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Exploring Efficiency and Potential of China's Textile and Apparel Export to the RCEP Countries Reflections on the Stochastic Frontier Gravity Model

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Abstract

The signing of the Regional Comprehensive Economic Partnership (RCEP) has brought new opportunities for the development of China's textile and apparel industry. The article uses the stochastic frontier gravity model (SFGM), selects the relevant data on China and RCEP countries from 2010 to 2022, and explores the factors influencing China's textiles and apparel exports to the RCEP countries. The results show that: in terms of export efficiency, China's export efficiency of textile and apparel products to Japanese and Cambodian countries is high, while its export efficiency to Brunei, New Zealand and Singapore is low, but its export potential and expansion space are large. In terms of influencing factors, bilateral Gross Domestic Product (GDP), government expenditure of importing countries, monetary freedom, dependence on foreign trade and free trade agreements have all significantly improved the export efficiency of China's textile and apparel products, while geographical distance, tariff level of importing countries and commercial freedom have significantly hindered the improvement of the export efficiency of China's textile and apparel products. Given the findings, China should dig deep into the markets of countries with low efficiency and great potential, and at the same time work with RCEP countries to promote the process of trade facilitation.

Keywords

China Textile, Apparel Products, Export Efficiency, Potential, Stochastic Frontier Gravity Model

1. Introduction

1.1. Background

China has always been a big exporter of textile and apparel products, especially after China's entry into World Trade Organization (WTO), relying on the low cost and large-scale production advantages brought by the demographic dividend. The export scale of China's textile and apparel products has greatly increased, and it has become the largest producer and exporter of textile and apparel products in the world (Zhao, 2021). At the same time, the textile and apparel industry has gradually developed into a dominant industry and a traditional pillar industry in China (Yuan, 2023). However, in recent years, with the gradual weakening of China's traditional comparative advantages, such as raw materials and labor costs, and the rise of global trade protectionism, the international trade environment has become increasingly complex. These make China's textile and apparel industry face double unprecedented challenges. Interestingly, the signing of the Regional Comprehensive Economic Partnership Agreement (RCEP Agreement) has brought new opportunities for the development of China's textile and apparel industry.

The RCEP agreement covers 15 countries in the ten countries from Association of Southeast Asian Nations (ASEAN), China, South Korea, Japan, New Zealand and Australia. And RCEP is considered to be the world's largest free trade area agreement, with the total population, economic volume and total trade volume of these 15 countries accounting for about 30% of the global total, which is an economic region with great trade development prospects. In 2022, China's textile and apparel products exports to RCEP partner countries reached 94.276 billion US dollars, accounting for 29.49% of China's total textile and apparel product exports, a year-on-year increase of 4.82% (United Nations commodity trade statistics database). China's export trade of textile and apparel products to RCEP member countries has shown a high growth rate. The signing of the RCEP agreement does not only bring direct "dividends", such as tariff reduction and exemption, investment and trade facilitation, but also help to reconstruct the industrial value chain in East Asia and accelerate the economic recovery process of various countries (Suo & Zhang, 2022). These have also brought great benefits to China's textile and apparel industry. An issue worthy of further in-depth discussion is how China can seize this opportunity, give full play to the comprehensive advantages of its complete industrial chain and complete supporting facilities, continuously improve its international competitiveness, and unleash its export potential. To that end, this study seeks to engage in an in-depth discussion of the export efficiency and trade potential of China's textile and apparel products to RCEP member countries.

1.2. Review of Related Studies

1.2.1. Research Related to the Export of Textile and Apparel Products

The early research on the export of textile and apparel products in China mainly focused on export competitiveness and the impact of trade barriers on the export of textile and apparel products. Xu et al. (2022) find that China and ASEAN

countries are highly competitive under the RCEP framework, and although the competitiveness of textile and apparel products in most RCEP partner countries has declined significantly due to the impact of the epidemic, China still has obvious competitive advantages in most fields. Lin (2019) examines the development strategy of China's textile and apparel trade in the context of Sino-US trade frictions, indicating that China's textile and apparel exports will be greatly affected, and China should accelerate the upgrading of the textile industry structure, expand the market, and reduce its dependence on the US market. Zhang & Zhang (2020) examine the trade competitiveness of Chinese and American textiles under technical barriers, and find that China's textile competitive advantage is still stronger than that of the United States, and the two countries show trade complementarity.

