

The Impact of Foreign Trade on Green Total Factor Productivity

-- Empirical Test based on 21 Prefecture-level Cities in Guangdong Province

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Abstract

Green development and the construction of a strong trade country have attracted great attention from all walks of life. Based on the theoretical explanation of the connotation and mechanism of foreign trade on green total factor productivity (GTFP), we use prefecture and city-level panel data of Guangdong Province from 2006 to 2021 to measure regional GTFP with the help of the SBM model of non-expected output and the Malmquist-Luenberger index, and construct a spatial Durbin model to empirically examine the the impact of foreign trade on GTFP. The results show that: (1) There is a significant spatial correlation of GTFP in Guangdong Province. (2) Current foreign trade is conducive to the enhancement of regional GTFP in Guangdong Province, and export trade has a significant negative effect on the growth of regional GTFP and an inhibitory effect on the enhancement of neighboring regions' GTFP; whereas, import trade exhibits a significant positive contribution to the growth of local GTFP, and the indirect effect on neighboring regions' GTFP is significantly positive.

Keywords

Foreign Trade; Green Total Factor Productivity; Guangdong Province; Pearl River Delta City Cluster; Spatial Durbin Modeling.

1. Research Background

Since the reform and opening up, China's economic level has increased rapidly, but in the meantime of social development, the contradiction between economic growth and environmental resources has become more and more prominent, ecological imbalance, energy depletion, etc. make people's life affected, and the economic development has been inhibited to a certain extent, the prevention and control of environmental pollution and the construction of a strong trade country are important paths for China to realize high-quality development in the new era (Xu and Deng, 2022). Guangdong Province, as the center of China's economic development, the establishment of special economic zones, the promotion of the "Belt and Road" initiative, and the successive opening of the China-European Union (CEU) liner train have all brought important development opportunities for the region, and in 2022, the resident population of Guangdong Province will be more than 120 million people, with a total economic volume of more than 12.9 trillion yuan, and the total amount of foreign trade of around 8309,811 billion RMB, with import and export trade accounting for 19% of the country's total, indicating that foreign trade plays a huge role in contributing to the economic development of Guangdong Province, and is the key to the future economic development of Guangdong Province. Under the premise of comprehensively considering the opening up of the foreign economy and environmental benefits, can Guangdong Province achieve a balanced development of the two? How does foreign trade affect the green total factor productivity of

Guangdong? Are there diffusion and spillover effects among different regions? All these questions deserve further in-depth analysis, so this paper intends to study the mechanism of foreign trade on the green total factor productivity of 21 prefectural-level cities in Guangdong Province to analyze the mechanism, in order to provide research ideas for promoting the improvement of green total factor productivity in the region and realizing the high-quality sustainable development of Guangdong Province's economy.

2. Literature Review

2.1. Studies on Foreign Trade

Foreign trade refers to the exchange of commodity goods or services between countries or regions and other countries or regions in the world on the basis of international industrial division of labor and economic exchange, which can effectively reflect the degree of a country's or region's participation in the international division of labor, and can also effectively measure the degree of opening up of a country's or region's economic development to the outside world. Since the reform and opening up, China's foreign trade has gone through an evolutionary process from gradually opening up the protection-oriented trade to the new development pattern which is mainly based on the internal cycle, to the internal and external cycle promoting each other (Cheng , 2021). The world economic situation is facing a lot of uncertainty in the macro-environment, and the smooth operation of the economy requires the synergistic development of the two major domestic and international markets to form new economic growth points, and the study of China's foreign trade pattern, kinetic energy and trends is conducive to the formation of industrial competitive advantages and the cultivation of the "two markets" to produce a significant positive linkage effect (Li, 2021). In terms of research areas, Fu and Zhang (2020) believe that the Guangdong-Hong Kong-Macao Greater Bay Area should rationally allocate energy resources in the east and west of the region, and promote the balanced development of the east and west coasts to increase the ability to cope with risks; the Pearl River Delta Economic Zone has a natural economic foundation, and it is important to take advantage of its externally oriented economy to strengthen the macro-guidance of the utilization of foreign capital, and to give full play to the dual role of the upgrading of the industrial structure in driving the growth of the economy and the development of foreign trade (Zhong and Shao , 2022).

