceted. Firstly, digitalization can mitigate the costs arising from information asymmetry. By leveraging digital technologies, firms gain access to more transparent and comprehensive market information, which can help them formulate effective and sophisticated strategies. For instance, advanced tools such as big data sentiment indices, stock data visualization, and AI-powered market prediction systems can enable firms to develop a multi-level market strategy layout and an intelligent and efficient operation management model. As a result, firms can enhance their core product competitiveness and improve their operational efficiency [45,46]. Secondly, digitalization can enhance transactional efficiency by providing firms with more researchable data. Technologies such as artificial intelligence, blockchain, cloud computing, and big data enable firms to adopt user-oriented product competition strategies. Empowered by digital technologies, enterprises are enabled to undertake comprehensive customer demand analysis, establish intricate user profiles, and integrate user data into their product management processes. Studies indicate that integrating user data into production management leads to more effective business productivity and enhances firms' competitiveness [47]. Thirdly, digital technologies help firms overcome traditional constraints, such as regional culture, language barriers, and country differences. By breaking the constraints of the physical environment on the supply of products, digital technologies enable firms to create more value for users in both time and space. Furthermore, digital technologies catalyze the deeper development of firms' innovation capabilities by providing advantages in information, technology, and resource integration. This reduces the cost of communication and collaboration between firms, enabling them to streamline their processes and focus on core competencies [48]. Based on these arguments, this paper proposes the following hypothesis:

Hypothesis 2. *Digitalization in firms improves firm performance by reducing external transaction costs.*

3.3. Theoretical Analysis: How Can Digitalization Help Enterprises Strengthen Internal Control?

The adoption of digitalization technologies, including artificial intelligence, big data, 5G, and cloud computing, presents opportunities for firms to transition to intelligent manufacturing and intelligent supply chain management, thereby reducing internal control costs. Firstly, digital technologies can break down the "information silos" within firms, enabling shorter communication distances among different departments and breaking down geographical barriers between parent companies and subsidiaries. This, in turn, reduces the costs of communication within the firm. Secondly, the adoption of digitalization offers the potential to mitigate labor costs by automating data collection, collation, and analysis processes, thereby relieving workers from these tasks. This technological advancement also allows firms to address concerns about hierarchical redundancy that may arise during business expansion. By embracing a user-centric organizational structure that decentralizes decision making, firms can enhance their flexibility and bolster their competitive edge in the market. Finally, digitalization can enable firms to develop and adjust sensible strategic plans in response to market conditions. By improving internal and supply chain management efficiency by creating an efficient operating system, and reducing the probability of errors in the production process through computer-led digitalization, firms can enhance their operational efficiency. Therefore, we propose the following hypothesis:

Hypothesis 3. *The digitalization of firms improves firm performance by strengthening internal control.*

Based on the above analysis, the framework of this paper is as shown in Figure 1. Firstly, this paper constructs a digital index using the text analysis method and matches it with listed company data. Second, the bidirectional fixed-effect model is used to explore the impact of digitalization on corporate performance, and the benchmark regression results confirm Hypothesis 1. Third, to further understand the way digitalization impacts enterprise performance, this paper adopts the mediation effect model. The results confirm Hypothesis 2 and Hypothesis 3. Finally, a series of robustness tests and heterogeneity analyses are made.
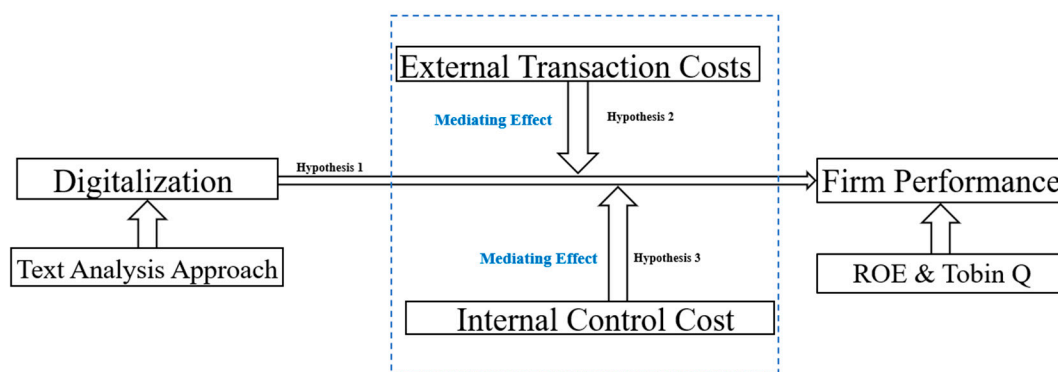
Figure 1. The framework.

