Frontiers in Economics and Management Volume 7 Issue 3, 2026
ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

Research on the Impact of Digital Finance on the Green Total Factor Productivity of the Yangtze River Economic Belt

Shuqi Zhang

School of Economics and Management, Southwest Petroleum University, Chengdu, China

Abstract

Green development in China's Yangtze River Economic Belt is increasingly driven by the digital economy. Based on a panel dataset of 108 cities in the region from 2011 to 2023, a significant positive impact of digital finance on green total factor productivity is identified in this study.This positive effect operates primarily through two channels: deepening the usage of financial services and advancing digital technologies, rather than merely expanding coverage. Digital finance promotes GTFP by supporting green technology innovation. The effect is particularly strong in non-resource-based cities. These findings highlight the importance of developing digital finance and fostering technological innovation to support the region's green transition.

Keywords

Digital Finance; Green Total Factor Productivity; Green Technology Innovation; Yangtze River Economic Belt.

1. Introduction

Spanning China's eastern, central, and western regions, the Yangtze River Economic Belt is a key strategic zone that brings together 11 provincial-level administrative units, such as Shanghai, Jiangsu, Zhejiang, and Anhui. By capitalizing on the Yangtze River's golden waterway, it creates a robust connection between the developed coastal east and the vast central and western interiors.With about one-fifth of the country's land area, this region contributes 47.3% of the national economic output and is one of the regions with the strongest comprehensive strength and the greatest strategic support role in China. Since the founding of the People's Republic of China, the Yangtze River Economic Belt has always been the core area for large-scale industrial construction and agricultural development in China. Today, it is a gathering place for major cities, industries and growth poles, occupying an irreplaceable position in the country's economic and social development. However, the long-term process of industrialization and urbanization has also brought severe ecological and environmental challenges. In the face of these challenges, the sustainable development of the Yangtze River Economic Belt urgently needs to shift to a green and low-carbon path [1]. Against this backdrop, the degree of coordination between economic growth and the resource environment is often measured by green total factor productivity, which is now widely adopted as a key benchmark for evaluating the high-quality development of the Yangtze River Economic Belt[2]. Enhancing green total factor productivity not only concerns the effective improvement of economic quality but is also an inevitable requirement for achieving harmonious coexistence between humans and nature and for the coordinated development of protection and exploitation.

By channeling resources and managing risks, the financial system is indispensable for supporting productive economic activities and dampening cyclical fluctuations[3]. The ascent of digital finance is injecting fresh vitality into the green transformation of the Yangtze River Economic Belt. Fueled by innovations in mobile internet, AI, big data, and blockchain, digital financial tools-notably Alipay and WeChat Pay-have seen widespread adoption, propelling a

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

paradigm shift from traditional finance toward a digital model.Digital finance not only enhances the efficiency of financial services by reducing information asymmetry and optimizing resource allocation [4], but also breaks down the barriers of traditional finance with its inclusive nature [5]. In August 2024, the strategic role of digital finance in the green transformation of the Yangtze River Economic Belt has been officially highlighted by the "Guiding Opinions on Further Enhancing Financial Support for the Green, Low-Carbon, and High-Quality Development of the Yangtze River Economic Belt." Jointly issued by the People's Bank of China and seven other departments, this policy document mandates the coordinated advancement of green finance, technology finance, and digital finance.Through empowering green technological innovation in industries, optimizing risk management, and promoting regional coordination, digital finance is expected to become an important engine for enhancing green total factor productivity [6].

A significant gap in the current literature is the predominant focus on the macroeconomic implications of digital inclusive finance, with insufficient attention paid to its spatial and temporal characteristics and driving forces from a regional standpoint. Conducting a thorough analysis of the mechanisms and outcomes of digital finance's impact on green total factor productivity in the Yangtze River Economic Belt is therefore essential. Such research not only fills this regional void but also supplies empirical support for supply-side structural reforms in finance, facilitating the Belt's high-quality advancement under the principles of ecological priority and green development. This study aims to uncover the intrinsic relationship between digital finance and green productivity, offering theoretical frameworks and practical strategies for policymakers to enhance financial resource distribution and promote coordinated regional green transformation.