2.2. Connotation and Measurement of Green Total Factor Productivity

Productivity theory has been developed along with the development of economic growth theory, from the rise of classical economic growth theory, economists have emphasized the important role of labor productivity, with the development of economic growth theory, productivity theory has roughly gone through the development process of single-factor productivity, total factor productivity, and Green Total Factor Productivity Theory (Li,2012). The concept of Green Total Factor Productivity (denoted as GTFP) was developed on the basis of the concept of Total Factor Productivity (denoted as TFP), and the mutual constraints between environmental factors and the economy were not reflected in the traditional factor measurement, resulting in the calculation results can not reflect the impact of environmental constraints in actual economic operation, resulting in the deviation of the calculation results. Total factor productivity measures can be broadly categorized into four types: the algebraic index method, the Solow residual method, the stochastic frontier production function (SFA) method, and the data envelopment analysis (DEA) method. The productivity calculation methods on this basis are also of three types, which are, in order, the Malmquist Productivity Index, the Malmquist-Luenberger Productivity Index , and the Luenberger Productivity Index.

2.3. The Impact of Foreign Trade on Green Total Factor Productivity

A considerable number of scholars have studied the impact of foreign trade on green total factor productivity (TFP), subdividing foreign trade to analyze the impact of import trade and export trade on green TFP, and the results of the studies generally agree that export trade has a significant negative impact on the growth of green TFP in the region (Song and Wang, 2022; Wang and Cai, 2022; Cheng, 2021); on the import side, Wang and Zhang (2012) argued that the technological spillovers as well as the competition effect brought by import trade would enhance the region's green total factor productivity, but the results may not be significant, while Wang Jingjing & Chen (2017) argued that the promotion effect of import trade on local green total factor productivity would only be obvious when the local economic development level reaches a certain threshold value.

However, academic research on foreign trade on green total factor productivity still has the following shortcomings: first, at the level of green total factor productivity measurement methods, less involved in analyzing the dynamic evolution characteristics and spatial distribution characteristics of green total factor productivity; second, in terms of the relationship between foreign trade and green total factor productivity, most of the literature in the research perspective is mainly from the overall level of the country, the industrial or manufacturing industry and other specific industry. Secondly, in terms of the relationship between foreign trade and green total factor productivity, most of the literature focuses on the overall national level, specific industries such as industry or manufacturing, and lacks of research on prefecture-level cities. Therefore, this paper combines the two themes of foreign trade and green total factor productivity, explores the role of the relationship between the two, and conducts a study on the panel data of prefecture-level cities, observes their evolution characteristics and spatial spillover effects using spatial models, and proposes a path of reflection accordingly, so as to provide a reference basis for the development of the region.

3. An Empirical Analysis of the Impact of Foreign Trade on Green Total Factor Productivity

3.1. Measuring Green Total Factor Productivity in Guangdong Province

In order to be able to consider the non-expected output and at the same time consider the slack variables of inputs and outputs in the objective function, and to effectively solve the problem of insufficient inputs and outputs as well as the problem of slack variables of the efficiency measure (Wu, 2020), this paper considers the SBM directional distance function with non-expected output, and in order to be able to consider non-expected outputs more comprehensively, this paper adopts Chung et al.'s (1997) development of the Malmquist-Luenberger (ML) productivity index, which is more suitable for measuring green total factor productivity indicators.

