



Research on the Impact of Cross-Border E-Commerce Pilot Zones on Green Total Factor Productivity

Yuchuan Jin

College of Economics and Management & China-Africa College of Economics and Management, Zhejiang Normal University, Jinhua, China

Email: 18982631137@163.com

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Abstract

In recent years, the cross-border e-commerce comprehensive pilot zone policy has been continuously promoted, and the scale has been continuously expanded, which has played an important role in China's economic development. Based on literature research, theoretical exposition and empirical testing, this paper constructs a research framework to study the relationship between the establishment of cross-border e-commerce comprehensive pilot zones and urban Green Total Factor Productivity (GTFP). This paper calculates the green total factor productivity of 260 prefecture-level cities in China through the super-efficiency SBM model, and empirically analyzes the impact of cross-border e-commerce comprehensive pilot zone policies on green total factor productivity of pilot cities from 2006 to 2021 by using the multi-period differential model.

Subject Areas

Business Communication

Keywords

Cross-Border E-Commerce Comprehensive Pilot Area, Green Total Factor Productivity, Multistage DID Model

1. Introduction

China has been at the low end of the industrial chain for a long time, and the transformation of the economy to high-quality development has become the goal of our country at this stage. In our country, the speed of economic development began to slow down, which is the key to the transition from the high-speed growth

stage to the high-quality development stage. In recent years, we can no longer simply take GDP growth rate as the only indicator to examine economic development. For the first time, the urgent requirement to improve total factor productivity was put forward, and it was proposed that technological progress, resource allocation optimization, Economies of scale and management improvements, among other means, are necessary to increase production efficiency and achieve higher output with lower inputs. The development of the national economy has a new concept and direction.

At present, cross-border e-commerce has become a new form of foreign trade in China with the fastest growth rate, the greatest potential and the strongest driving role. Cross-border e-commerce with online short chain transactions, agile demand adaptation, flexible production and personalized customization, low market access threshold and other highlights frequently “out of the circle”. China Customs data show that the proportion of cross-border e-commerce imports and exports in total foreign trade jumped from less than 1% in 2015 to 5.7% in 2022, of which the total import and export of comprehensive pilot areas contributed more than 90%. Since the implementation of the comprehensive pilot area, the construction of a green industrial chain supply chain and the implementation of carbon peak and carbon neutrality requirements have gradually become an important part of the development of cross-border e-commerce.

2. Literature Review

Cross-border e-commerce is an important starting point for the upgrading of trade formats. At present, most scholars mainly start from cross-border e-commerce and carry out relevant research on new trade formats. Based on the perspective of trade costs, such studies propose that cross-border e-commerce can break through space restrictions by simplifying the search process, reducing cross-border communication barriers and reducing contract costs [1], and superimpose advantages such as production efficiency, matching effect and scale effect [2], which is conducive to promoting the expansion of enterprises' export scale. However, some scholars believe that tariffs, parcel delivery, online payment systems and other related costs caused by cross-border e-commerce also increase the cost burden of export enterprises [3]. In terms of green technology innovation, existing studies mostly focus on the impact of e-commerce on low-carbon development and environmental performance [3].

In terms of the influencing factors of green total factor productivity, since the reform, the energy-saving and emission reduction policies implemented by the Chinese government have indeed effectively promoted the continuous improvement of green productivity [4]. Environmental regulation has an important impact on China's industrial structure transformation, but it has a “threshold effect” on the adjustment of industrial structure [5]. Not only can policies have an important impact on GTFP, but human capital can also play a similar role in the progress of GTFP [6].

In this paper, the super efficiency SBM model is used to measure and calculate green total factor productivity. Among the efficiency evaluation methods widely used today, Data Envelopment Analysis (DEA) can handle multiple input and output factors for total factor efficiency analysis without the need to set function or parameter weights in advance, thus avoiding the shortcomings of subjectivity and information compression. Some literature has used traditional radial distance or directional distance function models, neglecting the slack in variables. After improvement, the SBM model emerged, aiming for the maximization of actual profits rather than just the maximization of the efficiency ratio [7]. However, although the traditional SBM model differs from the traditional DEA model in efficiency measurement by directly introducing slack variables in the objective function, considering the slack part of inefficient decision-making units in its economic interpretation, and stripping away the impact of inefficient slack parts, it still results in multiple decision-making units with an efficiency of 1, making it impossible to distinguish and rank them. Therefore, Dong *et al.* [8] proposed the super-efficiency SBM model, allowing the efficiency value of decision-making units to be greater than 1, effectively addressing the shortcomings of the traditional SBM model. “Green Economic Efficiency” (GEE) considers both resource inputs and undesired outputs, incorporating resource utilization and environmental damage into the production process to obtain an efficiency value. Based on this, this paper calculates the green economic efficiency of Chinese cities according to the super-efficiency SBM model proposed by Tone [8]. The specific formula is as follows:

