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Study on the Impact of Green Finance on Total Factor Productivity of Manufacturing Enterprises in the Yellow River Basin of China

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Abstract

Improving the total factor productivity (TFP) of manufacturing firms is essential for attaining high-quality growth in the Yellow River Basin, with green financing serving a critical function in this endeavor. This study examines the influence of green finance on total factor productivity (TFP) using data from A-share listed manufacturing businesses in the Yellow River Basin from 2010 to 2020, and investigates the underlying causes. The empirical findings indicate that green finance substantially improves the total factor productivity of manufacturing firms. Moreover, the mechanism analysis indicates that green technological innovation serves as a mediator between green financing and total factor productivity (TFP). This study enhances the current literature by elucidating the connection between green finance and manufacturing total factor productivity (TFP), while presenting empirical evidence and policy recommendations for advancing sustainable development in the Yellow River Basin via green finance initiatives.

Keywords

Green Finance; Manufacturing Firms; Total Factor Productivity (TFP); Green Technology Innovation; Yellow River Basin.

1. Introduction

The Yellow River Basin, as a vital ecological barrier and economic zone in China, possesses a strong manufacturing foundation and is essential for the advancement of the country's manufacturing sector. It is essential for the nation's economic development, social advancement, and environmental stability. Nonetheless, swift economic advancement has resulted in increasingly significant environmental issues. The manufacturing sector's expansion in the region has been greatly hindered by issues such as a burdensome industrial framework, delayed green development, low value-added products, and uneven regional development. To tackle these challenges, it is imperative to promote high-quality growth in the manufacturing sector, transitioning from the conventional "high input, high energy consumption, and high pollution" model to a more sustainable, productivity-oriented growth trajectory that improves the total factor productivity of manufacturing firms.

Due to the restricted internal finance capacities of several manufacturing firms, external financial assistance is essential for enhancing total factor productivity (TFP). Green finance, as a significant external funding avenue, can assist firms in their shift from high environmental and energy consumption practices to sustainable, low-carbon, and circular development models. Green finance can promote innovation incentives and facilitate total factor productivity development by offering continuous financial support for green technology innovation. Green finance is becoming an essential instrument for advancing ecological civilization and high-quality development in the Yellow River Basin.

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Consequently, within the strategic objective of advancing high-quality manufacturing in the Yellow River Basin, investigating the mechanisms by which green finance and green technical innovation affect total factor productivity is of considerable theoretical and practical significance.

2. Literature Review

The conventional financial model largely allocates funds based on economic efficiency and the achievement of national policy objectives, frequently overlooking essential concerns such as resource scarcity, ecosystem equilibrium, and pollution[1]. Conversely, green finance encompasses financial activities that foster the sustainable growth of economies, resources, and the environment[2]. Green finance utilizes products including loans, insurance, securities, and industrial funds to effectively mitigate the externalities of environmental initiatives and information asymmetries, while promoting enhanced social responsibility among financial institutions and corporations[3]. The advancement of green finance is pivotal for fostering ecological civilization and attaining high-quality growth.

Nevertheless, several experts contend that green finance could impede corporate total factor productivity (TFP). Green credit rules, for example, substantially limit loan financing for polluting firms, elevating their costs and uncertainties, which therefore diminishes total factor productivity by distorting resource allocation in financial markets[4]. Ultimately, green innovation, particularly that focused on green technology, is vital for mitigating pollution, resource waste, and ecological degradation, which are crucial for fostering an ecological society and promoting high-quality economic and social development.

In recent years, green finance has become an essential instrument for fostering green technological innovation within firms[5]. Green finance actively promotes green technological innovation by optimizing resource allocation, mitigating information asymmetry, and decreasing financing costs via government subsidies for green loans[6]. Moreover, green technical innovation can draw social capital to green businesses, mitigating finance constraints and deficiencies in the green innovation process[7]. Considering the ecological susceptibility and resource-environment difficulties in the Yellow River Basin, it is both necessary and imperative to utilize green finance to promote green technological innovation and improve the total factor productivity of the industrial sector.