For the selection of relevant indicators, in the measurement of green total factor productivity, there are generally three first-level indicators, which are: input variables, desired output variables and non-desired output variables, and based on the principles of representativeness, availability and scientificity, this paper selects the above three basic indicators as the important first-level indicators for measuring green total factor productivity, drawing on the basis of many scholars' researches. For the selection of secondary indicators or sub-indicators, around the first-level indicators, academics generally measure nine secondary indicators, such as labor force, capital stock, energy consumption, real GDP, industrial sulfur dioxide, industrial wastewater, general industrial solid waste or industrial fume and dust, and comprehensive pollution indicators (Wu and Yao, 2021; Yuan et al., 2020).

3.2. Spatial Autocorrelation Test

According to the average green total factor productivity of each prefecture-level city above, there is an obvious regional differentiation of distribution characteristics within the Guangdong Province region, in order to further test the existence of spatial correlation and the nature and strength of the spatial correlation, the spatial correlation of the green total factor productivity of the observed prefecture-level cities is measured by importing the identified spatial matrix, which is also one of the important bases for the construction of a reasonable spatial econometric model. This judgment is also one of the important bases for constructing a reasonable spatial measurement model. In this subsection, the green total factor productivity of each prefecture-level city in each year is taken as the sample for analysis, and the global Moran index and local Moran index are analyzed at the same time, supplemented by Moran scatter plot to show the aggregation effect in spatial dimension more intuitively.

3.2.1. Global Moran Index

According to the global Moran Index I, there is a significant positive spatial correlation between the green total factor productivity level of Guangdong Province as a whole. Combined with Geoda's more detailed division of the Z and P values, the Z value is located in the range of 1.65-1.96 during the period of 2007-2011, with a P-value of less than 0.05, and the Z value is greater than 1.96 after 2011, with a P-value of less than 0.05. After 2011, the Z-value is greater than 1.96, and the P-value is less than 0.05, indicating that most of the years have passed the test of 95% confidence level, and that within the observed regions and years, the green total factor productivity shows an obvious spatial aggregation effect of "high-high, low-low", and the degree of aggregation is on a fluctuating upward trend.

Table 1. Green Total Factor Productivity Moran Index Test for Guangdong Province Results

| Year | I | z | p-value* | Year | I | z | p-value* |
|------|---------|-------|----------|------|----------|-------|----------|
| 2007 | 0.182** | 1.836 | 0.033 | 2015 | 0.175** | 2.009 | 0.022 |
| 2008 | 0.186** | 1.883 | 0.030 | 2016 | 0.186*** | 2.332 | 0.010 |
| 2009 | 0.155** | 1.722 | 0.042 | 2017 | 0.200*** | 2.470 | 0.007 |
| 2010 | 0.148** | 1.832 | 0.033 | 2018 | 0.186*** | 2.349 | 0.009 |
| 2011 | 0.161** | 1.787 | 0.037 | 2019 | 0.232*** | 2.379 | 0.009 |
| 2012 | 0.185** | 2.017 | 0.022 | 2020 | 0.218** | 2.307 | 0.011 |
| 2013 | 0.192** | 2.019 | 0.022 | 2021 | 0.176** | 2.159 | 0.015 |
| 2014 | 0.187** | 2.080 | 0.019 | | | | |

3.2.2. Localized Moran Index Test

From the figure below and the collated table of drop locations, most cities are located in the first and third quadrants, which is consistent with the test results of the global Moran Index. In terms of specific characteristics, the cities located in the first quadrant over the years include Guangzhou, Shenzhen and Foshan, indicating that these cities have high green total factor productivity on their own and are surrounded by other high-value cities. The second quadrant shows cities with low values that are surrounded by high-value cities, which are also the most affected by spillover and diffusion effects, represented by Zhongshan, Huizhou and Zhaoqing. There are more cities that are always in the third quadrant or fall into the third quadrant later, such as Maoming, Shantou, Jiangmen, Yangjiang, Meizhou, Yunfu, Jieyang, Heyuan, Zhanjiang, Qingyuan, etc., which represent low-value cities surrounded by low-value cities, and these cities

may have the problem of sloppy development that pursues economic growth unilaterally and ignores environmental protection, which is mainly found in the western and mountainous regions of Guangdong Province.

