Journal of Innovation and Development
ISSN: 2958-4752 | Vol. 13, No. 3, 2025

Impact of Digital Transformation on the High-Quality Development of Home Appliance Enterprises in the Context of New-Quality Productivity

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Abstract: Against the dual backdrop of deepening digital penetration and growing demands for high-quality economic development, the home appliance industry—an iconic representative of "Made in China"—is in urgent need of breaking through inherent development bottlenecks. This study takes 46 listed home appliance enterprises as research objects to systematically explore the impact mechanism and practical paths of digital transformation on their high-quality development, aiming to provide decision-making references for industrial transformation, strategic formulation, and new-quality productivity cultivation. The findings indicate that digital transformation exerts a significant positive effect on the high-quality development of home appliance enterprises, with digital innovation, innovation efficiency, and supply chain efficiency playing key mediating roles. Notably, this promoting effect exhibits obvious heterogeneity among enterprises of different ownership types and regional distributions.

Keywords: New-Quality Productivity; Digital Transformation; Home Appliance Enterprises; High-Quality Development.

1. Introduction

New-quality productivity, characterized by "advanced, innovative, green, and coordinated" core orientations, serves as a key grasp for implementing the new development concept. It not only clarifies the core direction of industrial transformation but also provides fundamental guidance for the high-quality development of various industries[1]. As digital technology extends from daily life scenarios to the core links of industrial production, it has emerged as a critical driving force for the transformation and upgrading of traditional industries. Relevant government departments have issued a series of policies, explicitly proposing to realize large-scale digital transformation of the light industry by 2030, which provides clear direction for the digital development of the home appliance sector.

After more than 70 years of development, the home appliance industry has achieved a leap from imitator to leader and from rule-follower to standard-setter, forming significant large-scale production advantages. However, amid the dual pressures of global industrial chain restructuring, intensified trade barriers, and domestic consumption upgrading, the industry still faces multiple challenges, including core technology bottlenecks, high operating costs, low production efficiency, insufficient industrial chain coordination, and severe product homogenization. As a sector integrating technology intensity and consumer orientation, the home appliance industry's development orientation is highly consistent with the "advanced, innovative, green" characteristics of new-quality productivity[2-3]. How to leverage digital transformation to address industrial development pain points and activate development momentum has become a core issue related to industrial progress.

2. Theoretical Basis and Research Hypotheses

2.1. Impact of Digital Transformation on the High-Quality Development of Home Appliance Enterprises

The new-quality productivity theory clarifies the core orientation of advanced technological innovation, high-efficiency production, and green and coordinated development, and digital transformation is exactly the key path for home appliance enterprises to align with this orientation, address industry development pain points, and achieve high-quality development[4-5]. The home appliance industry, as an important part of the manufacturing sector, has formed large-scale production advantages through long-term development. However, against the dual backdrop of global industrial chain restructuring and domestic consumption upgrading, it faces problems such as core technology bottlenecks, serious product homogenization, and low resource allocation efficiency. It is urgent to achieve a leap from “scale leadership” to “quality leadership” through digital transformation.

The resource-based view points out that heterogeneous resources are the core source for enterprises to build sustainable competitive advantages[6]. Digital transformation enables home appliance enterprises to accumulate "data" as a new type of strategic resource, and reconstruct the logic of resource allocation through the in-depth integration of data and traditional production factors. In the R&D link, by mining and analyzing user behavior data, home appliance enterprises can accurately identify the pain points of market demand, avoiding the "blindness" of traditional R&D; in the production link, through big data scheduling, the precise supply of raw materials and parts is realized, reducing inventory backlogs and resource waste; in the marketing link, precise marketing is achieved through user portraits, improving the return on marketing investment. This data-

driven optimization of resource allocation enables home appliance enterprises to concentrate limited technology, capital, and talent resources on high-value links, forming a heterogeneous competitive advantage with "value, scarcity, and inimitability", and injecting sustained momentum into high-quality development.