2. Theoretical Foundation and Research Hypotheses

2.1. The Direct Impact of Digital Finance on the Yangtze River Economic Belt

Digital finance, through technological empowerment, plays a significant role in enhancing the green total factor productivity of the Yangtze River Economic Belt [7].First, it alleviates financing constraints and stimulates green innovation vitality. Digital finance uses big data to build credit profiles, helping green small and medium-sized enterprises lacking collateral assets to obtain financing support, and connects idle social funds with green micro-projects through platforms, lowering financing thresholds [8]. Second, it enhances the efficiency of resource allocation while simultaneously curbing the channeling of resources toward highly polluting sectors.Relying on data technology, digital finance can accurately identify environmentally friendly projects and provide differentiated financial products, guiding capital towards green industries and promoting the green transformation of the regional industrial structure. Third, it shapes public environmental awareness and guides green consumption behavior. Through digital platforms such as Ant Forest and green point systems, digital finance enhances public participation in environmental protection, promotes green consumption, and drives the development of the green market from the demand side [9]. Fan Xin and Yin Qiushu (2021) [10], using 29 provinces in China as samples, empirically found that contribution of digital finance to improving green total factor productivity is significantly larger in regions with low urbanization rates and abundant physical capital.Tian Jie et al. (2021) [11] decomposed digital finance into three sub-dimensions and conducted regressions separately to understand which aspect of digital finance has the greatest and most core impact on green total factor productivity.

The preceding discussion motivates the formulation of Hypothesis H1: There exists a positive relationship between digital finance development and green total factor productivity in the Yangtze River Economic Belt.

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

2.2. Digital Finance Enhances Green Total Factor Productivity of the Yangtze River Economic Belt by Empowering Green Technological Innovation

Digital finance effectively alleviates the financing constraints of green technological innovation. By leveraging big data and intelligent algorithms, it can precisely assess and dynamically match the innovation needs and risks of enterprises, achieving efficient financial resource allocation [12]. Likewise,through the creation of green loans and green bonds and other targeted tools, digital finance guides funds to prioritize support for clean technology research and development and restricts the expansion of high-pollution industries from the source. Moreover, its inclusive nature breaks down geographical barriers, enabling green technology enterprises in the upper and middle reaches to conveniently access remote financial services. On the other hand, green technological innovation drives the improvement of green total factor productivity from multiple dimensions. It reduces consumption and pollution from the source by transforming production processes and optimizing resource utilization, directly enhancing production efficiency and resource recycling levels. At the industrial level, the emerging industries driven by technological innovation promote the upgrading of the industrial structure towards green and high-end, and through competitive effects, force traditional industries to transform [13]. At the consumption end, the popularization of green products guides the public to form low-carbon preferences, pulling the development of the green industry from the demand side and forming a virtuous cycle of supply and demand. According to the research by Hui Xianbo (2021) [14] on cities at the prefectural level across China, technological innovation acts as a mediating variable in the relationship between digital finance and urban green total factor productivity, enabling an indirect promotional effect; Xu Weicheng (2023) [15], using data from key industrial pollution source investigations, also found that digital finance has the capacity to spur improvements in enterprise-level green total factor productivity via technological channels.

The preceding analysis motivates Hypothesis H2: There exists an indirect effect wherein digital finance promotes green total factor productivity via green technological progress.

3. Research Design

3.1. Indicator Selection and Data Sources

3.1.1. Variable Selection

Dependent Variable

Green total factor productivity (GTFP) serves as the dependent variable in this paper. To derive this variable, the SBM directional distance function and GML model were applied, with input-output indicators processed via Matlab software to calculate GTFP for 108 cities in the Yangtze River Economic Belt from 2011 to 2023. The input side incorporates labor, capital, and energy factors; on the output side, GDP is treated as the desirable output, while industrial wastewater, sulfur dioxide, and smoke and dust are included as undesirable outputs.The specific calculation process draws on the approach of Yu Yi shan and Wei Ping (2025) [16]. The GTFP for 2011 is obtained by multiplying the benchmark value from 2010 (set to 1) by the corresponding GML index capturing productivity changes from 2010 to 2011.This process is repeated year by year to calculate the green total factor productivity for the remaining years [17].