3. Theoretical Analysis and Research Hypothesis

3.1. Analysis of the Mechanism by Which Green Finance Affects the TFP of Manufacturing Enterprises

Green finance represents a distinct model of financial development, diverging from conventional finance by effectively directing resources towards green industries through variable interest rates, differentiated credit, and other mechanisms. It encourages enterprises to transition from high-pollution, high-energy-consuming sectors to sustainable, low-carbon, and recycling-oriented practices by elevating lending rates and restricting loan availability. Nevertheless, concurrently, the crowding-out impact resulting from the advancement of green finance exacerbates the financing challenges for significantly polluting firms, constrains their production capacity, and elevates their production costs. For enterprises to secure increased financing in the green financial market, they must alter their internal financing constraints and subsequently modify the external financing environment to ensure their business operations align with the pertinent green finance policies[8], thereby necessitating a green transformation to enhance total factor productivity (TFP) [9]. Conversely, green finance facilitates the transformation of organizations into environmentally sustainable enterprises by reallocating

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capital from declining overcapacity sectors to technologically advanced growing industries. Thus, economic, resource, and ecological development will be synchronized, sustainable development will be realized, green economic growth will be fostered, and total factor productivity (TFP) will be improved.

H1. The development of green finance is conducive to the TFP of manufacturing enterprises.

3.2. Theoretical Analysis of the Mediating Role of Green Technology Innovation

Green technologies are those that fulfill green development criteria that enhance the safety, health, environmental sustainability, and carbon efficiency of complete industrial systems. Green technological innovation necessitates adequate investment in research and development, and firms frequently cannot fulfill their requirements only through endogenous financing; hence, green finance serves as a crucial source of exogenous funding for enterprises. Green finance can facilitate green technology innovation by lowering transaction costs, broadening financing avenues, and mitigating risk concerns. Moreover, the advancement of green finance enhances the financing landscape for enterprises, providing them with more diverse avenues to communicate externally, thereby reducing the information risk faced by external investors and more effectively facilitating the innovative activities of enterprises. Consequently, green technological innovation is facilitated by the environmental control of technology compensation for total factor productivity (TFP). Enhancement is evident in labor productivity[10], particularly for enterprises utilizing green technological innovation to elevate product quality, diminish the incidence of substandard products, enhance sales and output efficiency, and through product advancement and innovation, augment total factor productivity (TFP).

H2. Green finance development can promote TFP of manufacturing enterprises through green technological innovation.

4. Data and Research Design

4.1. Sample Selection and Data Sources

This study examines all A-share listed manufacturing firms in China's Yellow River Basin from 2003 to 2020. The sample is refined by excluding listed firms in the financial and insurance sectors, those with irregular trading (including ST, ST*, and PT), and those with incomplete relevant data. Additionally, the primary continuous variables are winsorized at 1%. This paper utilizes innovation data from the CNRDS database, while the primary financial data is sourced from the Wind and CSMAR databases. An unbalanced panel dataset including 3,305 valid observations from 288 enterprises has been established using the data matching process.

4.2. Definition of Variables

4.2.1. Explained Variables

This paper is based on the research idea of Olley-Pakes (OP) method[11] , constructing the model as follows:

$$lnY_{it} = \beta_0 + \beta_k lnK_{it} + \beta_l lnL_{it} + \beta_a age_{it} + \beta_s state_{it} + \beta_e EX_{it} + \sum_m \delta_m year_m + \sum_n \lambda_n prov_n + \sum_k \zeta_k ind_k + \epsilon_{it} \tag{1}$$

In this context, i denotes enterprise, t represents time, Y indicates business revenue, K refers to net fixed assets, L signifies the number of employees, age pertains to the age of the enterprise, stata indicates whether the enterprise is state-owned, and EX represents income derived from

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overseas business activities. The Olley-Pakes semiparametric three-step estimation method was utilized to regress the specified model using the opreg command. In this scenario, the state variables are lnK and age; the control variables are state and EX; the proxy variable is the firm's investment (lnI); the remaining variables, including year, prov, and ind, are classified as free variables; and the exit variable is Exit, determined by the firm's operational survival in Generation. The residual is TFP (TFP-OP). The generalized method of moments (GMM) is utilized to estimate total factor productivity (TFP) to ensure the robustness of the results.

4.2.2. Explanatory Variables

This research employs the combined coordination degree of urban financial development and urban green development to quantify urban green financing; the specific formula is as follows:

$$GF = 2\sqrt{\left[\frac{fina \times gdev}{\left(fina + gdev\right)^2}\right] \times \left(0.5 fina + 0.5 gdev\right)} \tag{2}$$

GF represents urban green finance, fina denotes normalized urban financial development, and gdev signifies normalized urban green development. Urban financial development is quantified by the ratio of loans issued by financial intermediaries at year-end to deposits held by these intermediaries at year-end. Urban green development is assessed through pollution output per unit of GDP, calculated as the ratio of environmental regulatory proxy variables (urban industrial wastewater output, urban industrial SO2 output, urban industrial soot output) to GDP. Given that pollution output per unit of GDP serves as an inverse indicator, it is positively normalized through dimensionless treatment utilizing the extreme value method.

