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Mechanism and Path Analysis of Digital Technology Driving Industrial Digital Transformation

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Abstract: The process of transitioning traditional industries into the digital era is a critical component of China's strategic move towards a phase of high-quality economic growth. The integration of digital technologies has revolutionized conventional business paradigms and has infused the industrial sector with a fresh wave of dynamism. This study utilizes panel data from 30 Chinese provinces spanning the years 2013 to 2020. It constructs a baseline regression model, an intermediary effect model, and a regulatory effect model. Utilizing fixed effects models and instrumental variable techniques, the study conducts an empirical examination of the mechanisms and pathways through which digital technology influences the digital transformation of industries. It is found that digital technology is conducive to promoting industrial digital transformation. Heterogeneity test shows that the difference of East, west, central and western regions and economic development level all affect the promoting impact of digital technology on the digitalization of industry., and the promoting impact is stronger in the core area and the cities with high economic development level. The intermediary mechanism test shows that digital technology can promote industrial digital transformation through economic scale expansion and technological innovation, and the adjustment mechanism test shows that institutional environment exerts a beneficial regulatory influence within the operational dynamics of how digital technology drives industrial digital transformation. Drawing from the analysis above, In the context of digital economy, digital technology have a ability to help industrial digital transformation through the intermediary role of economic scale expansion and technological innovation, and provide an important strategy basis for China's effective implementation of vigorously developing new quality productivity and digital construction.

Keywords: Digital Economy; Digital Technology; Traditional Industries; Industrial Digital Transformation; Mediating Effect

1. Introduction

Over the past few years, The swift progress and profound integration of cutting-edge technologies like big data, AI, and 5G have emerged as a potent force driving the rapid growth of the digital economy. These technologies are driving paradigm shifts in industrial processes and serving as a central force in the transformation of industries in the new era. As a result, the digital transformation of industries has become an inevitable trend, particularly for traditional sectors. On one hand, industrial digital transformation leverages the extensive connectivity of the internet to break through the limitations of traditional production cycles and models. This not only improves production efficiency but also enables businesses to expand production scales [1]. On the other hand, digital technologies provide tools for precise measurement, analysis, and optimization of all aspects of production and operational processes. These instruments assist companies in lowering expenses, streamlining operations, and elevating the caliber of their offerings and services and create opportunities for innovation in product offerings [2]. By integrating and upgrading traditional factors of production, digital technologies facilitate a transformative leap in productivity, paving the way for traditional industries to embrace digitalization and intelligence-driven development.

At the 2023 China International Intelligent Industry Expo, the government proposed "vigorously developing pillar industries within the digital economy, fostering the growth of digital industrial clusters, and applying digital technologies to comprehensively and systematically transform traditional industries". The initiative emphasized accelerating the digitalization of agriculture, manufacturing, and services to strengthen, optimize, and expand the digital economy. This policy direction provides a theoretical foundation for understanding how digital technologies drive industrial digital transformation and highlights the need to explore specific mechanisms through which such transformation is achieved [3-5]. Some scholars have investigated these mechanisms. For example, Yang Zhuofan [6] proposed that two distinct models characterize industrial digital transformation in China: the coercive model, which is driven by societal pressures, and the value-added service model, which is motivated by innovation[7]. Additionally, existing research has suggested that advanced technologies such as hybrid information systems, edge computing, and other innovative solutions can significantly accelerate the value realization of digital transformation for enterprises [8-10].

2. Study Design

2.1 Data Sources

This research utilizes pertinent metrics from 30 Chinese provinces spanning the years 2013 to 2020 to construct an indicator system that describes digital technology and industrial digitalization. The quantity of sanctioned patents applications is sourced from the official website of the China Patent Office, The Digital Inclusive Finance Index is sourced from the Digital Finance Research Center at Peking University. Other data are primarily derived from reports such as the *China Industrial Digitalization Report (2020)*, *China Economic Census Yearbook*, *China Statistical Yearbook*, *China City Statistical Yearbook*, as well as data published by local governments, the WIND database, the CSMAR database, and official websites. Due to incomplete indicators for Xizang, this region has been excluded from the analysis. The entropy method is employed to calculate digital technology and industrial digitalization indicators for the 30 provinces.

2.2 Variable Selection

2.2.1 Dependent variable

The dependent variable in this study is industrial digitalization (Dig). Many scholars have constructed indicator systems to measure industrial digitalization. Leveraging the conclusions of Zhu Jie and Wang Jun et al., Li Zhihui, Yang Wenpu, Yang Xueting, and Zhang Danning et al., this study adopts a dual-dimensional perspective, incorporating both inputs and outputs, to construct an indicator system for industrial digitalization. The indicators are calculated using the entropy technique and the linear weighting approach.