Core explanatory variable

The core explanatory variable in this paper is digital finance (Index). Considering authority and data availability, drawing on the research of Huang Yiping (2016) and Guo Feng (2020) [18], the Digital Inclusive Finance Index compiled by the Center for Mathematical Finance at Peking University is selected as the measurement indicator, which can better reflect the development status of digital finance in different cities. To further understand the impact path of digital

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

finance on green total factor productivity (GTFP), the three sub-dimensions of the Digital Inclusive Finance Index, namely coverage breadth (Cov), usage depth (Dep), and digitalization degree (Dig), are also taken as core explanatory variables for separate regression analysis. Due to the large numerical range of the original Digital Inclusive Finance Index, with most data reaching hundreds, a substantial gap in magnitude is observed relative to green total factor productivity.Directly including it in the regression model would result in very small regression coefficients, affecting the readability and interpretability of the results. As per the methodology of Zhang Lin et al. (2023), the Digital Inclusive Finance Index and its constituent sub-indices were rescaled through division by 100. The resulting transformation amplifies the regression coefficients by two orders of magnitude, thereby enhancing the interpretability of the core explanatory variable's marginal effect on the dependent variable.

Control variables

A set of six control variables is selected to isolate the net effect of digital finance. These include: economic development level (ED), quantified as the log-transformed per capita GDP; government intervention (Gov), gauged by the share of local fiscal expenditure in GDP; human capital (Hui), measured by the enrollment ratio of college students to total population; financial development (FD), expressed as the ratio of year-end institutional deposits and loans to GDP; urbanization (Urb), represented by the non-agricultural population share; and openness (Open), captured by the trade-to-GDP ratio.

Mediating variable

This study identifies green technological innovation (Tech) as the mediating mechanism. It is operationalized using the ratio of green invention patent filings to overall patent applications at the city level across the Yangtze River Economic Belt.

3.1.2. Data Sources and Descriptive Statistics

Economic panel data for 108 cities in the Yangtze River Economic Belt from 2011 to 2023 were compiled for this analysis.Due to the severe data shortage and difficulty in obtaining data for Bijie City and Tongren City, these two cities were not included in the research sample. Digital financial indicators were obtained from the official website of the Digital Finance Research Center of Peking University. Other original data were all from the "China City Statistical Yearbook", "China Environmental Statistical Yearbook", "China Energy Statistical Yearbook", the National Economic and Social Development Statistical Annual Report, the EPS database, and local statistical bulletins. Missing values were interpolated using Stata software.

Table 1. Descriptive Statistics

	Var	N	Ave	Sta	Min	Max
variable being explained	GTFP	1404	1.115	0.330	0.447	3.974
explaining variable	Index	1404	2.056	0.803	0.213	3.732
	Cov	1404	1.995	0.875	0.0510	4.083
	Dep	1404	2.019	0.717	0.133	3.543
	Dig	1404	2.327	0.866	0.0790	4.379
mediating variable	Tech	1,404	0.0893	0.0392	0.0143	0.589
	Is	1,404	7.607	1.112	4.195	11.22
control variable	ED	1404	10.80	0.702	8.991	12.66
	Gov	1404	0.193	0.0806	0.0760	0.675
	Hui	1404	0.0202	0.0247	4.75e-05	0.144
	FD	1404	2.543	1.009	0.764	7.174
	Urb	1404	0.339	0.182	0.0750	0.9970
	Open	1404	0.172	0.0303	0.0146	0.268

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

3.2. Regression Model

3.2.1. Baseline Model

This paper constructs the following dual fixed-effect model for the baseline regression:

$$GTFP_{it} = \alpha + \beta Index_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

i represents cities, andt represents years. $GTFP_{it}$is the dependent variable, representing the green total factor productivity of city i in year t ; $Index_{it}$ is the explanatory variable, representing the digital financial development level of city i in year t; X_{it} represents multiple control variables that affect green total factor productivity.α represents the intercept term, β is the impact coefficient of digital finance on green total factor productivity. If this coefficient is positive, it indicates that digital finance will have an enhancing effect on green total factor productivity; conversely, it will have a restraining effect. The equation incorporates city fixed effects μ_i and year fixed effects λ_t to eliminate confounding factors, making the model more focused on the true impact of the core variables, thereby improving the accuracy and reliability of model estimation. ϵ_{it}represents the random disturbance term, which can handle errors and simplify the model.

To deeply investigate how digital finance affects the green total factor productivity in the Yangtze River Economic Belt, the three sub-dimensions of the digital inclusive finance index, namely coverage breadth (Cov), usage depth (Dep), and digitalization degree (Dig), are included in the model as core explanatory variables. The new regression model is:

$$GTFP_{it} = \alpha + \beta_1 Cov_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$
$$GTFP_{it} = \alpha + \beta_2 Dep_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$
$$GTFP_{it} = \alpha + \beta_3 Dig_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

3.2.2. Mediating Effect Model

To uncover the transmission mechanism between digital finance and green total factor productivity, green technological innovation is employed as a mediator. In line with Jiang Tie (2022), the model is established as follows:

$$Tech_{it} = \alpha + \beta_1 Index_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

4. Empirical Results Analysis

4.1. Baseline Regression

The Hausman test was conducted to determine the appropriate estimation approach, and its results support the use of a fixed effects model. Accordingly, this model is applied to assess the impact of digital finance on green total factor productivity in the Yangtze River Economic Belt, with the corresponding regression outcomes reported in the following table.

