

The Impact of Digital Financial Inclusion on High-quality Economic Development in Dual-carbon Context

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Abstract: The emergence of digital technology has transformed the financial industry's growth paradigm, positioning digital inclusive finance as a key catalyst for economic expansion. Utilizing panel data from 31 Chinese provinces spanning 2011 to 2022, this study employs the entropy method to assess inter-provincial economic quality and investigates the impact of digital inclusive finance on regional economic advancement using bidirectional fixed effects and moderating effects models. Key findings indicate that digital inclusive finance significantly enhances China's economic quality, and two main sub-dimensional indices of digital financial inclusion - depth of use and degree of digitization - both contribute to high-quality economic development. Carbon emission intensity negatively moderates, while green innovation level positively moderates the impact. Notably, the positive influence of digital inclusive finance on economic quality is more pronounced in western and less developed areas.

Keywords: Digital Financial Inclusion, High Quality Economic Development, Entropy Method, Carbon Emission Intensity, Green Innovation

1. Introduction

As big data, cloud computing, artificial intelligence and other information technologies continue to advance swiftly, the fusion of digital technology with financial inclusion has become more profound. This has broadened and deepened the scope of digital financial inclusion in terms of its universality and benefits, thereby enhancing the ease and accessibility of financial services. Digital inclusive finance is becoming an effective way to ease financing constraints and broaden financing channels. At the same time, China's economic focus has transitioned from rapid expansion to a phase emphasizing quality. Consequently, in the contemporary era, a pivotal question for China's economic progression is how to optimize the financial sector's support for the real economy, leveraging the combined momentum of finance and technology.

Moreover, during economic growth, if the endless demand for nature and even the destruction of nature will inevitably be retaliated by nature. As a responsible major country, China is committed to achieving carbon peak by 2030 and carbon neutrality by 2060. The pressure to reduce carbon emissions brought about by the dual-carbon target will become a long-term constraint on the high-quality development of China's economy [1]. Therefore, how to achieve high-quality economic development under the conditions of achieving the goal of “dual-carbon” is a topic that needs to be solved urgently.

2. Theoretical Frameworks and Research Hypotheses

2.1. Digital Financial Inclusion and High-quality Economic Development

Under the traditional financial model, the popularity and availability of financial services are constrained by a number of factors. Firstly, the physical network type of traditional finance itself has a high cost of service leading to a low coverage. Especially in remote and rural areas, the accessibility of financial services has become a prominent problem. Second, some traditional financial institutions “prefer the rich to the poor”, resulting in 80% of the “long-tail population” being neglected, and these lower-income disadvantaged groups face serious financing constraints [2]. In addition, adverse selection and moral hazard, which are common in the financial market, have also plagued traditional inclusive financial services [3]. Nowadays, digital inclusive finance uses technologies like blockchain, big data, and AI to transform financial services, reducing costs and expanding access. AI improves credit scoring, enabling more people to access loans and financial products [4]. This digital transformation enhances the efficiency and effectiveness of financial support for economic growth.

From a macroeconomic perspective, digital financial inclusion is vital for optimizing economic structures and improving resource allocation efficiency. It enhances investment, consumption, and industrial structures through its broad reach and convenient services, boosting overall economic resource allocation efficiency [5]. Mobile payment apps like Alipay have increased payment efficiency, while lending platforms have eased budget constraints, promoting consumption upgrades. These consumption changes drive supply - side industrial adjustments. Upgraded industries meet the demand for high - quality products and services, creating a positive cycle. Digital inclusive finance also facilitates capital financing, activating idle capital and improving its efficiency. Enhanced capital liquidity allows for flexible allocation across industries, based on market judgement, greatly enhancing resource allocation efficiency. Therefore the hypothesis is proposed:

H1: Digital inclusive finance can significantly promote high-quality economic development.

2.2. The Moderating Role of Carbon Intensity

In areas characterized by high carbon emission intensity, the economic structure typically depends on industries that are heavily polluting and energy-intensive. Although these sectors may stimulate economic growth in the short term, the environmental pollution they generate poses a significant threat to sustainable economic development.