$$\min \rho = \frac{1 + \frac{1}{m} \sum_{i=1}^m \frac{s_i^-}{x_{ik}}}{1 - \frac{1}{q_1 + q_2} \left(\sum_{r=1}^{q_1} \frac{s_r^+}{y_{rk}} + \sum_{t=1}^{q_2} \frac{s_t^{b-}}{y_{tk}^b} \right)}$$

$$s.t. \begin{cases} \sum_{j=1, j \neq k}^n x_{ij} \lambda_j - s_i^- \leq x_{ik} \\ \sum_{j=1, j \neq k}^n y_{rj} \lambda_j + s_r^+ \geq y_{rk} \\ \sum_{j=1, j \neq k}^n y_{tj}^b \lambda_j - s_t^{b-} \leq y_{tk}^b \\ 1 - \frac{1}{q_1 + q_2} \left(\sum_{r=1}^{q_1} \frac{s_r^+}{y_{rk}} + \sum_{t=1}^{q_2} \frac{s_t^{b-}}{y_{tk}^b} \right) > 0 \\ \lambda, s^+, s^- \geq 0 \end{cases} \quad (1)$$

It is assumed that there exist n DMUs, and in each DMU, there are m production input factors, q_1 desirable output factors and q_2 undesirable output factors. ρ represents GEE, s_i^- , s_r^+ , s_t^{b-} are slack variables for input factors, desirable output and undesirable output factors, respectively; In the k th DMU, x_{ik} , y_{rk} , y_{tk}^b are the i th input parameter, the r th desirable output and the t th undesirable output parameter, respectively; λ is the weight vector.

3. Research Design

3.1. Research Hypothesis

Green total factor productivity is an important economic development index that takes environmental protection into account. In terms of environmental protection, digital trade, with the characteristics of clean technology and environmental friendliness, promotes the development of various industries in the direction of low energy consumption and achieves pollutant emission reduction. In terms of economic output efficiency, with the strong support of digital technology, the operating costs of the industry can be reduced, production efficiency can be improved, and industry value-added can be promoted. In summary, this paper proposes:

Hypothesis 1: The establishment of cross-border e-commerce comprehensive pilot area can improve the green total factor productivity in the region.

The establishment of cross-border e-commerce comprehensive pilot areas can integrate domestic and foreign resources and introduce advanced green technology and management experience to the region. Cross-border e-commerce breaks the geographical restrictions of traditional trade and enables regions to participate in international economic cooperation more widely. In this process, the policy support and platform advantages of the comprehensive pilot area will help attract the inflow of foreign green technology resources and provide external impetus for regional green technology innovation. Through the cross-border e-commerce platform, enterprises can more easily access the international leading green technology products and solutions, so as to stimulate local enterprises to carry out technological learning and innovation, in order to improve their own green development level; At the same time, the construction of cross-border e-commerce comprehensive pilot area will attract a large number of e-commerce enterprises and related industries to gather, intensifying market competition. Under the pressure of competition, enterprises will increase their investment in green technology innovation in order to gain competitive advantage. In summary, this paper proposes:

Hypothesis 2: The establishment of cross-border e-commerce comprehensive pilot area can improve green total factor productivity by promoting regional green technology innovation.

3.2. Research Model

3.2.1. Multi-Stage Difference-Difference Model

Considering the differences in the time when cross-border e-commerce comprehensive pilot zones are set up in each prefecture-level city, this paper constructs a multi-phase differential model to more accurately evaluate the policy effects of cross-border e-commerce comprehensive pilot zones with differences at the regional and time levels. Because the construction project of the cross-border e-commerce comprehensive pilot zone was not obtained in the same year, it also indicates that the time point and region of the cross-border e-commerce compre-

hensive pilot zone are different, so the traditional DID method is not appropriate in this situation. Based on this, we evaluated the impact of cross-border e-commerce comprehensive pilot zone policies on China's green total factor productivity through a multi-period DID approach. The specific model is set as follows:

$$ENTAY_{it} = \alpha_0 + \alpha_1 DIGE_{it} + \alpha_2 Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

wherein, the explained variable $GTFP_{it}$ represents the green economic efficiency of city i in year t ; The core explanatory variable was $Zone_{it}$, the policy dummy variable of cross-border e-commerce comprehensive pilot area. X_{it} is a set of control variables; λ_i and λ_t are regional fixed effects and time fixed effects, and ε_{it} is a random disturbance term.

