

The Impact of Digital Inclusive Finance on the Effectiveness of Industrial Structure Upgrading: An Empirical Analysis Based on Panel Data from 31 Provinces in China

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Abstract. In the context of the accelerating global digitization process and the increasingly interconnected global economy, China is striving to establish a modern financial system that is innovation-led, data-enabled, and inclusive to all. This study, based on panel data from 31 provinces in China from 2013 to 2022, employs a two-way fixed effects model to delve into the impact of digital inclusive finance on the advancement and rationalization of industrial structure. The findings reveal that: (1) digital inclusive finance has a significant positive effect on the upgrading of industrial structure; (2) innovation investment plays a partial mediating role in this process; (3) there are notable regional differences in the impact of digital inclusive finance on industrial structure upgrading. Therefore, it is recommended that local governments formulate policies based on their respective realities, strengthen financial supervision and technological infrastructure construction, fully tap the potential of digital inclusive finance in promoting industrial structure upgrading, and promote the deep integration of financial resources and technological innovation to achieve continuous optimization and upgrading of the industrial structure.

Keywords: Digital Inclusive Finance; industrial structure upgrading; Two-way Fixed Effects Model; Regional Innovation Level.

1. Introduction

Within the accelerating trajectory of global economic digitization, digital inclusive finance, an emerging industry, profoundly alters traditional financial services with its unique advantages. In the information era, technologies like big data and cloud computing significantly lower financial service barriers, broaden channels, and notably enhance efficiency, injecting new vitality into the real economy. Thus, exploring the relationship between digital inclusive finance and industrial structure upgrading is crucial for understanding economic trends and promoting industrial advancement.

Against the backdrop of global reindustrialization, upgrading industrial structure becomes pivotal for China's economic and social development. Digital inclusive finance plays a key role in this transition by supporting technological innovation, facilitating the rapid development of emerging industries, and optimizing financial resource allocation. Understanding this link is essential for policymaking and fostering China's high-quality economic development.

Moreover, digital inclusive finance not only drives industrial structure upgrading but also fosters rationalization. By breaking geographical barriers, it promotes cross-regional resource flow and industrial agglomeration, optimizing local industrial structures and promoting regional economic coordination. Studying its impact on industrial structure rationalization is crucial for balanced regional development and resource optimization.

The innovation of this paper lies in the use of panel data from 31 provinces in China from 2013 to 2022 and the adoption of a two-way fixed-effects model for empirical research, systematically analyzing the intrinsic relationship and impact mechanism between digital inclusive finance and the upgrading of industrial structure. Through empirical research, this paper not only deeply explores the specific effects of digital inclusive finance on the upgrading and rationalization of industrial structure but also reveals the heterogeneity of its impact mechanism and the effects of regional characteristics and location differences. Moreover, the model used in this paper is verified by robustness tests, demonstrating the stability and reliability of the model and providing solid theoretical basis and empirical support for relevant policy formulation.

2. Literature Review

Digital inclusive finance, facilitated by digital technologies, aims to provide accessible financial services, overcoming geographical and socio-economic barriers for financial inclusion (Qiu & Xiang, 2018). Leveraging technologies like big data and AI, it targets diverse customer segments, enhancing financial service coverage and quality (Guo & Zhu, 2021). Its development impacts economic growth and regional disparities, energizing entrepreneurship and household consumption (Xie et al., 2018; Yang et al., 2020; Zou & Wang, 2020).

Industrial structure upgrading, a critical phase in economic development, involves transitioning from simplicity to complexity, small-scale to large-scale, and rigidity to flexibility (Gao et al., 2015). Several intertwined factors influence this process. Technological innovation, a core driver, enhances industrial technological content and value-added, leading to high-end, intelligent, and green industry development (Fu, 1998). Changes in demand structure significantly impact industrial structure upgrading; consumer upgrades drive industries towards service-oriented and high-end development (Maddison, 1987). Resource endowment serves as a critical foundation for industrial structure upgrading, with its rational utilization and optimized allocation being essential (Sachs & Yang, 1999). The policy environment is indispensable, with governments guiding industrial structure upgrading through policies (Rodrik, 2006). These factors collectively drive industrial structure optimization and upgrading, crucial for achieving high-quality economic development.

Industrial structure rationalization, crucial for economic growth and competitiveness, is influenced by technological innovation, market demand, resource endowment, policy regulation, openness to foreign markets, and environmental regulations. Technological innovation enhances productivity and industry upgrades (Fu et al., 2014; Porter & Stern, 1999), while market demand guides industry optimization (Gan & Zheng, 2009; Schumpeter, 1942). Resource endowment affects industry distribution (Auty, 1993), and policy regulation directs industry optimization (Rodrik, 2004). Openness to foreign markets promotes industry upgrading (Kuznets, 1971), and environmental regulations drive green industrial transformation (Yuan & Xie, 2014).