Firstly, the problems of air, water and soil pollution brought about by environmental pollution not only jeopardize human health and lower the quality of life of residents, but also lead to the decline of industries such as agriculture, tourism and fisheries. The decline of these industries will increase the unemployment rate of the society, thus diminishing the effectiveness of digital inclusive finance in easing overall employment pressure [6]. The consequences of declining employment, such as lower labor supply, loss of investment confidence and lower fiscal revenues, can inhibit economic development. Second, the pressure of environmental pollution faced by regions with high carbon emission intensity forces governments to allocate more social resources to environmental governance and responding to environmental crises. This bias in resource allocation is not conducive to accelerating the digitization process of traditional finance. Based on this, the following hypothesis is formulated:

H2: Carbon emission intensity has a negative moderating effect

2.3. The Moderating Role of Green Innovation Levels

Driven by advanced technology and with green concepts as the kernel, green technology innovation can help the green transformation of the real economy [7], optimize the regional green, low-carbon

and recycling industrial system and consumption system, effectively promote the greening of the region [8], and form a new type of growth point for the high-quality development of the economy.

Several factors contribute to the moderating effect of green innovation levels. Firstly, in regions with advanced green innovation, digital inclusive finance can offer greater financial backing for green projects via specialized products, fostering green tech R&D and application. This support helps manage environmental risks, optimize market conditions, and drive the real economy's continuous transformation, thereby boosting high-quality economic growth [9]. It also aids green innovation firms in scaling up and increasing market share, enhancing their competitiveness. Secondly, green innovation empowers regions to overcome challenges like weak governance, underdeveloped low-carbon scenarios, and limited data flow channels, which otherwise hinder high-quality economic development [10]. Lastly, green tech innovation can stimulate regional economic quality by reducing energy use and emissions, cleaning up the industrial structure, and guiding market demand [11]. Therefore the hypothesis is proposed:

H3: The level of green innovation has a positive moderating effect

3. Variable Selection, Model Setting and Data Sources

3.1. Variables

3.1.1.Explained variable: Economic High Quality Development (EHI)

In high-quality development, innovation is the primary driving force, coordination is its intrinsic characteristic, green development is the universal form, openness is its basic path, and sharing is its fundamental goal [12]. To fully capture the features of urban economic high-quality development, this study, drawing on the "five development concepts" and referencing the work of Sun Siwei and Zhang Changbing [13] and Li Guijun et al. [14], constructs an indicator system for high-quality development, as detailed in Table 1.

Table 1: Economic quality development system.

L1 indicators	Secondary indicators	Measurement method	Causality
Coordinated development	Urban and rural coordination	urbanization rate	+
	Demand structure	Total retail sales of consumer goods/GDP	+
	Industrial coordination	Tertiary output/GDP	+
	Government debt burden	Government debt balance/GDP	-
Green development	Elasticity coefficient of energy consumption	Energy consumption growth rate/GDP growth rate	-
	Unit production wastewater	Wastewater discharge/GDP	-
	Exhaust gas from unit	Sulfur dioxide emissions/GDP	-
Open development	External trade dependence	Total exports and imports/GDP	+
	Share of foreign investment	Total foreign investment/GDP	+
	marketability	Area marketization index	+
Shared development	Share of fiscal expenditure on people's livelihoods	Proportion of local budget expenditures allocated to education, healthcare, housing security, social security and employment	+
	Elasticity of population income growth	Growth rate of per capita disposable income/GDP growth rate	+
	Urban-rural consumption gap	Consumption expenditure per urban resident/consumption expenditure per rural resident	-
	Workers' compensation share	Compensation of workers/GDP	+

Table 1: (continued).

Innovative development	GDP growth rate	Regional GDP growth rate	+
	R&D investment intensity	R&D Expenditure/GDP of Industrial Enterprises Above Scale	+
	Investment efficiency	Investment rate/GDP growth rate	-
	Technology transaction activity	Technology transaction turnover/GDP	+

3.1.2. Core Explanatory Variable: Digital Financial Inclusion (Duf)

This study employs the Digital Inclusive Finance Index from Peking University's Digital Finance Research Centre to gauge cities' digital finance development. The index encompasses three aspects: digital finance coverage breadth, usage depth, and inclusive finance digitization degree [15]. Due to the large discrepancy between this index's scale and other variables' data size, the index is divided by 100 in this study.