3.2.2. Intermediary Effect Model

Formula (1) reflects the direct effect of cross-border e-commerce comprehensive pilot area policies on green total factor productivity. In order to verify its intermediary path, this paper sets an intermediary effect model, which is set as follows:

$$MV_{it} = \beta_0 + \beta_1 DIGE_{it} + \beta_2 Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

$$ENTAY_{it} = \alpha_0 + \alpha_1 DIGE_{it} + \alpha_2 MV_{it} + \alpha_4 Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

Among them, M_{it} refers to the intermediary variable—green technology innovation.

3.3. Variable Selection

3.3.1. Explanatory Variable

The core explanatory variable of this paper is the cross-border e-commerce comprehensive pilot zone policy. The explanatory variable in this paper is the policy of cross-border E-commerce Integrated Pilot Zone ($Zone_{it}$), which is a dummy variable. In this paper, the pilot cities of the five batches of cross-border e-commerce comprehensive pilot zones are selected as the policy time points in 2015, 2016, 2018, 2019 and 2020 respectively. Assuming that city i is not included in the list of the five batches of pilot zones, the zone value is 0; if the i city is in the list of cross-border e-commerce comprehensive pilot areas, and the pilot starts in year t , the Zone value in year t and after is 1, and the previous Zone value is 0.

3.3.2. Explained Variable

The explained variable is green total factor productivity. In order to reduce the estimation error, the super efficiency SBM model we mentioned above will be used to measure the green total factor productivity. Below are instructions for the construction of specific input and output indicators in the model.

Input indicators: Energy Input. This paper chooses to measure the energy consumption in terms of ten thousand tons of standard coal. Where the conversion factor for natural gas to standard coal is 13.3 tce/10,000 m³, for liquefied petroleum gas is 1.7143 tce/t, and for electricity is 1.229 tce/10,000 kW·h. Capital Input: Calculated using the perpetual inventory method. Refer to (Zhang, 2004), the depreciation rate is set at 9.6%. Labor Input: The number of employees is used as a proxy indicator for labor input at the prefecture-level city.

Output indicators include desirable and undesirable outputs. Desirable output. In this paper, the GDP of the prefecture-level city is used as the desirable output indicator. Specifically, this paper uses the provincial GDP deflator to convert the regional GDP of 2006 to constant prices. Undesirable outputs include industrial wastewater, industrial fume and SO₂.

3.3.3. Intermediate Variable

Mechanism of cross-border e-commerce comprehensive pilot area policies on green economic efficiency from the perspective of green technology innovation. Among them, the green technology innovation was measured by the number of total green patent applications at the prefecture-level city in the year, and the data came from the State Intellectual Property Office.

3.3.4. Control Variable

In order to control other variables that may affect urban green total factor productivity, the control variables selected in this paper mainly focus on five aspects: population density, economic development level, financial development level, and government intervention level and urbanization level.

Population density (Pd) has an impact on urban green total factor productivity, which is measured by the ratio of regional resident population to urban area in this paper.

Xu X. F. (2023) deeply discussed the relationship between economic development level (Leo) and green total factor productivity, which was measured by per capita gross regional product (logarithm) in this paper.

Financial development Degree (Fd), which uses the ratio of outstanding loans of financial institutions to regional GDP, found that financial development significantly promoted green total factor productivity (GTFP).

The Urban level (Urban-lev) is derived from the statistical bulletins issued by each bureau of Statistics. In this paper, the proportion of urban permanent residents in the total local permanent residents is measured. Moderate urban sprawl has a significant improvement effect on green total factor productivity, but excessive sprawl may have an inhibitory effect [9].

The degree of government intervention (GI) is also an important factor affecting green total factor productivity [10]. Limited government intervention in the economic market can regulate resource allocation and alleviate problems such as monopoly and information asymmetry caused by market failure [11], which is conducive to the improvement of green total factor productivity. However, if the government intervenes too much in the market, it will disturb the market order, fail to adjust to a series of problems caused by market failure, and further cause the inefficiency of resource allocation, which is not conducive to the improvement of green total factor productivity. In this paper, the proportion of local fiscal expenditure to local GDP is used to measure the degree of government intervention.