In the early years of the test, the gap between the green total factor productivity of the cities is small, so there are more cities located in the first quadrant, with the intensification of the development of Guangzhou, Shenzhen, Foshan, Dongguan, etc., and gradually pull the gap with the rest of the region, and it is difficult to have cities to fall point again in the first quadrant, so its neighboring cities will gradually fall into the second quadrant, and it is impossible to judge the absolute low value of their green total factor productivity one-sidedly.

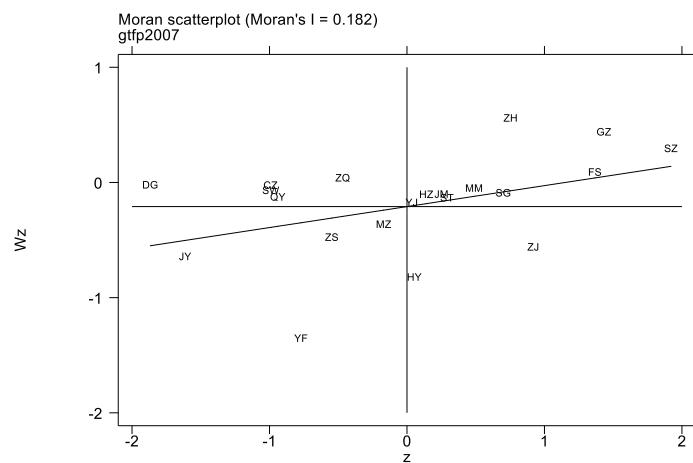


Figure 1. Scatterplot of localized Moran's index, 2007

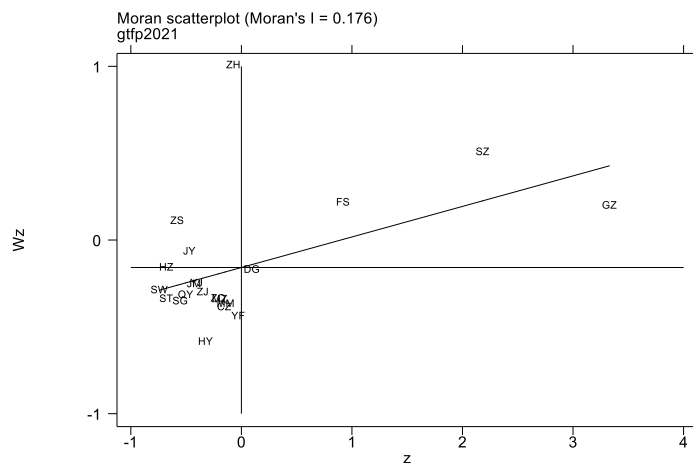


Figure 2. Scatterplot of localized Moran's index, 2021

3.3. Spatial Measurement Regression Analysis

3.3.1. Variable Setting and Interpretation

The selection of indicators is based on the green total factor productivity calculated above, and the selection of indicators for other variables and data description are explained below:

(1) Explained Variables (GTFP)

In this paper, green total factor productivity is selected as an explanatory variable, and the data are derived from the above SBM model, green total factor productivity measured by ML index, and recalculated fixed ratio data.

(2) Explanatory variables (EX, IM, TRA)

The focus of this paper is to explore the impact of foreign trade on green total factor productivity, which is measured by taking import and export trade dependence and export trade dependence as the core explanatory variables and applying the ratio between foreign trade amount and GDP. Due to the strong endogeneity between import and export trade dependence and import trade dependence, only import trade dependence is observed as a control variable for export trade dependence.

(3) Control variable

Industrial structure (IND): industrial structure refers to the proportion of regional output value of each industry in the regional economy, this paper adopts the proportion of the secondary industry in GDP to measure the industrial structure.