The regression results are presented in the table. As shown in Column (1), which reports estimates without control variables, the coefficient for digital finance on green total factor productivity in the Yangtze River Economic Belt is 0.3194, statistically significant at the 1% level. After incorporating control variables in Column (2), the coefficient increases to 0.3761, remaining significant at the 1% level. These findings confirm that digital finance positively contributes to the advancement of green total factor productivity in the region, thereby supporting Hypothesis H1.

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

Table 2. Baseline Regression

	(1)	(2)	(3)	(4)	(5)
	GTFP	GTFP	GTFP	GTFP	GTFP
Index	0.3194***	0.3761***	0.0591		
	(2.75)	(3.23)	(0.56)		
				0.2583***	
				(2.89)	
					0.1595***
					(3.86)
ED		0.7287***	0.7306***	0.7236***	0.7355***
		(5.26)	(5.26)	(5.22)	(5.32)
Gov		1.0469***	1.0885***	1.0468***	1.0437***
		(3.31)	(3.43)	(3.31)	(3.31)
Hui		4.3441***	4.3533***	4.3419***	4.2081***
		(2.88)	(2.87)	(2.87)	(2.79)
FD		-0.0780**	-0.0614*	-0.0552*	-0.0756**
		(-2.37)	(-1.85)	(-1.71)	(-2.33)
Urb		-0.4347***	-0.3991***	-0.3721***	-0.3889***
		(-5.03)	(-4.45)	(-4.38)	(-4.59)
Open		0.7031	0.7442	0.6817	0.8464*
		(1.45)	(1.53)	(1.41)	(1.75)
Cons	0.9986***	5.0128***	4.7661***	4.3691***	4.6643***
	(10.28)	(5.28)	(4.87)	(4.61)	(4.96)
Year	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes
N	1404	1404	1404	1404	1404
R^2	0.4809	0.5141	0.5102	0.5133	0.5157

Note: The numbers in parentheses represent the T value. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$, and the same applies below.

An examination of the sub-indices reveals heterogeneous effects. In Column (3), the estimated coefficient for coverage breadth is 0.0591 and lacks statistical significance, suggesting that simply expanding the accessibility of financial accounts-i.e., broadening coverage-exerts a limited direct impact on green productivity. Conversely, Columns (4) and (5) show that the coefficients for usage depth and digitalization level are 0.2583 and 0.1595, respectively, both passing the 1% significance test. This indicates that enhancing user engagement and advancing digital technologies are effective channels through which digital finance promotes green total factor productivity in the Yangtze River Economic Belt.

4.2. Robustness Test

Three robustness tests are conducted to verify the reliability of the baseline regression outcomes. The first test involves replacing the dependent variable with an alternative measure of green total factor productivity that includes carbon dioxide emissions as an undesirable output, in addition to the conventional industrial waste indicators. In the second test, the sample is adjusted by removing provincial capitals and directly governed municipalities from the Yangtze River Economic Belt to ensure the findings are not driven by these specific cities. The third test applies a 1% truncation to all variables, reducing the influence of outliers on the regression estimates.

A comparison reveals that the regression coefficients obtained from the three alternative specifications do not deviate substantially from the baseline estimates, thereby validating the robustness of the earlier empirical results.

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

Table 3. Robustness Check

	GTFP		
	(1) Replace the explained variable	(2) Exclude municipalities directly under the central government and provincial capitals.	(3) Winsorize at the 1% level
Index	0.2422***	0.2251**	0.3737***
	(3.35)	(2.11)	(3.73)
ED	0.6870***	0.7032***	0.6749***
	(5.21)	(5.08)	(5.48)
Gov	1.3024***	1.3679***	1.2381***
	(4.44)	(4.30)	(3.96)
Hui	6.3428***	9.5919***	4.0186***
	(3.96)	(4.47)	(2.86)
FD	-0.1065***	-0.1239***	-0.0768**
	(-4.47)	(-3.63)	(-2.58)
Urb	-0.3122***	-0.3403***	-0.3223***
	(-5.81)	(-4.41)	(-4.26)
Open	0.8738**	0.5188	0.9333**
	(2.30)	(1.16)	(2.16)
Cons	3.6849***	4.4290***	3.8019***
	(6.16)	(5.44)	(4.56)
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
N	1404	1261	1404
R^2	0.6063	0.5646	0.5673