4.2.3. Mediating Variable

This study employs the count of green invention patents (Ginno) filed by enterprises within the year as an indicator of green technology innovation.

4.2.4. Control Variables

This study identifies control variables, which encompass the growth rate of total assets (Growth), return on assets (ROA), operating profit margin (Profit), duration of enterprise operation (Age), executive shareholding status (Share), fixed assets ratio (PPE), proportion of independent directors (Indep), and the dual role of the chairman of the board of directors (Dual).

4.2.5. Descriptive Statistics

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max.
TFP_OP	3305	6.460	0.910	3.810	8.720
GF	3305	0.300	0.060	0.150	0.430
Ginno	3305	0.480	0.890	0	4.390
Growth	3305	0.160	0.310	-0.390	1.820
ROA	3305	0.060	0.070	-0.230	0.280
Profit	3305	0.030	0.260	-1.680	0.450
Age	3305	2.700	0.390	1.610	3.370
Share	3305	0.610	0.490	0	1
PPE	3305	0.280	0.160	0.0200	0.700
Indep	3305	0.360	0.0500	0.250	0.560
Dual	3305	0.150	0.360	0	1

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The pertinent statistics for each index are presented in Table 1. The green financial development index has a maximum value of 0.430, a minimum value of 0.150, and a standard deviation of 0.060, suggesting significant variability in development across regions. The total factor productivity of the manufacturing industry and green technological innovation exhibits significant disparities.

4.3. Modeling

This study aims to evaluate the relationship between green finance and total factor productivity (TFP), while also examining the mediating effect of green finance on the manufacturing sector through green technology innovation. To achieve this, model (3), model (4), and model (5) have been constructed as outlined below.

$$TFP\_OP_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_i Controls_{it} + \lambda_i + \mu_{it} + \epsilon_{it} \tag{3}$$

$$Ginno_{it} = \beta_0 + \beta_1 GF_{it} + \beta_i Controls_{it} + \lambda_i + \mu_{it} + \epsilon_{it} \tag{4}$$

$$TFP\_OP_{it} = \gamma_0 + \gamma_1 GF_{it} + \gamma_2 Ginnoit_{it} + \gamma_i Controls_{it} + \lambda_i + \mu_{it} + \epsilon_{it} \tag{5}$$

TFO_OPit represents the total factor productivity (TFP) of city i in year t, GFit indicates the level of green finance, Ginnoit refers to green technological innovation, and Controlsit denotes the control company variable. λi represents the time fixed effect, μit represents the industry fixed effect, and ϵit is the random error term. In accordance with the research conducted by Wen and Ye (2014) [12], the initial step involves the verification of coefficient α1 in model (3), followed by coefficient β1 in model (4), and subsequently coefficient γ2 in model (5). If all three coefficients are found to be significant, it indicates that the mediation effect is also significant. The second step involves verifying the coefficient γ1 in model (5). A significant value indicates the presence of a partial mediation effect, while a non-significant value suggests a full mediation effect. The third step involves comparing the signs of γ1 and β1γ2. If they share the same sign, this indicates a partial mediation effect. In this case, the mediation effect constitutes a proportion of the total effect, calculated as β1γ2/α1. If the sign differs, it indicates a masking effect, and the proportion of the mediating effect is represented as |β1γ2/γ1| .

5. Empirical Results and Analyses

Model (1) indicates the selection of a multidimensional fixed effect model for multiple regression analysis, with the regression results presented in Table 2. The initial column assesses the impact of green financial development on the total factor productivity (TFP) of the manufacturing sector. The regression coefficient for green finance is 0.821, which is significantly positive at the 1% level, indicating its positive impact on the total factor productivity of the manufacturing industry. The verification of Hypothesis H1 has been achieved. In the second column, green technology innovation serves as an explanatory variable, and the regression coefficient for green finance remains significantly positive at the 1% level. The regression coefficient is 1.071, indicating that the advancement of green finance positively influences the level of green technology innovation within the manufacturing sector. The third column utilizes total factor productivity (TFP) of the manufacturing industry as an explanatory variable, incorporating both green financial development and green technological innovation into the model. The regression coefficients obtained are 0.531 for green finance and 0.271 for green technological innovation, with both variables demonstrating statistical significance. The coefficient of green finance declines from 0.821 in the first column to 0.531 in the third column.