The degree of foreign investment (FDI): the degree of foreign investment can reflect the degree of openness of a region, this paper adopts the proportion of foreign direct investment in total GDP to explain the control variable.

Government intervention (GOV): the government is responsible for the macro-control of the country and the region, government policy, intervention or support, etc. affects the flow of resources and the direction of aggregation, this paper adopts the proportion of government expenditure to the total GDP as an indicator to measure the strength of government intervention.

Human capital level (HC): the level of human capital determines the quality of the level of labor force, this paper uses the ratio of the number of students enrolled in tertiary education to the resident population at the end of the year to reflect the level of human capital.

With environmental regulation intensity (REG): environmental regulation plays a direct role in protecting the environment, which also means that more costs need to be invested, this paper adopts the proportion of SO₂ even love emissions and industrial output value to measure, the higher the proportion indicates that the lower the level of environmental regulation.

Infrastructure development (INF): Infrastructure development represents to some extent the level of development of the town and is measured by the ratio of road mileage to the number of resident population, i.e., mileage per capita.

This paper selects 15 years of data from 21 prefecture-level cities in Guangdong Province from 2006 to 2021, totaling 315 samples, with individual outliers shrinking the tails, and in order to eliminate the effects of variance and order of magnitude among variables, this paper expands the units for individual variables with larger order of magnitude.

Table 2. Descriptive statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|----------|-----|-------|-----------|-------|-------|
| GTFP | 315 | 1.009 | 0.210 | 0.775 | 2.351 |
| EX | 315 | 0.348 | 0.342 | 0.021 | 1.884 |
| IM | 315 | 0.213 | 0.283 | 0.006 | 1.818 |
| TRA | 315 | 0.561 | 0.612 | 0.034 | 3.388 |
| FDI | 315 | 0.020 | 0.018 | 0.001 | 0.062 |
| GOV | 315 | 0.147 | 0.059 | 0.070 | 0.287 |
| REG | 315 | 0.518 | 0.718 | 0.001 | 0.529 |
| INF | 315 | 0.058 | 0.073 | 0.002 | 0.437 |
| HC | 315 | 0.012 | 0.017 | 0.002 | 0.066 |

3.4. Selection and Construction of Spatial Models

Referring to the practice of related papers, this paper utilizes the spatial Durbin model that contains both the spatial lag terms of the explanatory and interpretive variables to conduct the study with the following model setup:

$$GTFP_{it} = \beta_0 + \rho WGTFP_{it} + \beta_1 TRA_{it} + \beta_2 X_{it} + \sigma_1 WTRA_{it} + \sigma_2 WX_{it} + \varepsilon_{it}$$

$$GTFP_{it} = \beta_0 + \rho WGTFP_{it} + \beta_1 EX_{it} + \beta_2 IM_{it} + \beta_3 X_{it} + \sigma_1 WEX_{it} + \sigma_2 WIM_{it} + \sigma_3 WX_{it} + \varepsilon_{it}$$

$$\varepsilon_{it} = \lambda W \varepsilon_{it} + \mu_{it} \sim (0, \sigma_{it}^2)$$

In the above model expression, *i* stands for prefecture-level city (*i*=1,2..... 21), *t* stands for year, *W* is the constructed spatial weight matrix, *X* is the set of control variables, which includes FDI, GOV, REG, INF, HC, and IND; ε is the random perturbation term; ρ and σ are the coefficients of the spatial lag terms of the explanatory and explanatory variables, respectively, the degree of influence and spatial dependence between the variables; and λ is the coefficient of the spatial error term, which reflects the spatial relationship in the random error perturbation term. existence of spatial relationships.