3.1.3. Control Variables

To mitigate other economic variables' influence, this study includes four control variables: 1) Urbanization level (urban population ratio to total resident population) [16]. 2) Education level (logarithm of tertiary education enrollment per 100,000 people). 3) Population density (logarithm of year-end permanent resident count). 4) Government intervention level (proportion of local general budget expenditures to GDP) [17].

3.1.4. Mechanism Variables

Here, carbon intensity and green innovation are chosen as mechanism variables. Carbon intensity uses the logarithm of the ratio of total regional carbon emissions to GDP, characterizing the relative relationship between carbon emissions and economic output, and is more in line with the economic meaning of the “dual-carbon” goal [18]. The green innovation indicator uses the logarithm of the number of green patents granted plus one [19].

3.2. Model Setting

In order to verify H1, this paper firstly constructs the following regression model:

$$EHI_{it} = \alpha_0 + \alpha_1 Duf_{it} + \alpha_2 controls_{it} + province_i + year_t + \varepsilon_{it} \quad (1)$$

where i denotes province and t denotes year. Controls denotes control variables; province denotes province fixed effects, and year denotes time fixed effects; and ε is a randomized disturbance term.

To further examine, the subsequent moderating effect test model is formulated:

$$EHI_{it} = \beta_0 + \beta_1 Duf_{it} + \beta_2 mediator_{it} + \beta_3 mediator_{it} * Duf_{it} + \beta_4 controls_{it} + province_i + year_t + \varepsilon_{it} \quad (2)$$

where mediator is the moderating variables carbon intensity and green innovation level.

3.3. Data

In this study, we conducted an empirical analysis using data from 31 provinces in China spanning 2011 to 2022. The data sources include the Digital Financial Inclusion Index from Peking University and the Provincial Yearbooks from the China Statistical Yearbook for economic quality metrics and control variables. Carbon emission intensity data were sourced from the Center for Global Environmental Research (CGER), while green patent authorization data came from the State Intellectual Property Office (SIPO). Descriptive statistics for each variable are presented in Table 2.

Table 2: Descriptive Statistics.

VarName	Obs	Mean	SD	Min	Median	Max.
EHl	372	0.2352	0.100	0.08	0.20	0.58
Duf	372	2.4159	1.063	0.16	2.55	4.76
Urban	372	0.5917	0.130	0.23	0.58	0.90
education	372	7.8684	0.305	6.99	7.83	8.63
people	372	8.1314	0.842	5.73	8.26	9.45
GI	372	0.2905	0.205	0.11	0.23	1.35

4. Empirical Findings

4.1. Benchmark Regression

Table 3 shows the results of the regression of the full-sample fixed effects model using Stata17, where column (1) shows the regression results of the baseline regression, and columns (2)-(4) show the regression results of changing the core explanatory variables to Coverage span, Service depth, and Degree of digitization. According to Table 3, digital financial inclusion and its subordinate depth of use and degree of digitization are all significantly positively correlated with economic high-quality development at the 1% level, indicating that the development of digital financial inclusion can significantly promote economic high-quality development, which verifies the H1.

Table 3: Benchmark Regression Results for Fixed Effects Models.

VARIABLES	EHl	EHl	EHl	EHl
Duf	0.04007*** (3.93)			
Coverage span		-0.00012 (-0.83)		
Service depth			0.00024*** (4.73)	
Degree of digitization				0.00015*** (3.68)
Urban	0.30016*** (5.28)	0.24806*** (4.26)	0.35482*** (5.96)	0.30987*** (5.32)
education	0.02065* (1.82)	0.01919* (1.66)	0.02722** (2.40)	0.01401 (1.23)
people	-0.15287*** (-5.39)	-0.09399*** (-3.19)	-0.15263*** (-5.59)	-0.11519*** (-4.45)
GI	0.12415*** (4.52)	0.14357*** (5.17)	0.11869*** (4.36)	0.13507*** (4.96)
Constant	1.00531*** (4.30)	0.68759*** (2.78)	0.96043*** (4.23)	0.79245*** (3.50)
Observations	372	372	372	372
R-squared	0.985	0.984	0.985	0.985
Year	YES	YES	YES	YES
province	YES	YES	YES	YES

Note: t-values in parentheses, *, **, *** indicate passing the significance test at the 10%, 5%, and 1% levels (the same below).