3.4. Data Source

The sample observation period of this paper is from 2006 to 2021, and the selected

samples cover 280 prefecture-level cities. Relevant data are derived from the China City Statistical Yearbook, China Energy Yearbook and China Carbon Accounting Database (CEAD) of prefecture-level cities and Wind Database. Missing values are supplemented by linear interpolation.

4. Empirical Result Analysis

4.1. Baseline Model Regression

This paper first uses OLS estimation to investigate the static effect of the establishment of cross-border e-commerce comprehensive pilot zone on the improvement of green total factor productivity. Model (3) shows the effect of the establishment of cross-border e-commerce comprehensive pilot zone on green total factor productivity after adding control variables under the fixed individual effect and time effect, and the specific results are shown in **Table 1**. The estimated coefficient of the virtual variables in the cross-border e-commerce comprehensive pilot area for green total factor productivity is significantly positive, and is significant at the significance level of 1%, which indicates that the cross-border e-commerce comprehensive pilot area has a significant promoting effect on the improvement of green total factor productivity, and hypothesis 1 is verified.

Table 1. Impacts of cross-border e-commerce comprehensive pilot areas on urban green total factor productivity.

VARIABLES	(1)	(2)	(3)
	OLS	OLS	FIXED EFFECT
<i>Zone</i>	0.159*** (11.54)	0.103*** (7.85)	0.072*** (7.23)
<i>Pd</i>		0.016*** (5.88)	-0.025 (-1.22)
<i>Leo</i>		0.086*** (21.14)	0.020** (2.19)
<i>Fd</i>		-0.009*** (-3.82)	0.008*** (2.82)
<i>Urban-lev</i>		0.062*** (2.96)	-0.142*** (-4.67)
<i>Gl</i>		-0.112*** (-5.63)	-0.037 (-1.19)
<i>Constant</i>	0.311*** (170.15)	-0.615*** (-17.18)	0.274* (1.89)
Individual fixation effect	No	No	Yes
Time-fixed effect	No	No	Yes
Observations	4,480	4,480	4,480
Adjusted R-squared	0.069	0.213	0.662

4.2. Robustness Test

In order to verify the robustness of the conclusion that the establishment of cross-border e-commerce comprehensive pilot areas can significantly promote the improvement of urban green total factor productivity, this paper adopts parallel trend test, replacing the measurement indicators of explained variables, replacing standard errors, shrinking tail processing and other methods to conduct robustness tests.

4.2.1. Parallel Trend Test

The prerequisite for the validity of the conclusion of the multi-period differential model is that the model passes the parallel trend test, that is, there is no significant difference in green total factor productivity between the experimental group and the control group before the implementation of the cross-border e-commerce comprehensive pilot area policy. As can be seen from **Figure 1**, parallel trend test chart, the core explanatory variables were not significant before the implementation of the policy, which indicates that the change trend of green total factor productivity in the region with the cross-border e-commerce comprehensive pilot area is consistent with that in other regions before the implementation of the policy. In the year of policy implementation, there was a significant difference in the GTFP rate between the experimental group and the control group, indicating that the cross-border e-commerce comprehensive pilot area policy can effectively improve regional GTFP, and the model satisfies the parallel trend hypothesis. From the perspective of time heterogeneity, it can be seen that the effect of the cross-border e-commerce comprehensive pilot zone policy is “sustainable”. From the year when the cross-border e-commerce comprehensive pilot zone was established to the fifth year after its establishment, the green economy efficiency of the pilot cities has been improved year by year. That is, with the implementation and deepening of the cross-border e-commerce comprehensive pilot zone, the effect of the cross-border e-commerce comprehensive pilot zone policy has been continuously strengthened.

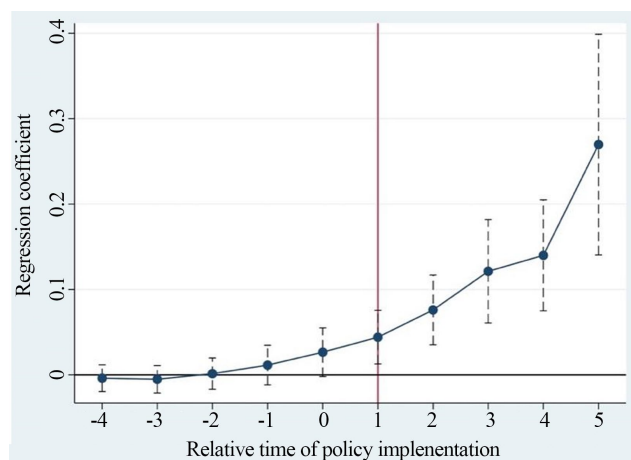


Figure 1. Parallel trend test diagram.