The dynamic capability theory emphasizes that in a rapidly changing market environment, enterprises need to have dynamic capabilities of "perceiving opportunities—integrating resources—innovating and responding"[7]. Currently, the home appliance industry is facing two core changes: first, under the global industrial chain restructuring, enterprises are confronted with uncertainties; second, the iteration of consumer demand is accelerating, and users' update cycle for home appliance products has shifted from "function satisfaction" to "experience upgrading". The traditional model of "large-scale production + channel distribution" is difficult to adapt. Digital transformation improves the dynamic capabilities of home appliance enterprises through three paths: first, through big data monitoring of global supply chain data, such as raw material prices, logistics timeliness, and policy barriers, to enhance the ability to perceive and warn supply chain risks; second, through the flattening reform of organizational structure, such as establishing digital business departments and cross-departmental data collaboration teams, to break the traditional "departmental barriers" and improve resource integration efficiency; third, digital technology shortens the cycle from R&D to market launch of products. The cultivation of this dynamic capability enables home appliance enterprises to quickly adjust their strategies, address development bottlenecks in a complex market environment, maintain sustained competitive advantages, and promote high-quality development.

Based on the above analysis, Hypothesis H1 is proposed: Digital transformation helps improve the high-quality development level of home appliance enterprises.

2.2. Mechanism of Digital Transformation Affecting the High-Quality Development of Home Appliance Enterprises

2.2.1. Mediating Role of Digital Innovation: Core Carrier of the "Advanced Technology" Attribute

The core feature of new-quality productivity is "high-tech and advanced technology-driven", and digital innovation is exactly the key link for home appliance enterprises to transform the achievements of digital transformation into advanced technological advantages[8]. The data empowerment theory points out that the value of data as a new production factor lies in transforming into innovation directions and technological breakthrough points through mining and analysis, and digital transformation provides "technical tools + data resources" dual support for the digital innovation of home appliance enterprises.

In terms of innovation direction, the innovation of traditional home appliance enterprises mostly focuses on "function upgrading", such as increasing the capacity of washing machines and improving the cooling efficiency of air conditioners, which is difficult to break through the predicament of technological homogenization; while the user data collection system built by digital transformation can accurately capture users' demand for digital attributes such as "intelligent interaction, scenario integration, and green low-carbon". For example, through user usage data, pain points such as "insufficient stability of remote control of home appliances" and "lack of multi-device linkage scenarios" are found, and targeted R&D of Internet of Things communication technology and scenario-based algorithms is carried out, promoting the transformation of innovation direction from "function optimization" to "digital technology breakthrough".

In the innovation process, digital transformation promotes the intelligent reconstruction of the R&D process: building virtual production scenarios through digital twin technology can simulate the product performance of different technical schemes, reducing the cost and cycle of physical prototype trial production; through cross-enterprise data collaboration, such as sharing technical data with chip enterprises and software enterprises, breaking the "information island" of R&D, and accelerating the integrated application of digital technology. This technology breakthrough with digital innovation as the core not only enables home appliance enterprises to produce digital patents that conform to the "advanced technology" attribute of new-quality productivity, such as intelligent control algorithm patents and Internet of Things communication patents, but also integrates digital technology into products and services, forming a high-value-added business model of "smart home appliances + scenario services", providing core technical support for the high-quality development of enterprises.

Hypothesis H2: Digital innovation plays a mediating role in the process of digital transformation promoting the high-quality development of home appliance enterprises.

2.2.2. Mediating Role of Innovation Efficiency: Key Response to the "High Efficiency" Attribute

New-quality productivity emphasizes "high efficiency", requiring enterprises to improve the input-output ratio of innovation while pursuing technological progress. Relevant research indicates that digital transformation effectively solves problems such as scattered innovation resources and insufficient collaboration in the innovation process of home appliance enterprises by integrating innovation resources and optimizing innovation processes, thereby significantly improving innovation efficiency[9].

The innovation process of traditional home appliance enterprises has three major efficiency bottlenecks: first, scattered R&D resources, and the disconnection of data between technical departments, marketing departments, and production departments, leading to the disconnection between R&D direction and market demand; second, blind innovation input, lack of accurate judgment on technical R&D hotspots and market prospects, which is prone to "invalid R&D"; third, too long R&D cycle, time-consuming links such as physical testing and sample trial production, which are difficult to quickly respond to market changes. Digital transformation addresses these bottlenecks through three paths: first, building a cross-departmental data collaboration platform to realize the real-time sharing of R&D, market, and production data, so that R&D plans can simultaneously match market demand and production capacity; second, monitoring the technical R&D trends of the global home appliance industry through big data analysis technology, providing accurate decision-making basis for innovation input, and reducing blind input; third, introducing digital tools such as virtual simulation and AI-assisted design, transforming the "physical testing" of product R&D into "digital simulation", and greatly shortening the R&D cycle. The improvement of innovation efficiency enables home appliance enterprises to obtain more

high-quality innovation achievements (such as digital patents and high-value-added products) with lower investment, reducing innovation costs and improving innovation return rates, which has become an important mechanism for promoting high-quality development.