3.5. Analysis of Empirical Results

Based on the results of the above selection and test, this paper carries out the regression analysis of the spatial Durbin model under double fixed effects by using STATA16.0 software based on the collated data of 21 prefectural-level cities in Guangdong Province from 2007-2021, and a total of the following two models are set up to carry out the regression respectively. Model (1) is a spatial Durbin model regression with total foreign trade dependence as the key explanatory variable, and model (2) is a regression model with export trade dependence as the core explanatory variable.

3.5.1. Analysis of Regression Results

Table 3. Spatial Durbin model regression results

| Variant | Model 1 | Model 2 |
|----------------|-------------------|-------------------|
| TRA | | 0.199*** (4.60) |
| EX | -0.182* (-1.68) | |
| IM | 0.636*** (5.91) | |
| FDI | -0.826 (-1.60) | -1.051* (-1.94) |
| GOV | -1.298*** (-3.77) | -1.491*** (-4.12) |
| REG | 0.020 (1.14) | 0.037** (2.04) |
| INF | 2.922*** (8.07) | 2.511*** (6.69) |
| HC | 0.338 (0.11) | -1.761 (-0.56) |
| IND | 0.266 (1.58) | 0.395** (2.26) |
| rho | -0.956*** (-3.69) | -0.753*** (-2.98) |
| Observations | 315 | 315 |
| Log-Likelihood | -850.9522 | -1511.4364 |

Note: z-statistics in parentheses ****p*<0.01, ***p*<0.05, **p*<0.1.

The autoregressive coefficients of models 1 and 2 are significantly negative, and the results show that the rho values are -0.956 and -0.753 and both pass the 1% significance test, which indicates that the green TFP has spatial and dependence within the Guangdong province region, i.e., the improvement of the green TFP in the region will inhibit the development of the green TFP in the other regions, which may be due to the occurrence of the transfer of polluting industries and the spread of pollution, etc.

Import trade on the green total factor productivity in Guangdong Province is heterogeneous, which may be due to the following reasons. First, due to the advantages of geographic location as well as transportation conditions, the competitive advantage of the market is obvious, and

the process of further upgrading and optimizing the foreign trade export structure makes the export trade have a significant positive impact on the regional green productivity. Secondly, although Guangdong's foreign trade exports are dominated by electromechanical products and manufactured goods, including machinery and equipment, their technological content is not high, and the long-term reliance on a low level and low value-added market expansion mode has led to foreign trade not being able to promote the improvement of regional green total factor productivity. Thirdly, for Guangdong's import trade, its promotion effect on the overall green total factor productivity level of the region is obvious, and the absolute value of the coefficient is significantly higher than that of the export trade, indicating that the region in the development of the import trade in the process of importing foreign high-technology and high-value-added products is stronger, and the technology spillover effect of the import trade and the driving force of the green total factor productivity are still showing obvious.

3.5.2. Analysis of Spatial Spillover Effects

Table 4. Spatial spillover results

| | Model 1 | | | Model 2 | | |
|-----|-----------|------------|------------|-----------|------------|------------|
| | DIRECR | INDIRECT | TOTAL | DIRECR | INDIRECT | TOTAL |
| TRA | | | | 0.227*** | -0.419*** | -0.237** |
| | | | | (4.96) | (-2.95) | (-2.30) |
| EX | 0.045 | -2.926*** | -2.881*** | | | |
| | (0.41) | (-5.13) | (-4.79) | | | |
| IM | 0.501*** | 1.717*** | 2.219*** | | | |
| | (5.29) | (3.52) | (4.17) | | | |
| FDI | -0.180 | -12.553*** | -12.373*** | -0.251 | -13.519*** | -13.770*** |
| | (-0.37) | (-4.53) | (-4.27) | (-0.49) | (-4.17) | (-4.13) |
| GOV | -1.222*** | -1.142 | -2.364 | -1.365*** | -1.542 | -2.907 |
| | (-3.44) | (-0.66) | (-1.44) | (-3.77) | (-0.82) | (-1.59) |
| REG | 0.010 | 0.139 | 0.149 | 0.020 | 0.301*** | 0.321*** |
| | (0.67) | (1.57) | (1.57) | (1.19) | (3.02) | (2.97) |
| INF | 3.277*** | -4.601*** | -1.325 | 2.852*** | -5.363*** | -2.511** |
| | (8.61) | (-4.05) | (-1.27) | (6.68) | (-3.99) | (-2.05) |
| HC | -2.849 | 42.523*** | 39.674*** | -3.768 | 37.134*** | 33.367** |
| | (-0.95) | (3.39) | (3.03) | (-1.26) | (2.71) | (2.32) |
| IND | 0.189 | 0.964 | 1.153* | 0.366** | 0.642 | 1.008 |
| | (1.25) | (1.41) | (1.68) | (2.11) | (0.84) | (1.27) |