4. Model and Data

4.1. Model Setting

4.1.1. Baseline Model

To investigate whether digitalization in firms affects firm performance, we use a panel analysis to measure outcomes of firm performance affected by firms' digitalization. Specifically, our regression equation is as follows,

$$Fp_{it} = \alpha + \beta_1 Digital_{it} + \lambda X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{1}$$

where Fp_{it} is the dependent variable, which represents the performance of firm *i* in year *t*. The independent variable $Digital_{it}$ signifies with the level of digitalization firm *i* in year *t*. The coefficient β_1 of $Digital_{it}$ is what we care about. We expect β_1 to be positive for the outcome of firm performance, denoting that firms' digitalization is effective. X_{it} represents the control variables. Meanwhile, we also control the firm-fixed effect and year-fixed effect to eliminate the impact of the factors that change with time and individuals, which are μ_i and γ_t, respectively.

4.1.2. Mediating Effect Model

To study the potential mechanism through which digitalization affects firm performance, we introduce the mediating effect model to explore whether the digitalization of enterprises can reduce external transactions and strengthen internal control to improve corporate performance. The specific formula is as follows,

$$MV_{it} = \delta_0 + \delta_1 Digital_{it} + \delta_2 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{2}$$

$$Fp_{it} = \theta_0 + \theta_1 MV_{it} + \theta_2 Digital_{it} + \theta_3 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{3}$$

where the *MV* variables are the mediating variables, the proxy of external transaction and internal control costs, respectively, and Fp_{it} $Digital_{it}$ X_{it}, μ_i, γ_t, and ε_{it} have the same definitions as above. The coefficients of Model (2) and Model (3) present the indirect effects of the mediating variables on firm performance, if they are both significantly positive,

indicating the presence of positive mediating effects. If the coefficient of θ_1 is significant but θ_2 is not significant in Model (3), it means that the previous MV is a full mediating effect; otherwise, it is a partial mediating effect.

4.2. Variables and Data

4.2.1. The Dependent Variable

The dependent variable in this study is firm performance, which is measured using return on equity (ROE) and Tobin Q as proxies. These variables were chosen based on the recommendations of Wang et al. (2015), Bennouri et al. (2018), and Gao et al. (2022b) [49–51]. ROE is a trustworthy gauge of asset operation efficiency and a robust indicator of long-term profitability, while Tobin Q provides insights into the market valuation and growth of a firm and is widely employed to assess industrial return on investment [52].

4.2.2. The Independent Variable

The independent variable is the digitalization index of firms, which is constructed using a text analysis approach due to the lack of consensus in the literature on enterprise digitalization measurement methods and the potential bias associated with using a single variable as a proxy. The construction process involves three steps.

First, there is the construction of a lexicon of terms related to enterprise digitalization. This study establishes an enterprise digitalization terminology dictionary based on the semantic framework of national policies. By conducting searches on the websites of the Central People's Government and the Ministry of Industry and Information Technology, more than 30 important national-level digital economy policy documents issued between 2012 and 2020 were manually selected to extract key terms related to enterprise digitalization. Specifically, these policy documents include recent publications such as the Government Work Report, the Special Action Plan for Empowering Small and Medium-sized Enterprises through Digitalization, and the 2020 Digital Transformation Trends Report. After undertaking Python-based tokenization and manual identification, we selected a relevant vocabulary of enterprise digitalization, including artificial intelligence, big data, cloud computing, industrial Internet, Internet finance, digital finance, B2B, B2C, C2B, C2C, Fintech, and NFC payment, among others. The frequency of appearance of the keywords is analyzed, and those with low frequency and less mention in recent years are excluded to enhance the accuracy and timeliness of the research. The remaining keywords constitute the dataset of digitalization vocabularies.

Second, a frequency analysis of digital keywords was conducted in the "Management's Discussion and Analysis" (MD&A) section of annual reports from listed companies in China. Specifically, the digitalization-related vocabulary was expanded using the "jieba" Python library, a third-party library for Python primarily designed for Chinese word segmentation. The digitalization-related descriptions in the board of directors' reports of the annual reports of Chinese listed firms from 2012 to 2020 were analyzed based on text analysis. The relevance of the digitalization-related descriptions in the annual reports was manually verified due to the potential irregularities in the format of some reports and the possibility of word-splitting ambiguity in the "jieba" library.