4.2. Robustness Tests

To ensure the robustness of our findings, we conducted robustness tests in three areas: reducing the observation period, excluding specific regions, and adding a control variable. The results are presented in Table 4.

"Digital financial inclusion" was officially introduced at the 2016 G20 Hangzhou Summit, highlighting its growing global significance. Consequently, this study reduced the observation period to 2017-2022 (column 1). Given the superior economic, financial, and fiscal status of Jiangsu, Zhejiang, and Shanghai, which have higher levels of digital financial inclusion, these regions were excluded to reduce sample bias (column 2). To address potential omitted variable bias, the employment rate (EMR) [20] was added as a control variable to the baseline regression (column 3).

Table 4: Robustness verification.

VARIABLES	EH1	EH1	EH1
Duf	0.06957*** (3.84)	0.04537*** (3.89)	0.03972*** (3.86)
Urban	0.06189 (0.37)	0.24831*** (3.89)	0.29779*** (5.18)
education	0.02338 (1.27)	0.02785** (2.34)	0.02043* (1.80)
people	-0.09087 (-1.10)	-0.16315*** (-5.45)	-0.15133*** (-5.23)
GI	0.06900* (1.75)	0.10917*** (3.81)	0.12596*** (4.47)
EMR			-0.00711 (-0.29)
Constant	0.51511 (0.76)	1.04040*** (4.28)	1.00019*** (4.26)
Observations	186	336	372
R-squared	0.990	0.982	0.985
Year	YES	YES	YES
province	YES	YES	YES

4.3. Endogeneity Test

To address the potential reverse causality issue between economic high-quality development and digital financial inclusion, this study employs the comprehensive Internet penetration index as an instrumental variable. This approach is inspired by the work of Huang Qunhui et al. [21], who standardized indicators across five dimensions: the number of Internet broadband access ports, subscribers, web pages, domain names, and mobile phone penetration rates in each province.

This instrumental variable meets the criteria of relevance and exogeneity. Firstly, digital financial inclusion is inherently linked to Internet technology development, establishing its relevance. Secondly, the comprehensive Internet penetration index is independent of other explanatory variables, ensuring exogeneity. The results are as follows:

Table 5: 2SLS regression results.

VARIABLES	Duf	EHI
Duf		0.026*** (3.61)
Internet_score	0.374*** (10.38)	
Controls	YES	YES
Constant	-6.084*** (-3.45)	-0.491*** (-3.11)
Observations	372	372
R-squared	0.513	0.677

5. Further Analysis

5.1. Moderating Effects Test

5.1.1. The Moderating Effect of Carbon Intensity

In order to test the regulating effect of carbon emission intensity, we used the second model, and the regression results were shown in Table 6. The significantly negative coefficient of the interaction term (digital*CO2) indicates that carbon emission intensity negatively moderates the relationship between digital inclusive finance and economic high - quality development, and H2 is verified.

Table 6: Moderating Effect - Carbon Emission Intensity.

VARIABLES	EHI	EHI
Duf	0.04007*** (3.93)	0.07027*** (5.47)
CO2		0.07701*** (4.09)
Digital*CO2		-0.00420*** (-2.67)
Controls	YES	YES
Constant	1.00531*** (4.30)	-0.24199 (-0.59)
Observations	372	372
R-squared	0.985	0.985
Year	YES	YES
province	YES	YES

5.1.2. The Moderating Effect of Green Innovation Levels

By the same method, the significantly positive coefficient of the interaction term (digital*CI) indicates that the green innovation level positively moderates the relationship between digital inclusive finance and economic development, verifying H3.

Table 7: Moderating Effect - Green Innovation Levels.