Regional innovation level, tied to regional innovation input, underpins the capacity for innovation within a region, facilitating technological progress, industrial upgrading, and economic competitiveness. Since the 1950s, scholars such as Arrow (1962) recognized innovation's pivotal role in driving economic growth. Subsequent studies by Romer (1986) and Lucas (199) expounded on the intrinsic mechanisms of economic growth, emphasizing the centrality of human capital and technology. Porter (1990) emphasized innovation's significance in national competitiveness. Researchers affirm innovation's correlation with economic development model transformations (Zhang, 2011), influencing discussions on innovation paths and processes (Hong, 2009; Gan, 2013). Innovation levels intersect with green development and factor endowments, impacting economic growth (Liu, 2012; Wang & Wang, 2022).

3. Research Design

3.1 Data Definition

This paper uses panel data from 2013 to 2022, covering 31 Chinese provinces, sourced from the "China Statistical Yearbook" and Wind financial data platform. Employing tail trimming techniques ensures data quality by removing outliers' potential impact on model estimation, enhancing robustness and accuracy. Econometric analysis on these processed data enables deeper exploration, resulting in empirically sound conclusions.

3.2 Dependent Variable

Per capita GDP & Urban-rural income. Per capita GDP is a key measure of industrial structure upgrading, reflecting regional development and technological progress. High-tech industries' emergence boosts per capita GDP, revealing industrial trends and aiding policy. Urban-rural income

indicates industrial rationalization, reflecting resource efficiency and welfare. These indicators effectively measure industrial upgrading and rationalization, meeting economic and social equity needs.

3.3 Independent Variable

The level of development of digital inclusive finance. This paper uses the Inclusive Finance Index (IF) compiled by the Digital Finance Research Center of Peking University as a proxy variable for the level of development of digital inclusive finance in various provinces of China. This index system also includes three dimensional indices of digital inclusive finance, namely coverage breadth, depth of usage, and degree of digitization.

3.4 Mediator Variable

Regional innovation level. This paper selects the regional innovation level as a mediating variable and follows the approach of Lu Feng and Han Shangrong (2015) to measure the level of technological innovation using patent grants in technology innovation inputs.

3.5 Control Variable

This paper includes additional factors as control variables that may impact industrial structure rationalization and upgrading: (1) level of education, (2) urbanization rate, (3) per capita foreign direct investment, (4) urban registered unemployment rate, (5) inflation rate, and (6) financial development level.

Data for China's 31 provinces (excluding Hong Kong, Macau, and Taiwan) were sourced from the Wind database, Ant Group's Digital Economy Open Research Platform*, and variable descriptions from the "China Statistical Yearbook," detailed in Table 1.

Table 1 Variable Description

Variable Type	Variable Name	Specific Indicator	Abbreviation
dependent variable	upgrading of industrial structure	logarithm of per capita GDP	ISU
	rationalization of industrial structure	per capita disposable income of urban and rural residents in each province	ISR
core independent variable	level of development of digital inclusive finance	Peking University Digital Inclusive Finance Index	IF
	depth of digital inclusive finance applications	Usage Depth Index in Peking University Digital Inclusive Finance Index	IFD
mediating variable	Regional innovation level	The logarithm of the number of patents granted in each province	RI
control variable	Level of education attainment among residents	$((\text{Population aged 6-11}) * 6 + (\text{Population aged 12-14}) * 9 + (\text{Population aged 15-17}) * 12 + (\text{Population with college degree or above}) * 16 + (\text{Population with postgraduate degree}) * 18) / \text{Total population aged 6 and above.}$	EDU
	Per capita foreign investment level	Total foreign investment amount / Total population	FDI
	Urbanization rate	Urban population / Total population	Urban

	Unemployment rate	Registered urban unemployment rate	Unemp
	Inflation rate	Consumer Price Index (CPI)	CPI
	Financial development level	Number of financial institution branches / Area of each province	Findev

Note:

(1) Urban registered unemployment rate data for 2022 are missing.

(2) Educational attainment indicators have changed over the past decade. Adjustments have been made to statistical categories based on data availability: vocational education data are excluded, and if data for postgraduates are unavailable, associate degrees and above are grouped together and assigned a uniform score of 17 to ensure accuracy. empirical analysis

4. Empirical Model

This paper establishes the following two-way fixed effects model to analyze the impact of digital inclusive finance on industrial structure upgrading.

$$ISU_{it} = \beta_0 + \beta_1 IF_{it} + \sum_{i=2}^n \beta_i X_{it} + \tau_t + \mu_i + \varepsilon_{it}$$

$$ISR_{it} = \beta_0 + \beta_1 IF_{it} + \sum_{i=2}^n \beta_i X_{it} + \tau_t + \mu_i + \varepsilon_{it}$$

Here, *i* represents provinces, *t* represents time, ISU stands for industrial structure upgrading, and ISR stands for industrial structure rationalization. ε represents the random error term, τ and μ respectively represent time and individual fixed effects, and β_0 is the constant term.