4.3. Endogeneity Test

Table 4. Regression Results of Instrumental Variable Approach

	(1)	(2)
	Index	GTFP
Net	0.0011***	
	(4.57)	
Index		2.2898***
		(2.68)
ED	0.0012	0.6654***
	(0.03)	(4.99)
Gov	0.1000	1.0530***
	(1.15)	(3.03)
Hui	0.1337	3.4429**
	(0.34)	(2.24)
FD	0.0573***	-0.1823***
	(7.04)	(-3.21)
Urb	0.1384***	-0.5803***
	(6.70)	(-4.13)
Open	0.0841	0.7633
	(0.70)	(1.61)
Cons	-1.0572***	5.7149***
	(-4.60)	(4.62)
Year	Yes	Yes
City	Yes	Yes
N	1404	1404
R^2	0.9952	0.4431
First stage F value	2324.543	

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

To address the endogeneity issues caused by omitted variables and mutual causality, and to ensure the scientific nature of the research results, this paper follows the research approach of Xie Xulin et al. (2018) [19] and selects the internet penetration rate (Net) as the instrumental variable for digital finance (Index). On one hand, there is a strong correlation between the internet penetration rate and the development of digital finance, which meets the condition of correlation with digital finance; on the other hand, there is no direct causal relationship between the internet penetration rate and the green productivity of regions, which meets the exogenous condition of being unrelated to green total factor productivity[20] [21]. Therefore, choosing this instrumental variable is feasible.

The validity of internet penetration rate as an instrumental variable is established by the first-stage regression, which yields an F-statistic of 2324.543-dismissing any weak instrument concern. Crucially, the second-stage results demonstrate that digital finance's positive impact remains unchanged in both significance and magnitude when instrumented, confirming that the benchmark findings are not driven by endogeneity.

4.4. Heterogeneity Test

The resource endowment of a city will have a significant impact on the green development of that city. Abundant natural resources can provide a strong driving force for urban development in the early stage, but excessive reliance on resources can instead hinder long-term and sustainable green development. On the contrary, cities with poor resource endowment, although starting from a difficult position, often have to take the path of innovation and efficiency improvement, and are more likely to turn to the green development model. In order to examine the differences in the impact of digital finance on the green development of different resource-endowed cities in the Yangtze River Economic Belt, this paper divides the 108 cities in the Yangtze River Economic Belt into 39 resource-based cities and 69 non-resource-based cities, and conducts regression separately.

Table 5. Analysis of Heterogeneity in Urban Resource Endowments

	GTFP	
	(1) resource-based city	(2) Non-resource-based cities
Index	0.0863	0.5507***
	(0.52)	(3.50)
ED	0.5240***	1.0915***
	(3.45)	(4.61)
Gov	0.4744	1.8422***
	(1.41)	(2.77)
Hui	12.9920***	1.4066
	(4.55)	(0.76)
FD	-0.0945*	-0.1286***
	(-1.84)	(-3.04)
Urb	-0.5205***	-0.5227***
	(-5.48)	(-3.15)
Open	-0.3742	1.7486**
	(-0.59)	(2.48)
Cons	6.5741***	5.5555***
	(6.56)	(3.00)
Year	Yes	Yes
City	Yes	Yes
N	507	897
R^2	0.5691	0.5096

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

The regression results stratified by city type are reported in Table 5. For resource-based cities in the Yangtze River Economic Belt, Column (1) gives a coefficient of 0.0863 for digital finance, which is not statistically significant. By contrast, Column (2) shows that in non-resource-based cities, digital finance yields a coefficient of 0.5507, significant at the 1% level. The substantially larger coefficient and higher significance observed in non-resource-based cities suggest that digital finance exerts a strong positive influence on green total factor productivity in these areas, whereas its effect is largely absent in resource-dependent cities within the region.