Third, the digitalization index of firms is constructed based on the frequency of digitalization keywords derived from the second step. The natural logarithm of the reported frequency of occurrence is used to estimate the digital proxy variable, as it enhances the data's analyzability. Specifically, the occurrence frequency of digitalization keywords for each listed firm is calculated, divided by the total number of digitalization keywords, and then the logarithm is taken. The term "digital" is used to represent the index. The inclusion of the names and dates of the researchers cited within parentheses strengthen the academic rigor of the study.

4.2.3. Mediating Variable

This study adopts enterprise asset specificity as a proxy for external transaction costs, following Williamson's (1985) [53] proposal. It uses the proportion of intangible assets to total

assets, based on the approach of Collis and Montgomery (1997) [54], to measure the degree of asset specificity in firms. Higher asset specificity increases the risk of asset "lock-in" and subsequently leads to higher external transaction costs. This paper uses management costs as a metric to gauge the degree of internal control. Prior research has shown that management costs effectively capture the internal control expenses incurred by enterprises [55].

4.2.4. Control Variables

This paper includes several firm-characteristic control variables, namely firm leverage, size, cash flow, book-to-market ratio, and the number of subsidiaries, which are potential factors correlated with firm performance. The selection of these variables is based on the existing literature, including the works of Dichev et al. (2013), Kurnia et al. (2020), and Gao et al. (2021b) [56–58]. We also control for the year-fixed effect in our analysis to address the potential time-varying relationship between digitalization and firm performance. Our sample consists of data from Chinese-listed firms from 2012 to 2020, obtained from the China Stock Market & Accounting Research (CSMAR) and Wind databases, which are economic and financial repositories specifically tailored to capture the unique economic landscape of China, providing valuable resources for both academic research and commercial applications. We process the data by (1) excluding observations from the financial industry; (2) removing ST, ST*, and PT firms; and (3) eliminating samples with missing or outlier data. This results in a final sample of 15,530 observations. All continuous variables are winsorized at the upper and lower 1% levels, and standard errors are clustered at the firm level in the regression analysis. Table 1 presents the descriptive statistics of the variables included in Model (1), with the digital variable exhibiting a minimum value of 0, a maximum value of 1.936, and a standard deviation of 0.358. These results indicate that there is considerable variation in the extent of digitalization across firms, with some firms not yet having undergone digitalization.

Table 1. Descriptive statistics.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
ROE	15,530	0.045	0.826	−36.535	23.739
TobinQ	15,530	2.081	2.053	0.706	102.430
Digital	15,530	0.236	0.358	0.000	1.936
Size	15,530	22.198	1.367	19.570	26.400
Lev	15,530	0.425	0.209	0.021	0.881
Cash	15,530	0.172	0.138	0.009	0.809
Mb	15,530	4.123	3.258	0.498	36.610
Sub	15,530	2.492	1.005	0.000	5.389

Note: This table presents the summary statistics of the main variables of the two groups: managers without environmental background and managers with environmental background, respectively. The construction of "digital" originates from Python, while the rest of the results are from Stata 17.

5. Empirical Results

5.1. The Baseline Regression Results

Table 2 presents the main results from our analysis, which demonstrate a significant positive impact of firm digitalization on firm performance, as measured by different proxies. Columns (1) and (3) report the results without control variables, while Columns (2) and (4) present the results with control variables. All regression models in Table 2 control for firm-fixed effects and year-fixed effects to address potential unobservable heterogeneity. The regression results in all Columns (1)–(4) are robust and significantly positive, providing strong support for Hypothesis 1 that digitalization can enhance firm performance. These findings are consistent with prior studies, including those of Dichev et al. (2013), Kurnia et al. (2020), and Gao et al. (2021b) [56–58], which highlights the positive impact of digital transformation on firm performance.

Table 2. The baseline results of digitalization in firms on firm performance.

	(1)	(2)	(3)	(4)
VARIABLES	TobinQ	TobinQ	ROE	ROE
Digital	0.337 **	0.272 **	0.067 ***	0.047 **
	(1.99)	(2.33)	(3.59)	(2.41)
Constant	1.571 ***	5.121 ***	0.081	−0.792
	(4.31)	(3.64)	(1.46)	(−1.19)
Control Variables	NO	Yes	NO	Yes
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	15,530	15,530	15,530	15,530
R-squared	0.139	0.441	0.140	0.330
Number of firms	2357	2357	2357	2357

Note: Robust *t*-statistics are shown in parentheses. ***, ** indicate the significance at the 1%, 5% levels, respectively. Yes represents the variables that are controlled; Control represents the other controlled variables. Firm and year are the firm-fixed effect and time-fixed effect, respectively. The above empirical results are obtained using the benchmark model and the software Stata 17.