5. Empirical Analysis

5.1 Descriptive Statistics

The descriptive statistical analysis reveals that the mean of the explanatory variable IF is 277.48, indicating significant development in digital inclusive finance with a concentrated and stable data distribution. The variable ISU shows a stable mean with a very low standard deviation, while the ISR variable exhibits a relatively high mean with manageable fluctuation, indicating rich and diverse data. Statistical tests confirm the stability of both ISU and ISR variables.

Table 2 Descriptive statistics

Variables	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Year	310	2017.5	2.876925	2013	2022
ISU	310	10.9357	0.0432	10.0028	12.1464
ISR	310	27246.1600	12498.9600	9740.0000	79609.7700
IF	310	277.4821	80.2664	113.1000	460.6909
IFD	310	266.3769	88.0842	107.2900	510.6945
EDU	310	9.0605	1.1380	4.2480	12.7664
FDI	310	6628.7920	14981.8300	0.0000	103282.3000
Unbanunit	310	60.4447	12.3563	23.9300	89.6000
Unemp	279	3.1896	0.6355	1.2000	4.6000

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CPI	310	101.9708	0.6919	100.1000	103.9000
Findev	310	0.0934	0.1317	0.0005	0.7046
RI	310	10.3308	1.1562	4.7958	13.6788

5.2 Benchmark Regression Results

Using a two-way fixed effects model, regressions were conducted for industrial structure upgrading and rationalization indicators, as shown in Table 2. Without control variables, coefficients for digital inclusive finance on both indicators are significantly positive at the 0.001 level, indicating its positive impact. This conclusion holds even after adding control variables.

Table 3 Benchmark regression results

	ISU	ISR
IF	0.0018264*** (0.0003798)	119.0649*** (10.63709)
EDU	0.038242** (0.0132285)	409.0397 (370.4988)
FDI	1.18e-06** (4.65e-07)	0.0776002*** (0.0130102)
UNBAN	0.0170313*** (0.0024387)	-689.5276*** (68.30183)
UNEMP	0.0010017 (0.0069858)	111.2207 (195.654)
CPI	0.0023265 (0.0063413)	-85.04823 (177.6039)
FINDEV	0.7351148 (0.6269692)	72550.66*** (17559.89)
CONSTANT	8.735326*** (0.6942603)	35749.73 (19444.55)
time fixed effects	Yes	Yes
individual fixed effects	Yes	Yes
N	279	279
R ²	0.8263	0.5229

5.3 Mediation Analysis Testing

Mediation analysis shows that digital inclusive finance indirectly promotes industrial structure upgrading through innovation inputs. It enhances financial inclusiveness, easing financing constraints and fostering increased innovation inputs. These inputs enhance innovation capabilities, driving new technology development and industrial upgrading. Experimental validation confirms innovation inputs partially mediate the relationship between digital inclusive finance and industrial structure upgrading, with a significant positive impact.

Table 4 Mediation analysis testing results

	ISU[Original]	ISU[With Mediating Variable]
IF	0.0018264*** (0.0003798)	0.0019369*** (0.0003692)
RI		0.0520488*** (0.0130175)
EDU	0.038242** (0.0132285)	0.0261053* (0.013177)
FDI	1.18e-06**	1.39e-06**

	(4.65e-07)	(4.53e-07)
UNBAN	0.0170313*** (0.0024387)	0.0160714*** (0.002376)
UNEMP	0.0010017 (0.0069858)	-0.00241 (0.0068249)
CPI	0.0023265 (0.0063413)	0.0081414 (0.0063164)
FINDEV	0.7351148 (0.6269692)	0.5589979 (0.609323)
CONSTANT	8.735326*** (0.6942603)	7.811298*** (0.711531)
time fixed effects	Yes	Yes
individual fixed effects	Yes	Yes
N	279	279
R^2	0.8263	0.8435

5.4 Heterogeneity Analysis

Regional disparities in China lead to varying effects of digital inclusive finance on industrial structure upgrading. The study divides the sample into East, Central, and West regions. Regarding upgrading, digital inclusive finance has a significantly positive impact, with the Central region showing the most significant effect, followed by the West. For rationalization, the East demonstrates the most significant impact, followed by the Central region, while the West faces challenges due to economic weaknesses and lagging digital inclusive finance development.