Hypothesis H3: Innovation efficiency plays a mediating role in the process of digital transformation promoting the high-quality development of home appliance enterprises.

2.2.3. Mediating Role of Supply Chain Efficiency: Industrial Support for the "Coordinated" Attribute

The supply chain, as the core link connecting home appliance enterprises with "upstream raw materials-midstream production-downstream markets", its efficiency directly affects the operating costs, market response speed, and risk resistance ability of enterprises. The home appliance supply chain is characterized by "many links, wide involvement of subjects, and large demand fluctuations". The traditional supply chain model has problems such as "lagging information transmission, rigid inventory management, and unbalanced supply and demand", which easily lead to product shortages caused by the "bullwhip effect". In contrast, digital transformation builds an industrial Internet-based supply chain collaboration system, which is in line with the "coordinated" requirement of new-quality productivity and helps improve supply chain efficiency.

In terms of information collaboration, the collaboration platform established through digital transformation realizes real-time sharing of production plans, inventory levels, and market demand data among upstream and downstream enterprises (raw material suppliers, component manufacturers, logistics enterprises, distributors, etc.). For example, home appliance enterprises can synchronize terminal market order data to component manufacturers in real time to enable them to produce on demand; component manufacturers can synchronize raw material demand data to suppliers to avoid blind stockpiling, fundamentally alleviating the "bullwhip effect".

From the perspective of inventory management, through big data demand forecasting algorithms, home appliance enterprises can accurately predict the market demand of different regions and products, realizing precise inventory management of "producing according to sales", reducing inventory backlogs, and lowering capital occupation costs. In terms of risk response, the supply chain risk monitoring system built by digital transformation can track risk factors such as raw material price fluctuations and logistics timeliness. When risks such as raw material shortages occur, alternative suppliers can be quickly switched to enhance risk resistance. The optimization of supply chain efficiency directly reduces enterprise operational costs and improves market competitiveness, thereby promoting high-quality development. For example, component manufacturers achieve digital upgrading through the supply chain collaboration platform, forming a virtuous cycle of "enterprise high-quality development - industrial chain coordinated upgrading".

Hypothesis H4: Supply chain efficiency plays a mediating role in the process of digital transformation promoting the high-quality development of home appliance enterprises.

3. Research Design

3.1. Sample Selection and Data Sources

This study selects Chinese listed home appliance enterprises from 2013 to 2023 as research samples, with the sample scope determined based on the Shenwan Industry Classification. Relevant data are collected from the CSMAR and Wind databases. To ensure the validity and reliability of the research, the following screening processes are conducted: (1) Exclude ST, *ST, and other enterprises with abnormal operating conditions; (2) Process extreme values through winsorization to avoid their impact on research results. Finally, 352 valid observation samples are obtained.

3.2. Variable Definition

3.2.1. Dependent Variable: Total Factor Productivity (TFP)

High-quality development not only pursues output growth but also focuses on the improvement of sustainability, efficiency, and technological progress, which is reflected in the improvement of total factor productivity (TFP)[10]. Referring to previous studies, this paper uses the LP method to measure TFP as the proxy indicator of enterprise high-quality development[11].