4.5. Green Technological Innovation Mediating Effect

Table 6. The Mediating Effect of Green Technological Innovation

	(1)	(2)	(3)
	GTFP	Tech	GTFP
Index	0.3761***	0.0456***	0.3375***
	(3.23)	(3.14)	(2.90)
Tech			0.8465***
			(3.80)
ED	0.7287***	-0.0656***	0.7843***
	(5.26)	(-3.79)	(5.66)
Gov	1.0469***	-0.0729*	1.1086***
	(3.31)	(-1.84)	(3.52)
Hui	4.3441***	-0.0533	4.3892***
	(2.88)	(-0.28)	(2.92)
FD	-0.0780**	-0.0133***	-0.0667**
	(-2.37)	(-3.25)	(-2.03)
Urb	-0.4347***	-0.0080	-0.4279***
	(-5.03)	(-0.74)	(-4.98)
Open	0.7031	-0.0632	0.7565
	(1.45)	(-1.04)	(1.57)
Cons	5.0128***	0.2296*	4.8185***
	(5.28)	(1.93)	(5.09)
Year	Yes	Yes	Yes
City	Yes	Yes	Yes
N	1404	1404	1404
r2_a	0.5141	0.4638	0.5191
F	12.7799	10.6324	12.9263

This paper uses the stepwise regression coefficient method to study the mediating effect of green technological innovation. Specifically, in the first step (1), a baseline equation regression is conducted. The regression results show that digital finance has a significant positive effect on the green total factor productivity in the Yangtze River Economic Belt and is significant at the 1% level, with a correlation coefficient of 0.3761. A three-stage mediation analysis is conducted to test the underlying mechanism. Column (2) reports the results of the second stage, where green technological innovation is regressed on digital finance, holding other covariates constant. The coefficient of 0.0456, statistically significant at the 1% level, confirms that digital finance significantly fosters green technological innovation across the Yangtze River Economic Belt. In the third stage, green technological innovation is introduced as a mediator alongside the original controls. The results show that the coefficient of digital finance on green total factor productivity remains positive and significant at the 1% level, but decreases from its baseline value to 0.3375. This reduction in coefficient size, coupled with the significant effect of digital

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

finance on the mediator, indicates the presence of a partial mediation effect. Thus, digital finance contributes to green total factor productivity growth by first elevating the level of green technological innovation. These findings provide empirical support for Hypothesis 2.

5. Conclusion and Policy Implications

With a coefficient significant at the 1% level, the results demonstrate that digital finance positively influences green total factor productivity in the Yangtze River Economic Belt. This underscores the potential of digital finance as a catalyst for regional green transformation.To analyze the specific mechanism of this impact, digital finance was divided into three dimensions. The regression results revealed that the coverage breadth had a relatively small and non-significant effect on green total factor productivity, suggesting that for most prefecture-level cities in the Yangtze River Economic Belt, the problem of starting from nothing has been largely resolved. Simply adding a base station or a digital outlet has been difficult to generate a significant marginal boost for the macro indicator of green total factor productivity, which focuses on quality and efficiency. The use depth had the greatest impact on green total factor productivity and passed the 1% significance test. Considering the actual situation of each region in the Yangtze River Economic Belt, from upstream's ecological agriculture and tourism, to midstream's manufacturing base, and to downstream's high-tech and service economy, the green transformation paths and financial demands of different industrial sectors vary greatly.Two key findings emerge. First, the significance of usage depth demonstrates that digital finance now fulfills industry-specific green financing needs through tailored products, moving well beyond its original payment-centric role. Second, the strong positive coefficient of digital finance on green total factor productivity confirms that technological empowerment enables digital finance to effectively boost green productivity throughout the Yangtze River Economic Belt.This implies that the main driver of green development is shifting from traditional capital and labor to new production factors centered on data, algorithms, and computing power.

Further, through multi-dimensional robustness tests, alternative explanations and accidental results were excluded, verifying the reliability of the conclusion and enhancing the academic rigor and persuasiveness of the research.Two methodological approaches yield important insights. First, instrumental variable estimation using internet penetration rate effectively addresses endogeneity concerns related to omitted variables and reverse causality. Second, heterogeneity analysis based on resource endowments demonstrates that digital finance significantly drives green productivity growth in non-resource-based cities within the Yangtze River Economic Belt, while its effect on resource-based cities remains negligible and statistically insignificant.To explore the indirect impact channel of digital finance on the Yangtze River Economic Belt, green technological innovation was introduced for testing. The results showed that digital finance not only directly functions but also indirectly but effectively promotes the improvement of green total factor productivity by stimulating technological change.