Table 5 Heterogeneity analysis results of ISU

	ISU		
	WEST	MIDDLE	EAST
IF	0.003227*** (0.0008537)	0.0033216** (0.0011834)	0.002952*** (0.000566)
EDU	0.0340117* (0.0176401)	0.0290106 (0.0492813)	0.0492173* (0.0229395)
FDI	- 2.28e-06 (2.32e-06)	9.85e-06 (0.0000171)	7.74e-07 (4.56e-07)
UNBAN	0.0109067* (0.0055862)	0.0216458 (0.0114966)	0.0073431* (0.0032002)
UNEMP	- 0.0000746 (0.0109494)	-0.0457454** (0.0181355)	0.0356637** (0.0122993)
CPI	0.0087323 (0.0088293)	0.0444978 (0.0238064)	-0.0043808 (0.0087363)
FINDEV	- 0.0229962 (4.742804)	1.579359 (7.451427)	0.889747 (0.5484618)
CONSTANT	8.244108*** (0.988308)	4.102031 (2.607883)	9.639421*** (0.9695179)
time fixed effects	Yes	Yes	Yes
individual fixed effects	Yes	Yes	Yes
N	108	72	99
R^2	0.7514	0.7560	0.7745

Table 6 Heterogeneity analysis results of ISR

	ISR		
	WEST	MIDDLE	EAST
IF	-12.99209 (10.34992)	59.56805*** (11.70061)	226.446*** (22.93138)
EDU	753.7953*** (213.8571)	-311.4996 (487.2638)	-10.97384 (929.3546)
FDI	0.2209522*** (0.0281011)	-0.1302552 (0.1693398)	0.0315144 (0.0184833)
UNBAN	-172.107** (67.72302)	461.2426*** (113.6712)	-840.7154*** (129.6489)
UNEMP	-5.310081 (132.7431)	-757.494*** (179.3126)	591.8223 (498.287)
CPI	-66.31148 (107.04)	-393.1604 (235.3832)	533.5621 (353.9363)
FINDEV	- 33544.55 (57498.55)	-163589.8* (73675.25)	66196.6** (22220.02)
CONSTANT	24635.66* (11987.92)	38037.46 (25785.18)	-27706.39 (39278.41)
time fixed effects	Yes	Yes	Yes
individual fixed effects	Yes	Yes	Yes
N	108	72	99
R ²	0.4821	0.4450	0.6671

5.5 Robustness Testing

Previous findings confirm significant effects between digital inclusive finance, innovation inputs, and industrial structure optimization, with technological innovation acting as a mediator. Robustness tests were conducted by replacing the proxy variable for digital inclusive finance with the depth of digital inclusive finance usage index for each province. Results indicate a positive correlation between the depth of digital inclusive finance usage index and industrial structure upgrading, confirming the robustness of the results.

Table 7 Robustness Testing results

	ISU	ISR
IFD	0.000896*** (0.0002372)	62.97199*** (6.962916)
EDU	0.0318733* (0.0138505)	-75.17306 (406.6404)
FDI	1.47e-06** (4.63e-07)	.0946933*** (.0136)
UNBAN	0.0191268*** (0.0025475)	-541.8735*** (74.7942)
UNEMP	-0.0000338 (0.0071173)	37.32598 (208.9581)
CPI	.0028393 (.0064665)	-42.01613 (189.8527)
FINDEV	1.000985 (.6461009)	91904.28*** (18969.06)
CONSTANT	8.735068***	33831.98 (200817.93)

	(0.7090746)	
time fixed effects	Yes	Yes
individual fixed effects	Yes	Yes
N	279	279
R^2	0.8137	0.6212

6. Conclusion

This paper utilizes panel data from 31 provinces in China to analyze the role of digital inclusive finance in industrial structure upgrading through a two-way fixed effects model. The study finds that digital inclusive finance significantly enhances both industrial structure rationalization and upgrading levels, confirmed through robustness tests. It also promotes industrial structure upgrading by increasing innovation inputs. Furthermore, the impact of digital inclusive finance varies by region, with the Central region showing the most significant effect, the Western region having great development potential, and the Eastern region requiring optimization of financial resource allocation. Innovation inputs play a mediating role in this process.

Based on the research findings, it is recommended to implement differentiated digital inclusive finance strategies, increase financial support and infrastructure investment in the Central and Western regions, optimize financial resource allocation in the Eastern region, encourage innovation inputs, enhance financial technology efficiency, and promote the upgrading and rationalization of industrial structure development.

The present invention relates to a cathode system of an electrostatic precipitator, in particular to a cathode frame of an electrostatic precipitator, particularly suitable for electrostatic precipitators with large electric field spans.

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