The level of foreign trade (TRA) positively affects the green total factor productivity of the region and passes the significance test at the 1% level, with each unit increase in foreign trade dependence in Guangdong Province increasing the green total factor productivity of the region by 0.227 units and decreasing the green total factor productivity of neighboring regions by 0.419 units. Further, the estimation results of the spatial regression of the import and export trade dependence subdivided into export trade dependence (EX) and import trade dependence (IM) show that, on the one hand, the export has a non-significant positive effect on the green total factor productivity of the region, and in combination with the spillover effect, it has a negative effect on the neighboring regions, which indicates that the competition effect of export products between regions in Guangdong Province is obvious, and that the intra-regional competition will result in more serious resources. This indicates that the competition effect of export products between regions in Guangdong Province is obvious, and intra-regional competition will cause more serious resource waste problems. On the other hand, import trade

is conducive to the enhancement of local green total factor productivity, and has a strong positive spillover and diffusion effect on the neighboring regions at a significant level of 1%, which indicates that the advanced management experience and technology brought by import trade can significantly drive the development of the local area, and the technological spillovers from the imported technology can positively affect the neighboring regions, promoting the synergistic development of green total factor productivity.

In terms of control variables, the empirical results show that the introduction of foreign investment may introduce foreign polluting enterprises into the country, which will adversely affect the environment of the local and neighboring regions; the intensity and measures of government intervention can significantly affect the development of GTFP in the region, and the core of green, coordinated, and sustainable development makes it necessary for enterprises to invest more resources, which will change the curve of the relationship between costs and benefits within a certain period of time. Environmental regulation has a non-significant role in promoting GTFP in the region, indicating that the current environmental regulation measures are not effective enough to balance ecological protection and economic development, but there is still room for optimization of the implementation path; the impact of human capital on the local green total factor productivity is negative, which is not in line with the conventional reality, but combined with the analysis of the long-term and short-term effects of the dynamic model, it can significantly affect the development of GTFP in the region. The analysis of long-term and short-term effects of the model shows that the benefits of human capital investment take some time to obtain, and there may be large differences in human capital between regions, brain drain, inter-regional development is not balanced, etc.; the impact of the industrial structure on green total factor productivity is a positive role in promoting, which indicates that the industrial structure of Guangdong Province is realizing a shift in the direction of the development of a green economy in favor of the region, and that the overall industrial structure transformation and upgrading has initially achieved certain results. This indicates that the industrial structure of Guangdong Province is realizing the transformation in the direction favorable to the development of regional green economy, and the overall transformation and upgrading of the industrial structure has achieved some initial results.

4. Research Conclusion and Countermeasure Recommendations

4.1. Conclusion of the Study

This paper applies the SBM model combined with the ML productivity index method to measure the green total factor productivity of each prefecture-level city in Guangdong Province from 2006 to 2021, and analyzes its spatial correlation. By constructing a spatial panel econometric model for empirical analysis, the impact of foreign trade on the green total factor productivity of Guangdong Province, and the spatial spillover effect are explored in depth. It is found that from 2006 to 2021, the growth rate of green TFP in Guangdong Province shows an inverted "U" trend, but there are significant differences in green TFP between the Pearl River Delta (PRD) region and the non-PRD region, which suggests that there is an uncoordinated and unbalanced inter-regional development, and that there is a "high-high", "low-low" aggregation effects are obvious. Under the spatial model, foreign trade has a significant positive spatial effect on the growth of green TFP, but the effects of imports and exports are heterogeneous, and foreign direct investment, infrastructure construction and industrial structure all have relevant effects on green TFP.