Based on the above research results, in order to fully leverage the role of digital finance in enhancing the green total factor productivity of the Yangtze River Economic Belt, promoting the coordination and unity of economic development and ecological protection, and achieving sustainable development goals, the following policy suggestions are proposed:

(1)Strengthen the construction of new infrastructure and vigorously develop digital finance

New infrastructure is the cornerstone for the development of digital finance. The downstream regions should first build ubiquitous intelligent networks composed of IoT and satellite internet, and plan financial data centers and computing power centers to support the real-time processing of massive financial data. The middle and upper regions need to promote network coverage in rural and remote areas, layout regional data centers, and build a collaborative

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

computing power system to ensure the comprehensive coverage of digital financial services. At the same time, financial core facilities should be upgraded, the payment and settlement system should be optimized, the application scenarios of digital currencies should be expanded, a unified supply chain financial information platform should be constructed, and the enterprise credit rating system and green credit evaluation should be improved. The development of digital finance also requires the construction of multiple-level platforms to enhance service efficiency. Encourage financial institutions and technology enterprises to cooperate to create a comprehensive service platform integrating financing, insurance, and risk control, using big data to connect green projects. For small and medium-sized environmental protection enterprises and rural areas, develop convenient and inclusive financial platforms to lower service thresholds. In addition, digital finance should focus on innovative products and services for green industries, such as green credit based on environmental benefits and preferential interest approval channels, to better serve the real economy.

(2)Explore digital technology innovation and cultivate innovative talents

Digital technology is the green engine of the new era, and its deep integration with fields such as environmental protection and finance can significantly improve efficiency. It is necessary to increase innovation investment and build a comprehensive ecosystem. A multi-pronged policy approach is recommended, wherein fiscal incentives-comprising dedicated funds, risk compensation schemes, and tax concessions-are deployed to galvanize private sector engagement in green technology innovation and to facilitate cross-pollination between digital finance and environmental technology domains. Parallel efforts should prioritize the conquest of pivotal core technologies through the establishment of collaborative platforms that integrate the research capabilities of universities, the expertise of institutions, and the application orientation of enterprises, thereby enabling the seamless conversion of scientific discoveries into productive forces aligned with ecological imperatives.

Talent is the foundation of innovation, and it is necessary to build a well-structured and high-quality talent team that meets the industrial demands of the Yangtze River Economic Belt. Support key cities' universities and leading enterprises to jointly establish industrial colleges and laboratories, strengthen interdisciplinary education, and cultivate digital, environmental, and financial-combined talents. Implement open and effective talent policies, set up special funds to introduce high-level overseas talents, and establish a flexible mobility mechanism within the region to encourage talents to flow from the downstream to the middle and upper regions, promoting knowledge sharing and technology collaboration.

(3)Promote regional coordinated development and narrow the green development gap

The regional development imbalance, especially the gap in digital finance development and green transformation processes, has become a prominent bottleneck restricting the high-quality development of the Yangtze River Economic Belt. Promoting regional coordinated development and narrowing the green development gap requires the construction of a multi-level regional collaborative governance system. First, improve regional coordination organizations and establish the Yangtze River Economic Belt Green Development Coordination Committee, and establish a regular joint meeting system. Set up special working groups to coordinate cross-regional environmental standards, industrial access, and green financial policies to ensure that all measures form a synergy. Secondly, break administrative barriers and promote the orderly flow of innovation factors. Build regional innovation communities, relying on innovation hotspots such as Shanghai Zhang jiang, Wuhan Guanggu, and Chengdu Tianfu, form the Yangtze River Economic Belt Green Technology Innovation Alliance, establish large-scale scientific research instrument equipment sharing platforms, and promote the open and intercommunication of scientific and technological resources. Finally, strengthen ecological environmental collaborative governance and innovate ecological compensation mechanisms.Uniformize environmental monitoring standards for water, air, and soil, and

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

establish a real-time monitoring system covering the entire river basin. Establish a cross-regional environmental risk early warning mechanism to achieve coordinated responses to major pollution incidents. At the same time, establish a horizontal ecological compensation system based on indicators such as water quality and forest coverage. The downstream beneficiary areas provide support to the upstream ecological protection areas through means such as financial assistance and industrial collaboration, achieving a balanced distribution of ecological and economic benefits.

References

[1] Lu Liven, Song Defeng, Li Xiaofan. Research on the Green Efficiency of Urban Development in the Yangtze River Economic Belt [J]. China Population, Resources and Environment, 2016, 26 (06): 35-42.

[2] Zhang Huan, Song Ting, Mei Yuzhen, et al. The Spatiotemporal Pattern Evolution and Driving Factors of Green Total Factor Productivity in the Yangtze River Economic Belt from the Perspective of Urban Agglomerations [J]. Journal of the Yangtze River Basin Resources and Environment, 2025, 34(07): 1413-1425.