In recent years, due to the bottleneck of China's textile and apparel industry, some scholars have gradually begun to pay attention to the export potential of China's textile and apparel products. Wang and Tian (2021) use the gravitational model to calculate the export potential of textile and apparel products between China and countries along the "Belt and Road". Zhang and Zhang (2019) use the stochastic frontier gravity model to calculate the potential and effect of China's textile and apparel product export trade to eight countries along the China-Pakistan Economic Corridor, and the most potential markets for China's textile and apparel product exports in the future are concentrated in India, Pakistan, and Afghanistan. Chen (2024) analyzes the impact of trade facilitation on China's textile exports by constructing an extended gravitational model, and calculated the trade potential of China's textile exports to RCEP member countries, and found that China's textile exports to RCEP member countries still have certain potential, and the trade potential needs to be further released.

1.2.2. Research Related to the Efficiency and Potential of Trade

It is generally believed that the pioneers of the gravitational model, who first applied the model to the field of international trade, are Tinbergen (1962) and Poyhonen (1963). They both established the gravitational model in terms of phenomenal function, believing that the trade flow of two countries is a function of their economic scale and geographical distance. However, the traditional gravitational model has some shortcomings, and the regression through the gravitational model is actually an average value close to the real trade volume, which does not take many random factors into account. Estimates may be subject to significant deviations (Zhang, 2022).

Subsequently, Aigner et al. (1977) were the first to apply the stochastic frontier theory in the field of industrial production function to measure production efficiency. So, the later scholar Armstrong (2007) applied a similar concept to measure trade flow, combined the trade gravity model with the stochastic frontier model, overcame some shortcomings in the traditional gravity model, and deduced the stochastic frontier gravity mode, put the trade inefficiency factors in the stochastic perturbation term for separate treatment. As a result, the real trade

potential is closer to the real value [15]. Based on the research of Wu (2003), scholars Shi & Li (2009) applied the stochastic frontier model to the analysis of the trade potential of various regions of China for the first time, correcting the "production potential" with the "export potential", which is closer to the real situation of trade potential.

In recent years, more and more scholars have used the stochastic frontier gravitational model to study international trade-related issues. Kamal et al. (2020) use a stochastic frontier gravity model to examine Pakistan's export efficiency and trade potential in Central Asia, and conclude that Pakistan and Central Asian countries previously had great trade potential. Dang & Zhao (2020) predict the efficiency and potential of China's agricultural exports under the framework of the Belt and Road Initiative, and the results show that economic size, population size of partner countries and the use of common languages have a positive impact on agricultural exports, while Chinese population size and geographical distance have negative effects on agricultural exports. In addition, China's trade efficiency in agricultural products with countries along the Belt and Road is low, but the trade potential is large.

1.2.3. Gap in Literature and Contribution of the Study

It is quite evident from the reviewed literatures that there is little research on the export efficiency or potential of textile and apparel products to their member countries under the RCEP framework. In addition, there are few studies that apply the stochastic frontier gravity model to the study of China's textile and apparel exports, and even fewer studies include human factors (trade inefficiency terms) in the analysis of the impact of textile export efficiency ...

2. Data Analysis

2.1. Scoping Textile and Apparel Products

Based on the classification of customs import and export commodity codes, this paper selects the eleventh category (chapters 50 - 63) as the research scope of textile and apparel products, including textile raw materials (HS 50 - 55), intermediate, decorative and industrial textile products (HS 56 - 60), clothing and accessories (HS 61 - 63).

2.2. Scale of China's Textile and Apparel Exports to RCEP Member Countries

Figure 1 shows China's exports of textile and apparel products to RCEP member countries and the world from 2012 to 2022, the total export value of China's textile and apparel products in 2022 is about 319.696 billion US dollars, an increase of 29.93% compared with 2012, exports to RCEP countries are about 94.276 billion US dollars, and the export value of textile and apparel products to RCEP partner countries is 46.94% higher than that in 2012. At the same time, in 2012, China's exports of textile and apparel products to RCEP countries accounted for 26.07% of China's total exports of textile and apparel products, and this proportion

