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Digital Inclusive Finance, Green Innovation and High-Quality Economic Development -An Empirical Study Based on the Northeast Region

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Abstract. This essay utilizes panel data from Liaoning province, Jilin and Heilongjiang province in Northeast China during 2011-2022 to construct a mediation effect model. This paper empirically explores how digital inclusive finance affects high-quality economic development and the transmission mechanism of green innovation. The results demonstrate that digital inclusive finance significantly promotes high-quality economic development in Northeast China, and green innovation acts as a partial mediator, accounting for approximately 39.5% of the total effect. The positive impact is stronger in Liaoning and Jilin, and is driven mainly by the usage depth and digitalization of digital inclusive finance rather than pure coverage expansion. Based on the empirical outcomes, this paper puts forward policy suggestions, including improving the digital inclusive financial system, encouraging green innovation, and advancing regional coordinated development, so as to provide empirical support for the high-quality development of old industrial bases in Northeast China.

Keywords: Digital Inclusive Finance, Green Innovation, High-Quality Economic Development, Northeast Region, Mediation Effect

1. Introduction

As a traditional industrial base in China, Northeast China faces problems such as irrational industrial structure, insufficient growth momentum, and increasing ecological pressure. With the digital economy and national "dual carbon" strategy, digital inclusive finance breaks traditional financial constraints through technology and injects new vitality into the regional economy [1]. Green innovation is a key way to reduce resource and environmental pressure and achieve sustainable growth. Exploring the relationship among digital inclusive finance, green innovation and high-quality development in Northeast China not only enriches relevant research but also provides practical policy support for regional revitalization.

Existing research focuses on three fields: digital inclusive finance and economic development, green innovation and high-quality development, and digital finance and green innovation. Most studies prove that digital inclusive finance promotes growth by easing financing constraints and optimizing resource allocation, but research on Northeast China is insufficient [2]. It is widely

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accepted that green innovation improves development quality by enhancing efficiency and reducing pollution [3]. Digital finance supports green innovation, but studies on the regional heterogeneity of the mechanism need to be improved [4]. Few studies focus on Northeast China and explain the mediating effect of green innovation [5]. This paper fills this gap.

This paper first sorts out theories and puts forward three hypotheses. Then it uses 2011–2022 panel data of three northeastern provinces, selects variables and builds a mediating effect model. Hypotheses are tested through regression, mediating effect test, heterogeneity analysis and robustness test. Finally, policy suggestions are put forward.

This paper takes Northeast China as the research object and makes up for the lack of research on digital inclusive finance and the high-quality development of old industrial bases. It reveals the mediating transmission mechanism of green innovation and enriches the research on their relationship.

2. Theoretical analysis and research hypotheses

2.1. Direct impact of digital inclusive finance on high-quality economic development in Northeast China

Digital inclusive finance lowers the financing threshold for small and medium-sized enterprises by virtue of digital technologies. It helps reduce financing costs, improves resource allocation efficiency, and guides capital to flow into high-efficiency and low-energy consumption industries. In addition, digital inclusive finance enhances financial accessibility, supports low-income groups to participate in economic activities, promotes consumption upgrading and employment expansion, and directly boosts high-quality economic development.

Hypothesis 1: Digital inclusive finance exerts a significant positive driving effect on high-quality economic development in Northeast China.

2.2. How digital inclusive finance influences green innovation in Northeast China

Green innovation often involves long research cycles, substantial funding input, and high risks, leaving it underfunded by the traditional financial system [6, 7]. Digital inclusive finance lowers approval costs via digital technology, offers tailored financial support to green firms and projects in Northeast China, and eases financing pressures. In addition, its information advantages reduce information asymmetry in green R&D, channel social capital toward low-carbon research, stimulate firms to raise green tech investment, and lift green innovation output. Thus, this study proposes:

Hypothesis 2: Digital inclusive finance can significantly improve the level of green innovation in Northeast China.

2.3. Mediating effect of green innovation

Digital inclusive finance facilitates high-quality economic development by optimizing resource allocation directly and acting via green innovation indirectly [8]. It supports enterprises' green technology R&D and application, curbs energy consumption and emissions, and accelerates industrial green and low-carbon transition. Enhanced green innovation optimizes Northeast China's economic growth, raises total factor productivity and achieves high-quality development. Therefore, this paper proposes:

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Hypothesis 3: Green innovation plays a mediating role in the influence of digital inclusive finance on high-quality economic development in Northeast China.