5.2. Instrumental Variables Method

Employing appropriate instrumental variables for dependent variables is an effective strategy for mitigating endogeneity concerns. In the case of firms' digitalization and performance, there may be bidirectional causality, where the adoption of digital technologies leads to better performance, and superior performance may incentivize firms to invest in digitalization. To address this issue, we use instrumental variables analysis in this study.

Following Nunn and Qian (2014) and Zhao et al. (2020) [59,60], we use the interaction between the lagged number of individuals with Internet access nationwide and the number of fixed telephones per 10,000 people by prefecture in 1984 as our instrumental variables. Table 3 presents the results of the instrumental variable analysis. The Kleibergen–Paap rk LM statistic is statistically significant at the 1% level, indicating that our instrumental variable is not under-identified. Moreover, the F-statistic of the first-stage regression is higher than that of the Stock–Yogo critical values at the 10% level, confirming that our instrumental variable is not weak. Therefore, the instrumental variable employed in this study is robust. Additionally, the regression estimates reported in Table 3 remain positive when we account for the instrumental variable, providing further evidence for the robustness of our main findings.

Table 3. The results of instrumental variables test.

	(1)	(2)
VARIABLES	TobinQ	ROE
Digital	0.153 **	0.021 **
	(2.13)	(2.21)
Constant	4.406 **	−0.648
	(2.53)	(−0.63)
Control Variables	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
Observations	14,689	15,530
Kleibergen–Paap rk LM statistic	8.248 ***	9.145 ***
Cragg–Donald Wald F statistic	19.587	22.369
	[16.38]	[16.38]

Note: Robust z-statistics are shown in parentheses. ***, ** indicate the significance at the 1%, 5% levels, respectively. Yes represents the variables that are controlled; Control represents the other controlled variables. Firm and year are the firm-fixed effect and time-fixed effect, respectively. The empirical results above are from Stata 17.

5.3. Robust Test

Table 4 presents the results of a regression analysis in which we exclude specific firms that could potentially affect the overall findings. We focus on excluding firms whose business operations are highly correlated with digital content, such as blockchains, big data, and artificial intelligence. To this end, we exclude firms listed on the growth enterprise market (GEM) and estimate Model (1) once again. Columns (1) and (2) report the regression results without control variables, while Columns (3) and (4) include the control variables. Furthermore, to account for the potential influence of firms' business nature or strategy on their digitalization efforts, we exclude firms whose residuals are in the top 20%. The results in all four columns demonstrate significantly positive coefficients, indicating the robustness of our findings even after narrowing the sample. These findings are consistent with our initial results and support our hypothesis that digitalization can enhance firm performance.

Table 4. Robust test of excluding specific firms.

	(1)	(2)	(3)	(4)
	Excluding GEM firms		Excluding firms in the top 20% of residuals	
VARIABLES	TobinQ	ROE	TobinQ	ROE
Digital	0.138 **	0.070 **	0.080 ***	0.010 **
	(2.07)	(2.42)	(3.57)	(1.99)
Constant	5.001 ***	−0.146	6.642 ***	−0.925 ***
	(2.85)	(−0.17)	(8.90)	(−8.98)
Control Variables	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	12,626	12,927	15,530	15,530
R-squared	0.404	0.024	0.665	0.106
Number of firms	1837	1839	2357	2357

Note: Robust t-statistics are shown in parentheses. ***, ** indicate the significance at the 1%, 5% levels, respectively. Yes represents the variables that are controlled; Control represents the other controlled variables. Firm and year are the firm-fixed effect and time-fixed effect, respectively. The above empirical results are obtained using the benchmark model and the software Stata 17.

6. Further Analysis

6.1. Mediating Effect Test

In order to investigate whether and how external transaction costs and internal control mediate the impact of firm digitalization on firm performance, we empirically explore the underlying mediating effect with the corresponding test results shown in Tables 5 and 6. As a reminder, Table 2 reports the benchmark results, indicating that firm digitalization can significantly improve performance.