3.2.2. Independent Variable: Digital Transformation (DIT)

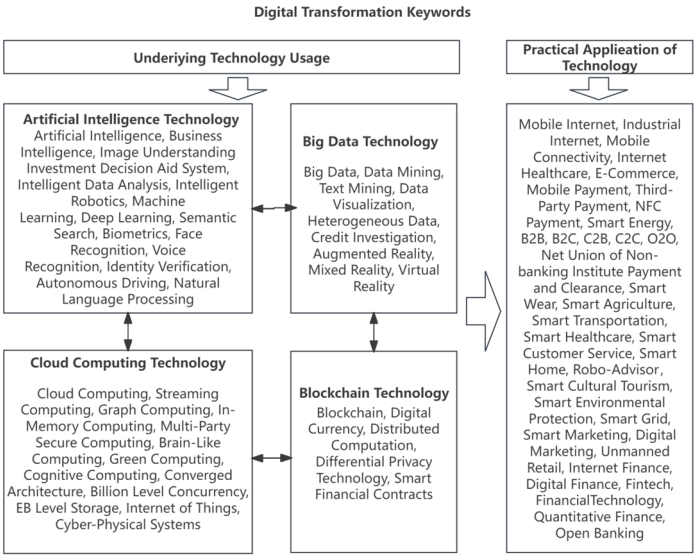

Fig 1. Digital Transformation Keywords

Referring to the research of Shan H[12], this paper uses the frequency of digital transformation-related keywords in enterprise annual reports to measure the degree of digital transformation. The core keywords include underlying technologies such as big data, mobile Internet, cloud computing, and blockchain (see Figure 1).

3.2.3. Mediating Variables

1) Digital Innovation (DIN): Referring to the research of S. Zhu et al.[13], we systematically analyzes the patent application documents of listed home appliance companies, screens the patents related to digital transformation technologies based on the International Patent Classification (IPC) and uses the natural logarithm of the number of digital patents obtained by each enterprise as an indicator to measure digital innovation level.

2) Innovation Efficiency (INE): Innovation efficiency refers to the conversion efficiency of innovation input to innovation output. Referring to the research of Fan F et al.[14], this paper uses the average number of patent applications corresponding to the unit R&D input of enterprises (total patent applications/total R&D input) as an indicator to evaluate innovation efficiency.

3) Supply Chain Efficiency (SCE): Supply chain efficiency reflects the coordination level of enterprises in resource allocation, inventory management, logistics scheduling, production and sales, and other links. Improving supply chain efficiency helps reduce costs, optimize product quality and services, and enhance enterprise competitiveness. Referring to the research of H. Zhou[15], this paper uses the reciprocal of inventory turnover days as a proxy variable—faster inventory turnover indicates higher supply chain efficiency.

3.2.4. Control Variables

Referring to relevant studies, the following control variables are selected referring to relevant studies: Enterprise Growth (Growth), Enterprise Size (Size), Asset-Liability Ratio (Lev), Cash Flow from Operating Activities (Cfo), Equity Concentration (Top10), Tobin's Q (TobinQ), and Dual Position (Dual).

3.3. Model Setting

To verify the direct impact of digital transformation on the high-quality development of home appliance enterprises, the following baseline regression model is constructed:

$$TFP_{it} = \alpha_0 + \alpha_1 DIT_{it} + \sum Controls + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

In the formula, the subscripts i and t respectively represent the enterprise and the year; TFP is the dependent variable (high-quality development level); DIT is the independent variable (digital transformation degree); Controls are control variables; α_0 is the constant term, α_1 is the estimated coefficient, μ_i is the enterprise fixed effect, δ_t is the year fixed effect, and ε_{it} is the random error term.

To verify the mediating roles of digital innovation, innovation efficiency, and supply chain efficiency, on the basis of Equation (1), referring to the method of H. Xie[16], the following mediating effect models are constructed:

$$MV_{it} = \beta_0 + \beta_1 DIT_{it} + \sum Controls + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

$$TFP_{it} = \gamma_0 + \gamma_1 DIT_{it} + \gamma 2 MV_{it} + \sum Controls + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

MV_{it} is the mediating variable, including digital innovation (DIN), innovation efficiency (INE), and supply chain efficiency (SCE). β_0 and γ_0 are constant terms, and β_1, γ_1, and γ_2 are estimated coefficients.

4. Empirical Tests and Research Results

4.1. Descriptive Statistics

Table 1 shows the descriptive statistical results of the main variables. For the dependent variable TFP, the mean value of sample enterprises is 9.156, the standard deviation is 1.074, the minimum value is 6.588, and the maximum value is 11.418, indicating that the overall high-quality development level of home appliance enterprises is relatively good, but there are significant differences among different enterprises. For the independent variable DIG, the mean value is 2.163, the standard deviation is 1.205, and the value range is 0-5.040, showing that the digital transformation of home appliance enterprises is steadily advancing, but some enterprises have not yet carried out in-depth digital transformation.