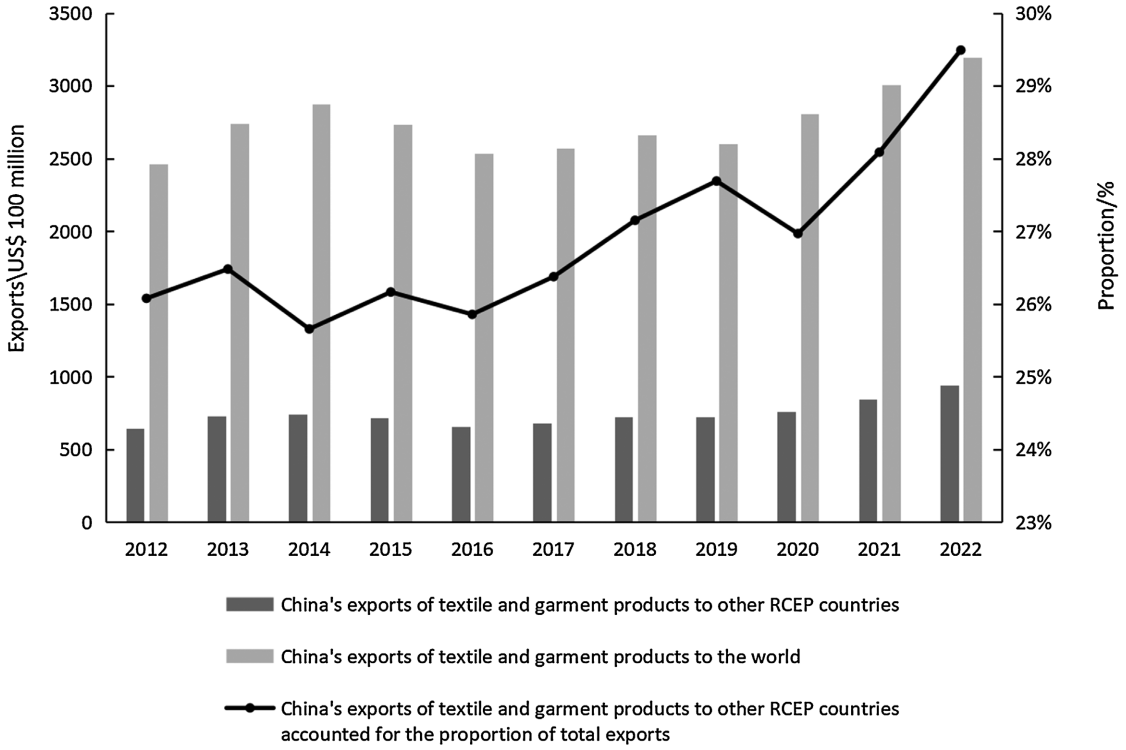

Figure 1. China's exports of textile and apparel products to other RCEP countries and their proportion.

showed an overall upward trend, rising to 29.49% in 2022. It has greatly reduced the negative impact of the outbreak of the epidemic, not only did not make China's exports of textile and apparel products to other RCEP member countries decline, but showed a stable growth trend. On the other hand, it also reflects that there is still a large room for growth in China's exports of textile and apparel products to RCEP partner countries. China's trade in textile and apparel products with other RCEP member countries is conducive to promoting trade between countries and regions, expanding economic ties among member countries, and improving exchanges and cooperation in textile and apparel products between countries.

2.3. Market Structure of China's Textile and Apparel Exports to RCEP Member Countries

As can be seen from Table 1, China's textile and apparel exports to RCEP countries are mainly concentrated in ASEAN and Japan, followed by South Korea and Australia. China's exports of textile and apparel products to New Zealand are relatively small, accounting for less than 2% in the past 11 years. In 2012, the ASEAN region was the largest export market for China's textile and apparel products, accounting for 41.54%, while Japan also accounted for a large proportion of 41.19%, slightly lower than ASEAN. Japan's share has declined in the nearly decade since 2012, falling to 20.74% in 2022, but it is still the second largest export market after ASEAN. Since 2012, ASEAN's proportion has increased year by year, and in 2022, it will reach 59.55%, accounting for half of China's textile and apparel export market. Because New Zealand is a relatively developed

Table 1. China's textile and apparel trade exports to RCEP countries and their proportion.