Columns (1) and (2) of Table 5 present the results of the mediating effect of TobinQ as a proxy for firm performance. The coefficient of digitalization in Column (1) is −0.276 and significant at the 1% level, suggesting that digitalization by the firm effectively reduces external costs. The coefficient of digitalization in Column (2) is 0.012, which is significant and positive, and the coefficient of Firm asset specificity is also significant at the 5% level, indicating that digitalization is effective in improving the performance of firms by reducing their external costs. These results are consistent with the findings of Kim (2018) [61]. Columns (3) and (4) of Table 5 display the results of the mediating effect of ROE as a proxy for firm performance, and similar outcomes can be observed. Our analysis supports Hypothesis 2, that digitalization in firms enhances firm performance by reducing external transaction costs.

Table 5. Impact of digitalization in firms on external transaction costs.

VARIABLES	(1) Firm asset specificity	(2) TobinQ	(3) Firm asset specificity	(4) ROE
Digital	−0.276 **	0.012 **	−0.025 **	0.003 *
	(−2.02)	(2.11)	(−2.19)	(1.77)
Firm asset specificity		−0.131 **		−0.020 ***
		(−2.28)		(−2.69)
Constant	5.069 ***	−0.781	5.162 ***	−0.830
	(3.58)	(−1.17)	(3.73)	(−1.25)
Control Variables	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	15,530	15,530	15,530	15,530
R-squared	0.441	0.230	0.441	0.240
Number of firms	2357	2357	2357	2357

Note: Robust t-statistics are shown in parentheses. ***, **, * indicate the significance at the 1%, 5%, and 10% levels, respectively. Yes represents the variables that are controlled; Control represents the other controlled variables. Firm and year are the firm-fixed effect and time-fixed effect, respectively. The above empirical results are obtained using the mediating effect model and the software Stata 17.

Table 6 presents the results of our mediating effect analysis on the degree of internal control. As our previous analyses suggest, firms' digitalization can enhance their performance by strengthening their internal control. The more sophisticated the management system is, the less management costs are required, and the more it contributes to improving business performance. Therefore, we use the share of management expenses as a proxy for firms' internal control degree. Columns (1)–(2) report the results using TobinQ as a proxy for performance, and Columns (3)–(4) report the results using ROE as a proxy for performance. The coefficients in Columns (1) and (3) are both significantly negative. Likewise, the coefficients of overhead costs in Columns (2) and (4) are also significantly negative, providing evidence to support the validity of Hypothesis 3, which proposes that digitizing the firm can enhance performance by strengthening internal management control and reducing overhead costs. Specifically, the coefficients of overhead costs in Columns (2) and (4) indicate that enterprise digitalization improves enterprise performance by enhancing internal controls.

Table 6. Impact of digitalization in firms on firms' internal control costs.

VARIABLES	(1) Management expenses	(2) TobinQ	(3) Management expenses	(4) ROE
Digital	−0.269 **	0. 067 ***	−0.394 **	0.110 **
	(−2.34)	(3.22)	(−2.42)	(2.23)
Management expenses		−0.020 *		−0.007 **
		(−1.65)		(−2.24)
Constant	4.944 ***	−0.486	3.929 ***	−0.434
	(3.48)	(−0.70)	(2.61)	(−0.57)
Control Variables	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	15,530	15,530	15,191	15,191
R-squared	0.142	0.280	0.058	0.274
Number of firms	2357	2357	2350	2350

Note: Robust t-statistics are shown in parentheses. ***, **, * indicate the significance at the 1%, 5%, and 10% levels, respectively. Yes represents the variables that are controlled; Control represents the other controlled variables. Firm and year are the firm-fixed effect and time-fixed effect, respectively. The above empirical results are obtained using the mediating effect model and the software Stata 17.

6.2. Heterogeneity Analysis

Table 7 presents the results of our analysis of firm heterogeneity. The impact of digitalization on firms may differ depending on their nature. We divide the database into state-owned enterprises (SOEs) and non-SOEs, and employ regress Model (1) to investigate this. Columns (1) and (2) report the results for SOEs, while Columns (3) and (4) report the results for non-SOEs. The coefficients for SOEs are significantly positive, while those for non-SOEs are not as positive. This may be because firms often need to invest significant amounts of money in equipment purchases and structural modifications during the initial phase of digitalization. Unlike non-SOEs, SOEs have more funding and policy support to facilitate this process. Also, when considering the institutional isomorphism theory (DiMaggio and Powell, 1983) [42], the behavior of a company is shaped by policies and regulations. In contrast to non-SOEs, SOEs demonstrate higher sensitivity to government initiatives and measures that promote digital policies, resulting in a more rapid pace of digital transformation. SOEs are typically subject to direct or indirect influence from the government in their digital transformation efforts. The government may employ measures such as policy regulations, funding support, and tax incentives to drive the digital development of enterprises. As integral components of the government, SOEs often maintain closer collaborative relationships and have easier access to policy guidance and resources. Therefore, SOEs are more likely to benefit from digitalization. Similar concerns were raised by Gao et al. (2021a) [62].