4.2.2. Replace the Dependent Variable

In this paper, the superefficient CCR model is used to replace the superefficient SBM model when measuring green total factor productivity, although the super-efficient SBM model is more accurate when dealing with non-radial efficiency. The superefficient CCR model is equally effective when dealing with radial efficiency and can provide further differentiation from efficient DMUs. The regression results are still significant, further increasing the robustness of the conclusion that the establishment of cross-border e-commerce comprehensive pilot areas can significantly promote the improvement of urban green total factor productivity.

4.2.3. Replace Clustering Standard Error

In regression analysis, clustering standard error is a common robustness test method, especially when dealing with panel data. Clustering standard errors can effectively deal with intra-group correlations and provide more accurate standard error estimates. Therefore, by clustering standard errors from the provincial level, this paper can more accurately assess the impact of cross-border e-commerce comprehensive pilot areas on green total factor productivity. The clustering criteria mistakenly consider the correlation between observations within the provinces, and the regression results are still significant, as shown in **Table 2**, which also provides a more robust statistical inference.

4.2.4. Tailing Treatment

Tailgating is a data preprocessing method used to reduce the impact of extreme values on statistical analysis. By replacing extreme values with some threshold (usually some percentile), you can make the data more robust. In this paper, 99% tail reduction ratio is used for tail reduction processing of control variables and explained variables, and then the panel data after processing is regressed, as shown in **Table 2**. We can find that even after tail reduction processing, the impact of cross-border e-commerce comprehensive pilot area on green total factor productivity is still significant, and the result is robust.

4.3. Analysis of Influence Mechanism

Green technology innovation is the fundamental driving force to promote low-carbon transformation. Since total green patents can more directly reflect the green technology innovation ability and quality of cities, this paper takes the number of green patent applications in prefecture-level cities as the intermediary variable, and adopts Equations (2) and (3) for regression. From the results of column (3) in **Table 2**, it can be seen that the policy of cross-border e-commerce comprehensive pilot area can effectively stimulate the innovation vitality of pilot cities and promote urban green technology innovation. Column (2) indicates that green technology innovation plays a partial intermediary role; that is, the implementation of the cross-border e-commerce comprehensive pilot zone policy will promote green technology innovation, and then promote the growth of green total factor productivity. Hypothesis 2 is verified.

Table 2. Mediation mechanism test.

VARIABLES	(1)	(2)	(3)
	GTFP	Green technology innovation	GTFP
<i>Total number of green patent applications</i>			0.000*** (8.75)
<i>Zone</i>	0.072*** (7.23)	2491.053*** (12.92)	0.030*** (3.01)
<i>Pd</i>	-0.025 (-1.22)	731.075*** (3.31)	-0.037* (-1.89)
<i>Leo</i>	0.020** (2.19)	-415.143*** (-3.99)	0.027*** (2.97)
<i>Fd</i>	0.008*** (2.82)	84.181* (1.88)	0.007*** (2.69)
<i>Urban-lev</i>	-0.142*** (-4.67)	-3101.927*** (-4.05)	-0.090*** (-3.27)
<i>Gl</i>	-0.037 (-1.19)	-2517.356*** (-6.21)	0.006 (0.19)
<i>Constant</i>	0.274* (1.89)	2243.230 (1.39)	0.236* (1.68)
Individual fixation effect	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes
Observations	4480	4480	4480
Adjusted R-squared	0.662	0.698	0.676

5. Conclusion

The research shows that: 1) Cross-border e-commerce comprehensive pilot zone policies can significantly improve the green TFP of pilot cities. This conclusion has passed a series of robustness tests such as parallel trend verification, replacement variable, replacement standard error, and tail shrinkage processing. 2) The policies of cross-border e-commerce comprehensive pilot areas affect urban green total factor productivity mainly through the means of green technology innovation. In view of the above conclusions, this paper puts forward the following suggestions: First, continue to deepen reform, rely on institutional innovation, improve the cross-border e-commerce comprehensive pilot zone upgrading strategy, and release the policy advantages of cross-border e-commerce comprehensive pilot zone. Second, from the point and line to the surface, expand the cross-border e-commerce comprehensive pilot area policy to enhance the radiation range of green innovation efficiency by promoting green technology innovation.

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Conflicts of Interest

The author declares no conflicts of interest.

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