3. Empirical design

3.1. Variable selection

(1) Explained Variable: High-quality Economic Development (GTFP)

We use green total factor productivity measured by SBM-DEA model and Malmquist-Luenberger index. Inputs include capital, labor and energy; outputs include expected GDP and undesired emissions.

Core Explanatory Variable: Digital Inclusive Finance (DIF)

We adopt the provincial digital inclusive finance index released by the Institute of Digital Finance, Peking University, which covers coverage breadth, usage depth and digitization level.

Mediating Variable: Green Innovation (GI)

Measured by the logarithm of green patent applications, which can directly reflect regional green technology output with good availability and representation.

Control Variables

To eliminate the interference of other factors on high-quality economic development, the following control variables are selected:

Per capita GDP(Pgdp);

b. Industrial structure(Is);

c. Government intervention (Gov);

d. Urbanization level (Urban);

e. Human capital (Hc);

f. Opening-up level (Open).

3.2. Model specification

3.2.1. Benchmark model

To verify Hypothesis 1, this paper constructs a benchmark regression model to examine the impact of digital inclusive finance on high-quality economic development.

$$GTFP_{it} = \alpha_0 + \alpha_1 DIF_{it} + \sum_{j=2}^{n} \alpha_j Controls_{jit} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where 'i' denotes the provincial sample (Liaoning, Jilin and Heilongjiang), and 't' represents the study period from 2011 to 2022.

$GTFP_{it}$ serves as the explained variable to measure high-quality economic development ; DIF_{it}, as the core explanatory variable of digital inclusive finance; $Controls_{jit}$ as the control variable group is included in the model.$\alpha 0$ stands for the intercept term, while $\alpha 1$, α_j are regression coefficients. In addition, μ_i is provincial fixed effects, λ_t as time fixed effects, ε_{it} is random disturbance term.

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3.2.2. Mediating effect model

To test Hypothesis 2 and Hypothesis 3, this paper adopts the three-step mediation effect test method and establishes the models as follows.

In the first step, this paper examines the influence of digital inclusive finance on green innovation, and the specific model is set out below.

$$GI_{it} = \beta_0 + \beta_1 DIF_{it} + \sum_{j=2}^{n} \beta_j Controls_{jit} + \mu_i \gamma_j Controls_{jit} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Second step: This paper introduces both digital inclusive finance and green innovation simultaneously to examine their combined impact on high-quality economic development. The model is specified as follows.

$$GTF_{it} = \gamma_0 + \gamma_1 DIF_{it} + \gamma_2 GI_{it} + \sum_{j=3}^{n} \gamma_j Controls_{jit} + \mu_i + \lambda_t + \varepsilon_{it} \gamma_j Controls_{jit} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where the mediating variable GI_{it} denotes green innovation; β_1, γ_1, γ_2 represents the core regression coefficient. If β_1, γ_2 is statistically significant and the magnitude and significance of γ_1 differ from those in the benchmark regression model, it indicates the existence of a mediating effect.

3.3. Sample selection and data sources

The sample covers Liaoning, Jilin and Heilongjiang from 2011 to 2022. Data are collected from China Statistical Yearbook, provincial statistical yearbooks, CSMAR database and the Peking University Digital Finance Research Center [9].

4. Empirical analysis

4.1. Descriptive statistics results

Table 1. Descriptive statistics of variables

Variable Name	Variable Meaning	Mean	Std.Dev.	Min	Max
GTFP	Green Total Factor Productivity	0.852	0.124	0.581	1.103
DIF	Digital Inclusive Finance Index	2.864	0.527	1.723	3.986
GI	Green Innovation (logarithmic value)	8.251	0.683	6.912	9.524
Pgdp	Per Capita GDP (logarithmic value)	10.583	0.426	9.721	11.352
Is	Share of Tertiary Industry (%)	48.26	5.31	39.82	56.74
Gov	Fiscal Expenditure Ratio (%)	22.58	4.12	15.63	31.27
Urban	Urbanization Rate (%)	65.32	8.75	52.18	80.26
Hc	Share of College Students in Total Population (%)	2.15	0.63	1.08	3.52
Open	Ratio of Actual Utilized Foreign Investment (%)	1.82	0.95	0.51	4.28

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From Table1, the average value of GTFP is 0.852, indicating a moderate level of high-quality development. The average DIF index is 2.864, showing steady growth. The average GI in logarithm is 8.251, with obvious provincial differences. All variables are stable without extreme outliers.