Table 1. Descriptive statistics

Variables	Obs	Mean	SD	Min	Max
TFP	352	9.156	1.074	6.588	11.418
DIG	352	2.163	1.205	0	5.040
DIN	352	5.558	1.853	0.693	9.762
INE	352	0.184	0.067	0.034	0.335
SCE	352	4.765	1.135	0.017	8.173
Growth	352	0.112	0.187	-0.313	0.835
Size	352	22.845	1.414	20.144	26.91
Lev	352	0.491	0.177	0.122	0.808
Cfo	352	0.072	0.067	-0.08	0.269
Top10	352	0.58	0.162	0.271	0.929
TobinQ	352	1.893	0.992	0.853	5.969
Dual	352	0.347	0.477	0	1

4.2. Baseline Result Analysis

To verify whether digital transformation helps promote the cultivation of new-quality productivity and thus drive the high-quality development of home appliance enterprises, this paper uses model (1) to conduct multiple regression analysis. The regression results are shown in Table 2. Column (1) shows the regression result without adding control variables and fixed effects. The coefficient of DIG is 0.164, which is significant at the 1% level, indicating that digital transformation has a significantly positive impact on the high-quality development of home appliance enterprises. Column (2) adds time and individual fixed effects, and the coefficient of DIG is 0.062, still significant at the 1% level. Column (3)

adds control variables without fixed effects, and the coefficient of DIG is 0.124, significant at the 5% level. Column (4) adds both control variables and time-individual double fixed effects, and the coefficient of DIG is 0.057, significant at the 1% level. Although the regression coefficients of digital transformation in the four regression tests are slightly different, they all pass the significance test, indicating that digital transformation can significantly promote the high-quality development of home appliance enterprises, which verifies the research hypothesis H1.

To verify whether digital transformation promotes the high-quality development of home appliance enterprises by improving total factor productivity, multiple regression analysis is conducted. The regression results are shown in Table 2. Column (1) shows that the coefficient of DIG is 0.164, which is significant at the 1% level, indicating that digital transformation has a significant positive impact on the high-quality development of home appliance enterprises. Column (2) adds time and individual fixed effects, and the coefficient of DIG is 0.062, still significant at the 1% level. Column (3) includes control variables without fixed effects, and the coefficient of DIG is 0.124, significant at the 5% level. Column (4) includes both control variables and time-individual double fixed effects, and the coefficient of DIG is 0.057, significant at the 1% level. These results consistently confirm that digital transformation can significantly promote the high-quality development of home appliance enterprises, which is consistent with the research hypothesis.

Table 2. Baseline regression result

Variables	(1) TFP	(2) TFP	(3) TFP	(4) TFP
DIG	0.164***	0.062***	0.124**	0.057***
	(7.08)	(7.55)	(6.48)	(5.43)
Growth			0.273***	0.298**
			(3.25)	(3.32)
Size			0.593***	0.346***
			(3.73)	(2.73)
Lev			0.513***	0.361
			(3.29)	(0.25)
Cfo			0.765***	0.710**
			(3.51)	(2.09)
Top10			-0.045***	-0.413***
			(-3.29)	(-3.52)
TobinQ			-0.009***	-0.016**
			(-13.45)	(-1.98)
Dual			-0.0471	-0.0294
			(-1.38)	(-0.56)
Year FE	No	Yes	No	Yes
Individual FE	No	Yes	No	Yes
N	352	352	352	352
R^2	0.5039	0.5554	0.5405	0.6962

Note: ***p<0.01, **p<0.05, *p<0.1; t-values are in parentheses, the same below.

4.3. Robustness Tests

4.3.1. Instrumental Variable Test

To solve the potential endogeneity problem (such as mutual causality between digital transformation and enterprise high-quality development). Specifically, referring to the method of X. Zhao et al.[17], this paper uses the lagged term of digital transformation as the instrumental variable for regression. The regression results are shown in Column (1) of Table 3, the coefficient of the IV in Column (1) is 0.865, which is significantly positive at the 1% level, indicating that the instrumental variable of this paper satisfies the correlation condition with the enterprise's digital transformation. The result in Column (2) is consistent with the baseline regression result, indicating that the research conclusion is robust.