Table 7. Heterogeneity effect of different types of firms.

	(1)	(2)	(3)	(4)
	SOE		non-SOE	
VARIABLES	TobinQ	ROE	TobinQ	ROE
Digital	0.864 ***	0.144 ***	0.098	0.086
	(3.25)	(2.93)	(0.57)	(0.55)
Constant	3.677	0.933	5.666 ***	−1.322
	(1.57)	(0.94)	(2.65)	(−1.44)
Control Variables	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Observations	6204	6204	9326	9326
R-squared	0.546	0.330	0.419	0.231
Number of firms	870	870	1487	1487

Note: Robust t-statistics are shown in parentheses. *** indicate the significance at the 1% levels. Yes represents the variables that are controlled; Control represents the other controlled variables. Firm and year are the firm-fixed effect and time-fixed effect, respectively. The above empirical results are obtained using the benchmark model and the software Stata 17.

7. Conclusions

This study examines the impact of digitalization on firm performance using a digitalization index and a dataset of Chinese-listed firms from 2012 to 2020. Our findings suggest that digitalization significantly enhances firm performance. The mechanisms underlying this relationship appear to involve reductions in external transaction costs and strengthened internal control costs. Our firm heterogeneity analysis further reveals that SOEs benefit more from digitalization than non-SOEs, as SOEs tend to have greater funding and policy support for digitalization initiatives. As with the institutional isomorphism theory, firm behavior is shaped by policies and regulations. Compared with non-state-owned enterprises, SOEs have shown a higher sensitivity to government initiatives and measures to promote digital policies, resulting in a faster pace of digital transformation. The conclusions of this paper contribute to the existing literature on digitalization and firm performance and provide insights into how digitalization can improve firm performance. Enterprise digital transformation is of great significance to the green development and sustainable development of enterprises. The limitation of this paper is that it only considers

the impact of digital transformation on enterprise performance and does not sufficiently discuss the impact of digital transformation on the enterprise's sustainable development. Therefore, this paper will further explore the correlation between enterprise digitization and the enterprise's green performance in future studies.

Based on our findings, we suggest several policy implications. First, the government should encourage enterprises to develop and adopt digitalization to promote the country's high-quality development. In today's era of rapid digital transformation, it is vital to keep pace with technological advances and avoid falling behind. The empirical results of this paper confirm the significant promoting effect of enterprise digitization on enterprise performance. Therefore, the government should formulate policies to promote digitization, especially for non-state-owned enterprises and service industries. At the same time, enterprises should develop strategies to adapt to the changes brought by digitalization to improve their performance.

Second, enterprises can improve their performance through digital active participation to reduce external and internal operating costs. Our analysis shows that digitalization helps reduce external transaction costs and internal control costs, providing a potential way for companies to leverage digital technology. Digital platforms promote the transparency and dissemination of information and break the barriers of time and space. They can also speed up information sharing within companies, saving resources previously spent on communication, research, and strategy. Therefore, the introduction of enterprise digitization can make the daily operation of enterprises more efficient and improve the performance of enterprises.

Third, government policies should target specific firms to maximize their impact. Our heterogeneity analysis shows that digitalization has a limited impact on non-SOEs and firms in the service industry. SOEs tend to have greater funding and policy support for digitalization initiatives, making them better equipped to take advantage of digitalization. According to the institutional isomorphism theory, a company's behavior is influenced by government policies and regulations. Therefore, to enhance the efficiency of digital transformation in non-SOEs, local governments must provide necessary support and create an enabling environment. This includes developing favorable policy frameworks for their digital transformation, providing certain means of financial support and incentives, establishing platforms for digital transformation collaboration and knowledge sharing between the government and non-SOEs, driving the development of digital infrastructure, and creating a favorable digital environment. These measures aim to facilitate the smooth digital transformation of non-SOEs, leading to economic growth and improved competitiveness.

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