2.2.2 Independent variable

The independent variable is digital technology (Ted). This variable is defined with reference to the *White Paper on the Development of China's Digital Economy* and is based on the connotation and characteristics of digital technology, as well as the research of Han Zhao'an et al. It is measured across three dimensions: the scale, communication capacity, and the standard of service the telecommunications industry; the scale and development of software information technology and the Internet; and digital transactions. (See Table 1)

Table 1 Digital Technology Performance Indicators

Primary Indicator	Secondary Indicators	Tertiary Indicators	Attribute	Weight
Digital Technology	Scale, Communication Capacity and Service Level of Telecommunications Industry	Total telecommunications business volume	+	0.1115
		Density of internet access ports	+	0.1682
		Fiber optic cable density	+	0.1255
		Mobile phone penetration rate	+	0.0294
		Mobile base station density	+	0.1076
	Scale and Development of Software and Internet	Revenue from the software industry	+	0.1746
		Number of corporate legal entities in the Internet sector	+	0.1087
		Internet domain names per 1,000 people	+	0.1477
	Digital Transactions	Digital Inclusive Finance Index	+	0.0269

2.2.3 Mediating and moderating variables

The mediating variables in this study are as follows: (1) Economic Scale Expansion (Pdp): Drawing from the research of Yue Yujun and Ma Yixuan, the variable is measured using "regional per capita GDP / 10,000". (2) Technological Innovation (Tech): Compared to the granting of utility model patents and design patents, patent application authorizations better reflect a region's technological innovation capability. Therefore, the study uses The count of approved patent applications per 10,000 members of the population as a measure of technological innovation level. The moderating variable in this study is the Institutional Environment (Ins): Following the research of Shangguan Zeming et al., the marketization index is adopted as its measure.

2.2.4 Control variables

To reduce the possible bias resulting from variables that were not included, the study incorporates several control variables that may influence digital technology and industrial digitalization, Guided by the empirical evidence by Han Xianfeng et al.: (1) Urbanization Level (Urb): Measured by the ratio of urban resident population to total permanent population. (2) Science and Technology Support Intensity (Sts): Assessed by the ratio of public spending on science and technology to the regional Gross Domestic Product (GDP). (3) Government Attention to Digital Technology (Gdt): Measured by government focus on the digital economy. (4) Industrial Structure (Ids): Evaluated by the proportion of the tertiary sector's value added to that of the secondary sector. (5) Foreign Direct Investment (Ovi): Determined by the share of foreign direct investment in relation to the regional Gross Domestic Product (GDP). (6) Degree of Openness (Dop): Assessed based on the proportion of the combined value of imports and exports to the regional Gross Domestic Product (GDP).

2.3 Model Construction

This research utilizes panel data from 30 Chinese provinces over the period from 2013 to 2020 to conduct an empirical analysis of the effects of digital technology on the digitalization of industries. To this end, the following econometric model is constructed:

$$Dig_{it} = \alpha_0 + \alpha_1 Ted_{it} + \alpha Controls_{it} + \varepsilon_i + u_t + \varphi_{it} \quad (1)$$

Where, Dig represents industrial digitalization, Ted denotes digital technology, i corresponds to provinces, t stands for years, Controls is the set of control variables, ε captures province fixed effects, μ accounts for time fixed effects, and φ is the random error term. To further investigate the mediating mechanism, the study references the mediation effect test approach proposed by Wen Zhonglin et al. (2014) and develops the subsequent econometric models grounded in the aforementioned Model. (1):

$$U(Pdp,Tech)_{it} = \beta_0 + \beta_1 Ted_{it} + \beta Controls_{it} + \varepsilon_i + u_t + \varphi_{it} \quad (2)$$

$$Dig_{it} = \gamma_0 + \gamma_1 Ted_{it} + \gamma_2 U(Pdp,Tech)_{it} + \gamma Controls_{it} + \varepsilon_i + u_t + \varphi_{it} \quad (3)$$

Where, U represents the mediating variables, which in this study refer to economic scale expansion and technological innovation. α1 demonstrates the comprehensive effect of digital technology on industrial digitalization, γ1 represents the straightforward influence of digital technology on industrial digitalization and β1*γ1 signifies the indirect influence of digital technology on industrial digitalization through the mediating variable.

3. Measured Results and Conversation

3.1 Analysis of Baseline Estimation Results

Table 2. Baseline Regression Results

	(1)	(2)
	dig	dig
ted	0.702***	0.518***
	(26.51)	(15.25)
urb		0.397***
		(7.26)
sts		4.750***
		(2.93)
gdt		0.000**
		(2.30)
ids		-0.017**
		(-2.37)
ovi		-0.241
		(-1.50)
dop		-0.000
		(-0.00)
_cons	0.133***	-0.087***
	(40.05)	(-3.19)
Province/year	Yes	Yes
N	240.000	240.000
r2	0.771	0.878
r2_a	0.738	0.856

Note: The statistics inside parentheses indicate t-values adjusted using clustered robust standard errors. *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively; the same applies hereafter.

Table 2 displays the fundamental regression outcomes regarding the influence of digital technology on industrial digitalization. Following the Hausman test results, this research opts for a fixed effects (FE) model. for regression analysis. The regression digital multiplier technology is considerable positive when control variables are not included, with a coefficient of 0.702. After incorporating control variables, the coefficient remains significant at the 1% level, with a value of 0.518. This indicates that for every 1 percentage point increase in digital technology, industrial digitalization increases by 0.518 percentage points.