4.3.2. Alternative Dependent Variable

To further verify the reliability of the research conclusion, this paper adopts an alternative indicator for total factor productivity. Referring to the research of Liu H et al. (2022)[18], the OP method is used to re-measure TFP (denoted as TFP_OP) and introduce it into the regression model (1) for robustness regression analysis. The regression result is shown in Column (3) of Table 3. The coefficient of DIG is 0.073, significant at the 1% level, which is consistent with the baseline result, further verifying the consistency and robustness of the research conclusion under different measurement methods.

4.3.3. Alternative Independent Variable

To further test the core independent variable, this paper introduces a substitute indicator. Specifically, the ratio of the number of digital technology-related patents to the total number of disclosed patents is used as a substitute indicator for digital transformation (denoted as DIG_Alt). The regression result is shown in Column (4) of Table 3. The coefficient of DIG_Alt is 0.062, significant at the 1% level, which further verifies the positive impact of digital transformation on the high-quality development of home appliance enterprises.

4.3.4. Exclusion of Policy Interference

Considering the particularity of the home appliance industry in terms of policy support, which may affect enterprise digital transformation behavior and thus the research conclusion, this paper excludes enterprise data in policy-supported regions for regression analysis to eliminate potential policy interference. The result is shown in Column (5) of Table 3. The coefficient of DIG is 0.047, still significant at the 1% level, consistent with the baseline result, indicating that the research conclusion has strong reliability.

Table 3. Robustness test

Variables	(1) DIG	(2) TFP	(3) TFP_OP	(4) TFP	(5) TFP
IV	0.865***				
	(5.53)				
DIG		0.132***	0.073***		0.047***
		(6.21)	(6.72)		(6.28)
DIG_Alt				0.062***	
				(7.37)	
Growth	0.408***	0.320***	0.259***	0.247***	0.294***
	(7.47)	(3.92)	(3.34)	(2.73)	(3.66)
Sise	0.237***	0.357***	0.378***	0.231***	0.327***
	（3.07）	(3.79)	(3.46)	(3.37)	(3.25)
Lev	-0.059	0.320***	0.372***	0.205***	0.536***
	(-1.26)	(4.52)	(2.71)	(3.35)	(3.45)
Cfo	-0.320	0.753***	0.678***	0.920***	0.827***
	(-0.22)	(5.44)	(4.71)	(6.00)	(2.87)
Top10	0.060**	-0.508***	0.337***	0.309***	0.1480
	(2.21)	(-4.14)	(3.40)	(3.16)	(1.59)
TobinQ	0.088***	-0.027***	-0.031***	-0.028***	-0.017***
	(13.69)	(-11.46)	(-12.19)	(-11.49)	(-11.26)
Dual	-0.011	-0.007	-0.015	-0.009	-0.012
	(-0.68)	(-0.44)	(-0.76)	(-0.37)	(-0.69)
Year FE	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes
N	352	352	352	319	352
R^2	0.5381	0.6743	0.6538	0.5861	0.6385

4.4. Heterogeneity Analysis

4.4.1. Ownership Heterogeneity

To explore the heterogeneous impact of digital transformation on enterprises of different ownership natures, this paper divides the sample into state-owned enterprises and non-state-owned enterprises for group regression. The results are shown in Table 4. For non-state-owned home appliance enterprises, the coefficient of DIG is 0.062, significant at the 1% level; in contrast, for state-owned home appliance enterprises, the coefficient of DIG is 0.056, significant at the 5% level. The results indicate that the promoting effect of digital transformation on the high-quality development of non-state-owned home appliance enterprises is stronger. The reason may be that non-state-owned enterprises have a stronger market orientation and operational flexibility, and can more quickly utilize market opportunities to improve production efficiency and innovation capabilities through digital transformation.

Table 4. Regression results of ownership structure heterogeneity

Variables	TFP	
	(1)	(2)
	State-owned Enterprises	Non-state-owned Enterprises
DIG	0.056***	0.062***
	(2.56)	(5.35)
Control variables	Yes	Yes
Year FE	Yes	Yes
Individual FE	Yes	Yes
N	112	240
R^2	0.6273	0.7319

4.4.2. Regional Heterogeneity

Due to differences in overall economic development, marketization degree, digital infrastructure construction, and technological innovation capabilities among different regions in China, the impact of digital transformation may exhibit regional heterogeneity. Referring to the method of X. Wang et al.[19], this paper divides the sample into eastern, central, and western regions for group regression. The results are shown in Table 5. In the eastern region, the coefficient of DIG is 0.074, significant at the 1% level; in contrast, the impact coefficients in the central and western regions are 0.043 and 0.032 respectively, which are relatively weak and significant at the 10% level. The reason may be that the eastern region has a more mature marketization degree, improved digital infrastructure, and a superior digital technology application environment. In this context, enterprises are more likely to integrate digital technology into production and operation processes, thereby effectively improving resource utilization efficiency and innovation capabilities, and promoting high-quality development.