4.2. Benchmark regression analysis

The fixed-effect regression shows that the coefficient of DIF is 0.162 and significant at 1% level. Digital inclusive finance significantly promotes high-quality economic development, which supports Hypothesis 1.The results are shown in Table 2:

Table 2. Benchmark regression results

variable	Pooled OLS	Fixed Effects (FE)
DIF	0.185***(3.24)	0.162***(2.87)
Pgdp	0.321***(5.18)	0.295***(4.62)
Is	0.082**(2.11)	0.078**(2.03)
Gov	-0.054*(-1.76)	-0.048*(-1.62)
Urban	0.123**(2.35)	0.118**(2.29)
Hc	0.092**(2.24)	0.085**(2.17)
Open	0.041*(1.72)	0.038*(1.65)
Constant	1.254***(6.82)	1.321***(7.15)
R2	0.682	0.715
N	36	36

Notes: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively, with t-statistics in parentheses.

4.3. Mediation effect test

The three-step mediation effect test is conducted in sequence, and the results are presented as follows (see Table 3):

Step 1: DIF has a positive coefficient of 0.286 on GI, proving that digital inclusive finance promotes green innovation (Hypothesis 2 supported).

Table 3. Regression results of DIF on GI

Variable	Coefficient	t-value
DIF	0.286***	4.31
Control Variables	Controlled	-
Constant	6.521***	8.24
R2	0.735	-
N	36	-

Step 2: After adding GI, the coefficient of DIF decreases to 0.098, while GI is significantly positive. Green innovation plays a partial mediating role (see Table 4), with a mediating effect ratio of about 39.5% (Hypothesis 3 supported).

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Table 4. Regression results of DIF and GI on GTFP

Variable	Coefficient	t-value
DIF	0.098**	2.15
GI	0.224***	3.87
Control Variables	Controlled	-
Constant	1.025***	6.13
R2	0.782	-
N	36	-

4.4. Heterogeneity analysis

Regional heterogeneity shows that the promotion effect is more significant in Liaoning and Jilin than in Heilongjiang. Dimensional heterogeneity indicates that usage depth and digitalization level contribute more to high-quality development than coverage breadth.

5. Policy recommendations

5.1. Improving the digital inclusive finance system

Promote the coordinated construction of digital financial infrastructure in Northeast China. Financial institutions are encouraged to develop customized inclusive financial products for green industries and small enterprises to improve service efficiency and risk control capabilities.

5.2. Enhance green innovation incentives

Strengthen policy support such as fiscal subsidies and tax preferences for green R&D and achievement transformation. Use digital inclusive finance to ease financing constraints and build a stable connection between digital finance and green industries.

5.3. Optimizing the pattern of regional coordinated development

Strengthen policy coordination among Liaoning, Jilin and Heilongjiang. Accelerate the improvement of digital finance and green innovation in underdeveloped regions to narrow the internal development gap in Northeast China [10].

5.4. Focusing on the deep empowerment of digital finance

Focus on improving the usage depth and digitalization level of digital inclusive finance. Use digital tools to accelerate industrial green upgrading and help old industrial bases achieve low-carbon and high-quality development.

6. Conclusion

This study finds that digital inclusive finance significantly promotes high-quality economic development in Northeast China, and green innovation plays a partial mediating role. The driving effect is more obvious in Liaoning and Jilin, and mainly depends on usage depth and digitalization.

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Therefore, promoting the development of digital inclusive finance and green innovation is of great significance to the transformation and revitalization of Northeast China.

This paper has some limitations. It does not analyze long-term dynamic effects and micro-firm behaviors. Future research can expand the sample scope and use more detailed data to further explore the internal mechanism.

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