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Additionally, the signs of γ1 and β1γ2 are positive, indicating that green technological innovation serves as a mediating factor in the relationship between green finance and the total factor productivity (TFP) of the manufacturing industry. The mediating effect constitutes 35.35% of the total effect (β1γ2/α1). The empirical findings confirm hypothesis H2, indicating that green finance can indirectly improve the total factor productivity (TFP) of the manufacturing sector by fostering green technological innovation.

Table 2. Benchmark regression and mediation regression results

	(1)	(2)	(3)
	TFP_OP	Ginno	TFP_OP
GF	0.821 ***	1.071 ***	0.531**
	(0.269)	(0.239)	(0.261)
Ginno			0.271 ***
			(0.017)
Growth	-0.123**	0.047	-0.136**
	(0.055)	(0.049)	(0.053)
ROA	2.409 ***	0.722 ***	2.213 ***
	(0.305)	(0.204)	(0.294)
Profit	0.778 ***	0.103*	0.751 ***
	(0.081)	(0.053)	(0.078)
Age	0.209 ***	0.282 ***	0.133 ***
	(0.049)	(0.049)	(0.047)
Share	0.061**	0.138 ***	0.023
	(0.028)	(0.027)	(0.027)
PPE	0.173	-0.281***	0.249 **
	(0.112)	(0.092)	(0.109)
Indep	-0.284	-0.690**	-0.097
	(0.261)	(0.276)	(0.248)
Dual	-0.077**	-0.117 ***	-0.045
	(0.037)	(0.041)	(0.035)
cons	5.544 ***	-0.390**	5.649 ***
	(0.177)	(0.171)	(0.169)
Industry FE	YES	YES	YES
Time FE	YES	YES	YES
	3305	3305	3305
RÂ²	0.379	0.287	0.429

Standard errors in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

6. Robustness Tests

6.1. Instrumental Variable Method

The empirical analysis presented necessitates addressing the endogeneity issue resulting from mutual causation. Green finance enhances the total factor productivity (TFP) of the manufacturing sector by facilitating advancements in green technology. A high level of total factor productivity (TFP) indicates high-quality economic development, which may also promote the growth of green finance. Conversely, while observable variables are incorporated

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into the model as essential explanatory and control variables, unobservable factors associated with TFP may persist, potentially resulting in omitted variable bias.

This study addresses the endogeneity issue arising from reciprocal causality by employing the one-period lagged term of green finance development as an instrumental variable (IV). Table 3 presents the estimation results. The first-stage regression results demonstrate a significant positive relationship between the instrumental variable and the green finance index. The results of the second-stage regression corroborate that the index of green financial development exhibits a significant and positive correlation with manufacturing total factor productivity, aligning with the baseline analysis findings.

This study also performs identification tests, such as the under-identification test, over-identification test, and weak instrumental variable test. The findings presented in Table 3 indicate that the Kleibergen-Paap rk LM statistic significantly rejects the null hypothesis of under-identification of instrumental variables, thereby affirming the relevance of the instrumental variables employed. The Kleibergen-Paap rk Wald F statistic and Cragg-Donald Wald F statistic values surpass the Stock-Yogo 10% critical value (16.38), thereby rejecting the hypothesis of "weak instrumental variables" and confirming the validity of the chosen instrumental variables.

Table 3. Regression Results of Instrumental Variable Approach

	(1)	(2)
	first	second
VARIABLES	GF	TFP_OP
L.GF	0.798***	
	(0.0174)	
GF		1.305***
		(0.357)
Growth	0.00270	0.138*
	(0.00296)	(0.0714)
ROA	0.00625	2.039***
	(0.0130)	(0.309)
Profit	-0.000611	0.828***
	(0.00349)	(0.0841)
Age	0.00201	0.227***
	(0.00234)	(0.0530)
Share	-0.00198	0.0711**
	(0.00128)	(0.0294)
PPE	0.00117	0.140
	(0.00462)	(0.116)
Indep	0.0154	-0.405
	(0.0115)	(0.269)
Dual	-0.00276*	-0.0636
	(0.00147)	(0.0394)
Industry FE	YES	YES
Time FE	YES	YES
Observations	2,999	2,999
R-squared		0.178
Kleibergen-Paap rk LM statistic		656.12***
Kleibergen-Paap Wald rk F statistic		2116.24 [16.38]
Cragg-Donald Wald F statistic		4684.68 [16.38]

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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6.2. Substitution Method

The explanatory variables are replaced to ensure that the conclusions of this paper remain unaffected by specific measurement methods. Consequently, the GMM method is employed to re-evaluate TFP. Empirical results in Table 4 indicate that GF and Ginno's coefficient is significantly positive at the 5% level, suggesting that the conclusions of this paper are robust against specific methods of measuring TFP in individual firms.