Table 5. Regression results of regional heterogeneity

Variables	TFP		
	(1)	(2)	(3)
	Eastern Region	Central Region	Western Region
DIG	0.074***	0.043*	0.032*
	(4.89)	(1.87)	(1.72)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
N	198	88	66
R^2	0.712	0.635	0.597

4.5. Mediating Effect Analysis

4.5.1. Mediating Role of Digital Innovation

Column (2) of Table 6 shows the regression result of digital transformation on digital innovation. The coefficient of DIG is 0.386, significant at the 1% level, indicating that digital transformation has a significant positive impact on the digital innovation of home appliance enterprises. Column (3) adds

the digital innovation variable to the baseline model. The coefficient of DIN is 0.082, significant at the 1% level, while the coefficient of DIG drops to 0.028, which is lower than the baseline coefficient of 0.057 and still significant. This indicates that digital transformation not only directly promotes the high-quality development of home appliance enterprises but also indirectly strengthens this effect through the driving role of digital innovation, verifying Hypothesis H2.

4.5.2. Mediating Role of Innovation Efficiency

Column (4) of Table 6 shows the regression result of digital transformation on innovation efficiency. The coefficient of DIG is 0.035, significant at the 1% level, indicating that digital transformation effectively improves the innovation efficiency of home appliance enterprises. Column (5) further adds the innovation efficiency variable to the baseline model. The coefficient of INE is 0.793, significant at the 1% level, while the coefficient of DIG drops to 0.030, still significant. This result indicates that innovation efficiency plays a partial mediating role in the process of digital transformation promoting the high-quality development of home appliance enterprises, verifying Hypothesis H3.

4.5.3. Mediating Role of Supply Chain Efficiency

Column (6) of Table 6 shows the regression result of digital transformation on supply chain efficiency. The coefficient of DIG is -0.214, significant at the 1% level. Since SCE is the reciprocal of inventory turnover days, this negative coefficient indicates that digital transformation shortens the inventory turnover days of home appliance enterprises, thereby improving supply chain efficiency. Column (7) adds digital innovation, innovation efficiency, and supply chain efficiency to the regression model simultaneously. The coefficient of SCE is -0.098, significant at the 1% level, while the coefficient of DIG is 0.038, still significant. This indicates that supply chain efficiency plays a partial mediating role in the process of digital transformation promoting the high-quality development of home appliance enterprises, verifying Hypothesis H4.

Table 6. Results of the mediation effect test

Variables	(1) TFP	(2) DIN	(3) TFP	(4) INE	(5) TFP	(6) SCE	(7) TFP
DIG	0.057***	0.386***	0.028***	0.035***	0.030***	-0.214***	0.038***
	(5.43)	(8.92)	(3.15)	(7.64)	(3.42)	(-6.87)	(4.01)
DIN			0.082***				
			(6.73)				
INE					0.793***		
					(5.89)		
SCE							-0.098***
							(-5.36)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	352	352	352	352	352	352	352
R^2	0.6962	0.7385	0.7241	0.6837	0.7193	0.6752	0.7105

5. Research Conclusion and Policy Implications

5.1. Research Conclusion

Based on the data of Chinese listed home appliance enterprises from 2013 to 2023, this paper empirically tests the impact of digital transformation on their high-quality development, as well as the mediating roles of digital innovation, innovation efficiency, and supply chain efficiency, and the heterogeneous effects of ownership and region. The main conclusions are as follows:

First, digital transformation significantly promotes the high-quality development of home appliance enterprises. By reconstructing resource allocation logic and enhancing dynamic capabilities, digital transformation helps enterprises address development pain points, which is consistent with the core orientation of new-quality productivity.