VARIABLES	EH1	EH1
Duf	0.04007*** (3.93)	-0.00007 (-0.01)
CI		-0.00542* (-1.79)
Digital*CI		0.00227*** (3.72)
Controls	YES	YES
Constant	1.00531*** (4.30)	0.97447*** (4.14)
Observations	372	372
R-squared	0.985	0.986
Year	YES	YES
province	YES	YES

5.2. Heterogeneity analysis

5.2.1. Heterogeneity analysis across geographic locations

We further explore whether digital financial inclusion has regional heterogeneity for high-quality economic development. The results, presented in Table 8, reveal that the regression coefficient for the Western region is 0.08532, significant at the 1% level. This coefficient is higher than those for the Eastern and Central regions, suggesting that digital inclusive finance is particularly beneficial for enhancing economic quality in China's less developed Western areas.

Table 8: Heterogeneity Analysis - Geographic Location.

VARIABLES	Eastern part EH1	Central part EH1	Western part EH1
Duf	-0.02787* (-1.97)	-0.01125 (-0.45)	0.08532*** (2.87)
Controls	YES	YES	YES
Constant	1.13848*** (2.93)	-2.31735** (-2.32)	1.32202** (2.45)
Observations	132	96	144
R-squared	0.994	0.932	0.857
Year	YES	YES	YES
province	YES	YES	YES

5.2.2. Heterogeneity at Different Levels of Development

The creation of digital inclusive finance is inseparable from economic development and digital development, and the difference in the degree of economy and digitalization will inevitably lead to the imbalance in the development of digital inclusive finance among regions. The first 50% of the total GDP during 2011-2022 was divided into developed provinces and the last 50% into less developed provinces, and then the grouped regression analysis was carried out, as shown in Table 9. The absolute value of the regression coefficient for the underdeveloped provinces is 0.03702, which

is greater than that for the developed provinces, suggesting that the role of digital inclusive finance in promoting high quality economic growth is stronger among the less developed provinces.

Table 9: Heterogeneity Analysis - Level of Economic Development.

VARIABLES	Developed provinces EHI	Less developed province EHI
Duf	-0.00125 (-0.09)	0.03702** (2.02)
Controls	YES	YES
Constant	1.73016*** (4.18)	0.15063 (0.57)
Observations	180	192
R-squared	0.993	0.969
Year	YES	YES
province	YES	YES

The possible explanation is that for the western and less developed regions, the development of digital inclusive finance eases the credit constraints faced by local people to a certain extent, and not only helps backward regions to obtain financial support for upgrading their human capital and other inputs through the provision of education-specific savings and loans and other services[10], but also provides sufficient financial support for entrepreneurial talents through credit services, thus enhancing the entrepreneurial and employment capacity of local residents. The entrepreneurial and employment capacity of local residents can be improved, which can further promote the regional economy, while the credit constraints faced by residents in other regions are weaker, and the effect of digital-driven financial inclusivity will naturally be lower.

6. Conclusions and Suggestions

The main conclusions are as follows:

Digital inclusive finance significantly boosts economic growth of superior quality. Usage depth and digitization significantly aid development, while coverage breadth has a non - significant effect. These conclusions hold after 2SLS regression and robustness tests. Tests show carbon emission intensity negatively and green innovation level positively moderate digital inclusive finance's impact on economic development. Heterogeneity analysis reveals that digital financial inclusion's economic benefits are higher in western and less - developed regions than in central, eastern, and developed regions.

Based on the conclusions, the following suggestions are proposed:

Hasten the construction of digital inclusive finance- related infrastructure. Enhance digital finance's functions in payment, credit, and insurance to boost its inclusivity and deepen financial supply - side reforms. Focus on improving the depth and digitization of digital finance to integrate it with the real economy and meet high - quality economic development's financial needs.

With "dual - carbon" goals in mind, prioritize green development. The government should increase green innovation investment, encouraging enterprises to innovate in green energy - saving technologies. Promote a low - carbon economy concept, encouraging consumers to buy green products. This dual - pronged approach on both demand and supply sides can optimize resource allocation and promote the large - scale application of green and low - carbon technologies.

Given regional differences in digital inclusive finance's impact, local governments should craft policies based on local economic and digital finance advancement levels. In western and underdeveloped regions, pay special attention to leveraging digital inclusive finance for regional economic growth, making it a driver of high - quality economic development.

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