3.2 Robustness Checks and Endogeneity Tests

3.2.1 Switching the principal explanatory variable

The variable employed for explanation in this research was determined through constructing an indicator system employing the entropy method. To ensure robustness, the explanatory variable is substituted by single-variable measures inspired by the research of Han Xianfeng et al. (2024). Specifically, the employee roster in the information technology sector, An ensemble of high-tech enterprises, and the total profits of high-tech enterprises are used as alternative indicators for digital technology. This substitution further underscores that the emergence of digital technology is a complex systems engineering process. Relying solely on a single indicator or studying it from a single dimension may severely underestimate the influence of digital technology on the digitalization of industry. Nonetheless, the mechanism estimation results remain robust.

3.2.2 Quantile regression

Ordinary linear regression models mainly focus on the mean, examining how the expected mean of the dependent variable changes given the values of the explanatory variables. In contrast, quantile regression allows an exploration of the changing influence trends of explanatory variables on the dependent variable at different quantiles. It also identifies which explanatory variables play significant roles at various quantile levels.

3.2.3 Introducing instrumental variables

Endogeneity is an unavoidable concern in economic research. Considering the framework of this investigation, the swift expansion of industrial digitalization is inherently connected to the innovation and advancement of digital technology. Conversely, the progression of digital technology is closely tied to the dynamics of industrial digitalization, suggesting an inherent causal relationship between the two. Moreover, many factors influence industrial digitalization, and the control variables included in the study may omit certain relevant variables. Given these potential issues of inherent causality and omitted variables, this study addresses endogeneity by introducing instrumental variables.

3.3 Heterogeneity Analysis

3.3.1 Regression by time period

According to *A Brief History of Digital Technology*, the internet era concluded in 2015, ushering in the era of a new generation of information technologies from 2016 onwards. Given the lagging influence of digital technology, it is essential to partition the sample period into two stages: 2013–2016 and 2017–2020, and subsequently conduct regression analysis for each period.

3.3.2 Regional heterogeneity analysis

The baseline regression results indicate that digital technology significantly promotes industrial digitalization. However, considering China's vast territorial expanse, the disparity in resources, characteristics, and development objectives across provinces inevitably results in regional differences in digital technology and varying challenges in industrial digitalization transformation. Numerous cross-regional studies have demonstrated that the impact of digitalization on industrial digitalization levels varies across regions. Therefore, based on China's geographical divisions, this study categorizes regions into the eastern, central, and western areas and performs Quantitative analysis for each of these three regions.

3.3.3 Heterogeneity in economic development levels

To examine the igital innovation's impact on industrial digitalization in cities with varying levels of economic development, this study draws on Wang Yongqin et al.'s classification criteria for urban economic development levels. It uses per capita GDP as an indicator to measure the stage of economic progress. and divides the sample into two groups: high economic development and low economic development. Regression analysis is then conducted for each group.

3.4 Mediation Mechanism Test

While the preceding analysis has confirmed that digital technology facilitates industrial digitalization, the specific pathways by which industrial digitalization is enhanced remain unclear. Based on the characteristics of digital technology development at different stages, This research utilizes a mediation model to explore the pathways by which digital technology affects industrial digitalization via two distinct avenues.: "economic scale expansion" and "technological innovation".

3.5 Moderation Mechanism Test

To explore the moderating role of the institutional environment, an interaction term between digital technology and the institutional environment is introduced into Model (1), resulting in the following model:

$$Dig_{it} = \chi_0 + \chi_1 Ted_{it} + \chi_2 Ins_{it} + \chi_3 Ted_{it} \times Ins_{it} + \chi Controls_{it} + \varepsilon_i + u_t + \varphi_{it} \quad (4)$$

The continuous advancement of digital technology, coupled with the incentives and constraints of the institutional environment, fosters healthy competition that promotes industrial digitalization. This study adopts the marketization index as a proxy variable for the institutional environment (Ins). By incorporating the interaction term of digital technology and the institutional environment (Ted×Ins) into Model (1), the modified model (4) is obtained.

4. Conclusion

This study analyzes Data from thirty provincial-level administrative divisions in China over the period from 2013 to 2020 are paneled. excluding Xizang region due to data insufficiency, to investigate. The significance of digital technology development on industrial digital transformation. The investigative conclusions reveal the following: First, digital technology significantly promotes industrial digital transformation. After conducting robustness checks, including substituting core explanatory variables, quantile regression, introducing instrumental variables, and examining regional heterogeneity, this conclusion remains valid. Second, The penetration of digital technology on industrial digital transformation exhibits notable heterogeneity, displaying a stronger effect in the central regions and areas with more advanced economic conditions. Third, economic scale expansion and technological innovation serve as the intermediating factors by which digital technology influences the digital transformation of industry. Finally, the institutional environment positively moderates the function of digital technology in promoting the digitalization of industry.

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