Second, digital innovation, innovation efficiency, and supply chain efficiency constitute the key mediating paths for digital transformation to promote high-quality development. Specifically, digital innovation serves as the core carrier of the "advanced technology" attribute of new-quality productivity, promoting the transformation of enterprises' innovation direction from functional optimization to digital technology breakthrough; innovation efficiency responds to the "high efficiency" requirement of new-quality productivity, optimizing the innovation process and improving the R&D input-output ratio; supply chain efficiency meets the "coordinated" attribute of new-quality productivity, reducing operational costs through information collaboration and inventory optimization, and enhancing risk resistance ability. All three play partial mediating roles.

Third, the enabling effect of digital transformation has obvious heterogeneity. In terms of ownership nature, the promoting effect on non-state-owned home appliance enterprises is stronger, relying on their stronger market flexibility and orientation; in terms of regional distribution, due to improved digital infrastructure and high marketization degree, the effect of digital transformation in the eastern region is more significant, reflecting the important impact of the external environment on the transformation effect.

5.2. Policy Recommendations

5.2.1. Enterprise Level: Precisely Promote Digital Transformation and Consolidate the Core Path of High-Quality Development

Enterprises should formulate differentiated transformation strategies based on their own ownership attributes and regional development foundations. State-owned home appliance enterprises need to focus on optimizing organizational structure, reducing administrative intervention, and improving operational flexibility to better adapt to market changes and accelerate the application of digital technology to enhance innovation capabilities. Non-state-owned enterprises should give full play to their market sensitivity

advantages, increase investment in digital technology R&D, and further expand the transformation dividend.

Enterprises in the eastern region can leverage regional industrial dividends, prioritize the improvement of digital infrastructure, focus on core business links to steadily promote digital transformation, and avoid blind follow-up layout; enterprises in the central and western regions should strengthen cooperation with leading enterprises and research institutions, introduce advanced digital technology and management experience, and gradually narrow the digital gap.

Enterprises should increase targeted layout of digital patents around market demand pain points such as intelligent interaction, scenario integration, and green low-carbon, and build a cross-departmental data collaboration platform to realize the integration and sharing of R&D, production, and marketing data. Introduce digital tools such as virtual simulation testing to optimize the R&D process, reduce R&D costs and cycles. Build a supply chain collaboration system covering upstream and downstream based on the industrial Internet, realize real-time sharing of production plans, inventory levels, and market demand data, and achieve accurate supply and demand matching to shorten the inventory turnover cycle. At the same time, attach importance to the accumulation of data elements, establish a standardized data collection, storage, and analysis system, and transform various data into strategic resources to drive the optimization of the entire industrial chain.

5.2.2. Government Level: Optimize the Transformation Ecosystem and Strengthen Policy Guidance and Support

The government should formulate targeted support policies according to the pain points and development needs of home appliance enterprises in digital transformation. Introduce special subsidies and tax preferential policies, focus on supporting home appliance enterprises in digital patent R&D and digital talent introduction, and give policy inclination to enterprises in the central and western regions to narrow the regional digital divide.

Build a diversified public service platform, integrate industry data resources, and provide enterprises with technical consulting, standard specifications, talent training, and other services. Promote industry-university-research collaborative research on digital technology bottlenecks, break through core technical barriers, and provide technical support for the digital transformation of home appliance enterprises.

Improve the market mechanism and standard system, formulate laws and regulations on the digital economy, regulate data transactions and safe use, formulate evaluation standards and certification systems for home appliance digital products, and guide enterprises to carry out transformation practices in an orderly manner. Strengthen the construction of digital infrastructure in the central and western regions, improve the coverage and quality of digital networks, and create a favorable external environment for the digital transformation of enterprises in less developed regions.

Acknowledgments

This paper is one of the research outcomes of the National Social Science Fund Project "Analysis of Dilemmas and Research on Practical Paths for Comprehensively Promoting Rural Revitalization" (24SGC021), the 2025 Shaanxi Provincial Intellectual Property Decision Consulting Research Project "Research on Policies for Strengthening Intellectual Property Financial Services in the Transformation and Application of Intellectual Property Rights" (YJ2025-09), the 2025 Shaanxi Provincial Philosophy and Social Sciences Research Special Project "Research on Cultural Industry Empowering Urban Renewal Based on the MIPS Method" (2025YB0046), and the 2025 Key Soft Science Project of Xi'an Science and Technology Program "Research on Paths and Practices of High-Level Science and Technology Innovation Platforms Supporting the High-Quality Development of Local Economy"(25RKYJ0001).

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