[3] Wang Ruchui, Tao Shige. Research on the Impact of Digital Finance on the Resilience of China's Real Economy [J]. Modern Economic Discussion, 2024, (11): 10-23.

[4] Kumar R. Biases in Artificial intelligence applications affecting human life: A review[J].International Journal of Recent Technology and Engineering, 2021(1):54 - 55

[5] Sun Yuhuan, Zhang Tingyu, Wang Xueni, et al. The Current Situation, Problems and Prospects of China's Digital Inclusive Finance Development [J]. Quantitative Economics and Technical Economic Research, 2021, 38 (02): 43-59.

[6] Yan Zhiqing, Yang Zisheng, Zhong Wen. The Impact of Digital Finance Development on Urban Green Total Factor Productivity: Effects and Mechanisms [J]. Statistics and Decision, 2024, 40 (23): 138-143.

[7] Yu Jintao, Zhang Rui, Gong Xinyu. How Does Digital Finance Affect Green Total Factor Productivity? -- Dynamic Characteristics, Mechanism Identification and Spatial Effects [J]. Contemporary Economic Science, 2022, 44 (06): 42-56.

[8] Sun Xuetao, Tian Yang. The Impact of Digital Finance on County-level Green Total Factor Productivity [J]. Shandong Social Sciences, 2022, (04): 156-163.

[9] Zhu Jietang, Jiao Ranqing, Xie Weili. How Does Digital Inclusive Finance Affect Green Total Factor Productivity: Theoretical Analysis and Empirical Evidence [J]. Financial Regulatory Research, 2022, (03): 54-70.

[10] Fan Xin, Yin Qiushu. Has Digital Finance Improved Green Total Factor Productivity? [J]. Journal of Shanxi University (Philosophy and Social Sciences Edition), 2021, 44 (04): 109-119.

[11] Tian Jie, Tan Qiuyun, Chen Yiming. Digital Inclusive Finance, Factor Distortion and Green Total Factor Productivity [J]. Western Forum, 2021, 31 (04): 82-96.

[12] Hu Xinyun, Guo Pengfei, Li Meng. Research on the Impact of Digital Economic Development in the Yangtze River Economic Belt on Green Total Factor Productivity [J]. Statistics and Decision, 2025, 41 (06): 121-125.

[13] Tang Song, Wu Xuchuan, Zhu Jia. Digital Finance and Enterprise Technological Innovation: Structural Characteristics, Mechanism Identification, and Effect Differences under Financial Regulation [J]. Management World, 2020, 36 (05): 52-66 + 9.

[14] Hu Xianbo. Digital Inclusive Finance and Urban Green Total Factor Productivity: Intrinsic Mechanism and Empirical Evidence [J]. Southern Finance, 2021, (05): 20-31.

[15] Xu Weicheng. Digital Finance, Heterogeneous Environmental Regulation and Green Total Factor Productivity [J]. Economic Science, 2023, (11): 1-16.

[16] Yu Yishan, Wei Ping. Research on the Measurement of China's Urban Green Total Factor Productivity [J]. Ecological Economy, 2021, 37 (03): 43-52.

ISSN: 2692-7608 DOI: 10.6981/FEM.202603_7(3).0001

[17] Lu Liven, Song Defeng, Huang Can. Measurement of Green Total Factor Productivity of Cities in the Yangtze River Economic Belt: A Case Study of 108 Cities in the Yangtze River Economic Belt [J]. Urban Issues, 2017, (01): 61-67.

[18] Guo Feng, Wang Jingyi, Wang Fang, et al. Measuring the Development of Digital Financial Inclusion in China: Index Compilation and Spatial Characteristics [J]. Quarterly Journal of Economics, 2020, 19(04): 1401-1418.

[19] Xie Xulin, Shen Yan, Zhang Haoxing, et al. Can Digital Finance Promote Entrepreneurship? Evidence from China [J]. Journal of Economics (Quarterly), 2018 (4): 1557-1580.

[20] YIN Z, GONG X, Guo P, Wu T. What drives entrepreneurship in digital economy? Evidence from China[J]E-conomic Modelling, 2019, 82(3):66 - 73.

[21] Shen Y, Ren X. Digital Finance and Upgrading of Industrial Structure:Prefecture-level Evidence From China [J].Finance Research Letters,2023,(55).