Table 4. Replacement of explanatory variables regression results

	(1)	(2)	(3)
	TFP_GMM	Ginno	TFP_GMM
GF	0.784 ***		0.649 ***
	(0.210)		(0.208)
Ginno		0.129 ***	0.126 ***
		(0.013)	(0.013)
Growth	-0.159 ***	-0.162 ***	-0.165 ***
	(0.044)	(0.044)	(0.044)
ROA	2.138 ***	2.047 ***	2.047 ***
	(0.246)	(0.245)	(0.244)
Profit	0.604 ***	0.589 ***	0.591 ***
	(0.069)	(0.069)	(0.069)
Age	0.132 ***	0.098 ***	0.097 ***
	(0.037)	(0.037)	(0.037)
Share	0.006	-0.016	-0.011
	(0.022)	(0.022)	(0.021)
PPE	-1.510 ***	-1.473 ***	-1.475 ***
	(0.092)	(0.092)	(0.092)
Indep	-0.055	0.048	0.031
	(0.204)	(0.201)	(0.200)
Dual	-0.027	-0.017	-0.012
	(0.028)	(0.027)	(0.027)
cons	3.061 ***	3.293 ***	3.110 ***
	(0.137)	(0.129)	(0.135)
Industry FE	YES	YES	YES
Time FE	YES	YES	YES
	3305	3305	3305
RÂ^2	0.420	0.435	0.437

Standard errors in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

6.3. Bootstrap Methodology

The Bootstrap method, utilizing a 95% confidence interval, is employed to re-validate the mediation mechanism of "green finance - green technology innovation - TFP of manufacturing enterprises," with the number of repetitions set at 2000. A 95% confidence interval that excludes 0 indicates a significant direct or indirect effect. The table and5 indicates that the 95% confidence intervals for the direct and indirect effects are [0.0246615, 1.036662] and [0.1580371, 0.4224255], respectively, both of which do not encompass 0. Consequently, it is evident that both the mediating effect of green technological innovation and the direct effect of

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green finance on total factor productivity (TFP) are significant, thereby reinforcing the conclusions of hypothesis H2.

Table 5. Further tests of intermediary robustness

	Observed coefficient	Bootstrap std.err.	z	P>z	Normal- based [95% conf. interval]	
indirect effect	0.2902313	0.0674472	4.30	0.000	0.1580371	0.4224255
direct effect	0.5306618	0.2581682	2.06	0.040	0.0246615	1.036662

7. Conclusion and Policy Recommendations

Green represents the fundamental color of ecological civilization construction, while finance serves as the foundation for high-quality development. This study focuses on manufacturing enterprises in the Yellow River Basin, utilizing panel data from all A-share listed manufacturing firms in the region from 2003 to 2020. It conducts empirical testing to investigate the effects of green finance on green total factor productivity (TFP) and analyzes green technological innovation as a mediating variable. Green finance is found to enhance total factor productivity (TFP) and withstands robustness testing. Green financing enhances total factor productivity in manufacturing by fostering green technological innovation.

Based on the aforementioned research results, the following suggestions are put forward:

The policies implemented by the Government to promote green finance, including the creation of a green finance fund and the offering of tax incentives, have successfully directed financial institutions to enhance their investments in environmentally sustainable sectors. This approach not only increases financial support for manufacturing enterprises in the Yellow River Basin but also fosters green technological innovation, thereby significantly improving the green total factor productivity (TFP) of these enterprises.

In addition, the Government has alleviated financing constraints for green technology innovation projects in the manufacturing sector by providing preferential loans and financing guarantees. This initiative has enabled enterprises to address capital shortages, expedited the research and development and application of green technologies, and further advanced the improvement of green total factor productivity.

The green technology innovation support system established by the Government, which includes R&D subsidies and enhanced intellectual property protection, has significantly incentivized enterprises to boost their investment in green technology innovation. This ensures a robust framework for the green transformation of manufacturing enterprises in the Yellow River Basin and fosters the green development of the entire region.

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