4.2. Optimization Path

4.2.1. Optimizing the Structure of Foreign Trade and Fostering New Trade Patterns and Characteristic Industries

Through the empirical results in chapter 5 show that the larger the import trade, the greater the green total factor productivity of the local and neighboring regions will increase, imports can bring many intermediate or capital goods for the domestic, and the spillover of advanced environmental protection technology contained therein is conducive to improving the domestic technological progress, so it is necessary to pay attention to the quality of imports, as well as their own ability to learn, utilize and transform. In addition, the export structure of each prefecture-level city should be optimized to improve the quality and competitiveness of exports, and to promote the upgrading of the export trade, which is mainly assembly and processing, to the medium- and high-end direction of research and development, design, etc., which can reduce the environmental costs involved.

4.2.2. Regional Synergies and Balances to Improve Capacity to Respond to Risks

As can be seen from the results of the calculations in Chapter 4, the level of economic development of prefecture-level cities in Guangdong Province varies, and there are also differences in factor endowments due to their geographical locations, the liberalization policy should also be tailored to local conditions. The Pearl River Delta (PRD) region, with its unique geographical location, proximity to Hong Kong and Macao, and strong momentum in the development and construction of the FTZ, should be further explored and a new FTZ port should be built on this basis. The other three regions are relatively backward in terms of infrastructure and industrial structure, so they should first focus on opening up within the region, open up exchanges with neighboring prefectures and cities, carry out industrial transformation and upgrading, and rationalize the division of labor, and then make full use of the platform of the Pearl River Delta FTZ to expand opening up, optimize the business environment, attract more advanced technologies, promote investment and trade facilitation, and gradually form a new high ground for opening up.

4.2.3. Improving the Quality of Human Capital and Enhancing Intra-regional Human Capital Mobility

Human capital has a non-significant negative contribution to the enhancement of green total factor productivity in Guangdong Province, indicating that the absorption and accumulation of regional human capital and the overall quality of its cultivation are still insufficient. Therefore, Guangdong Province should continue to strengthen its investment in human capital, implement positive and effective regional talent introduction and incentive policies, attract the influx of high-tech talents and high-quality labor resources, enhance the intra-regional mobility and spillover of high-quality human capital, and promote the maximization of the efficiency of the overall utilization of regional human capital. In addition, it is also necessary to pay attention to the level and depth of human capital accumulation, improve the quality of education and training, and improve the mechanism of talent cultivation and selection through a variety of ways, so as to enable them to fully absorb and make use of the advanced management experience and technological spillovers brought about by trade openness, and to further increase the green total factor productivity of the region.

4.2.4. Reasonably Enhance Environmental Regulation and Promote Green Transformation of Regional Economy

An appropriate level of environmental regulation is usually conducive to the growth of regional green total factor productivity. Currently, environmental regulations have a non-significant positive effect on green TFP in Guangdong Province, indicating that the current environmental regulations have taken into account the needs of economic development while proposing

environmental protection requirements and standards, so that local enterprises may face higher costs of pollution control and expenditures on research and development of cleaner technologies while taking into account the economic benefits. However, since its effectiveness is not significant, environmental regulations should be further rationalized to promote enterprises to enhance green R & D and innovation capacity and environmental protection and pollution control technology level, and at the same time, to develop more stringent environmental standards for enterprise production and the exit mechanism of high-pollution, high-energy-consuming production enterprises, and to promote the realization of the regional green economic transformation.

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