Year	Australia		Japan		New Zealand		South Korea		ASEAN	
	Exports (US$ 100 million)	Percentage (%)	Exports (US$ 100 million)	Percentage (%)	Exports (US$ 100 million)	Percentage (%)	Exports (US$ 100 million)	Percentage (%)	Exports (US$ 100 million)	Percentage (%)
2012	45.83	7.14	264.25	41.19	7.14	1.11	57.83	9.01	266.53	41.54
2013	48.67	6.71	261.97	36.12	7.69	1.06	66.91	9.22	340.13	46.89
2014	52.34	7.09	237.68	32.22	8.58	1.16	80.03	10.85	359.12	48.68
2015	52.53	7.34	209.45	29.28	8.57	1.20	88.77	12.41	355.92	49.76
2016	48.03	7.34	196.53	30.02	8.05	1.23	75.48	11.53	326.58	49.88
2017	48.21	7.10	196.99	29.03	7.99	1.18	78.68	11.59	346.77	51.10
2018	51.02	7.06	202.14	27.98	8.61	1.19	77.23	10.69	383.50	53.08
2019	49.39	6.85	192.69	26.74	7.99	1.11	80.71	11.20	389.78	54.09
2020	58.64	7.75	207.44	27.42	8.55	1.13	87.85	11.61	393.94	52.08
2021	65.95	7.81	191.90	22.73	9.69	1.15	91.55	10.85	485.02	57.46
2022	76.62	8.13	195.57	20.74	9.58	1.02	99.61	10.57	561.38	59.55

Source: United Nations commodity trade statistics database.

economy, its consumption quality requirements are higher, the consumer market is mainly high-quality textiles and wool, etc., China's export products and consumer demand are quite different, so China exports less textile and apparel products to it.

According to the classification of UN Comtrade and the two-digit coding method of HS code, textile and apparel products are divided into 14 categories, namely: HS50 silk, HS51 wool, HS52 cotton, HS53 Vegetable textile fibers, HS54 Man-made filaments, HS55 Man-made staple fibers, HS56 non-woven fabrics, etc., HS57 carpet, HS58 special woven fabrics, etc., HS59 industrial textiles, HS60 knitted fabrics, HS61 knitted apparel, HS62 non-knitted apparel, and HS63 textile articles.

As can be seen from Table 2, from 2012 to 2022, China's average annual exports of different textile and apparel products to RCEP countries were the highest in knitted apparel products, with an average export value of 20.292 billion US dollars. The average annual export value of non-knitted apparel was 16.921 billion US dollars, second only to the total exports of knitted apparel. In addition, the average annual export value of textile articles, knitted fabrics, Man-made filaments and cotton products is also relatively high, higher than 5 billion US dollars, while the average annual export of silk and Vegetable textile fibers is only 249 million US dollars and 458 million US dollars, less than 500 million US dollars, so in China's export of textile and apparel products, knitted apparel products and its non-knitted apparel products are more competitive. The average annual export value of silk products, vegetable textile fibers products, wool products and carpet

Table 2. Total value of China's exports of textile and apparel products to RCEP countries in different categories from 2012 to 2022 (unit: US$ 100 million).

Year	Silk, etc.	Wool, Etc.	Cotton, Etc.	Vegetable textile fibers, etc.	Man-made filaments, etc.	Man-made staple fibers, etc.	Non-woven fabrics, etc.
2012	3.76	7.89	42.63	3.23	32.47	29.04	11.65
2013	3.67	8.33	57.75	3.57	37.71	31.47	13.8
2014	3.4	8.35	52.44	4.39	42.07	43.07	16.11
2015	2.81	8.45	51.89	5.03	44.21	46.74	17.88
2016	2.5	8.37	52.62	4.01	47.36	42.95	18.97
2017	2.46	7.33	56.84	4.21	51.86	39.79	19.34
2018	2.28	8.96	55.21	6.43	59.99	38.63	21.27
2019	2.03	8.78	49.45	5.84	63.53	36.77	23.72
2020	1.11	5.51	40.11	3.9	54.55	31.21	35.7
2021	1.37	5.67	43.52	4.81	74.90	35.79	32.63
2022	2	8.04	47.45	4.95	88.91	39.62	32.88
average	2.49	7.79	49.99	4.58	54.32	37.73	22.18
Year	Carpet, etc.	Special woven fabrics, etc.	Knitted fabrics, etc.	Industrial textiles, etc.	Knitted apparel, etc.	Non-knitted apparel, etc.	Textile articles, etc.
2012	8.61	8.87	31.08	19.17	237.68	151.9	53.6
2013	8.98	9.11	39.31	21.09	264.46	164.95	61.16
2014	9.18	11.01	43.91	22.11	223.92	192.51	65.26
2015	8.76	11.29	51.14	21.87	202.95	179.74	62.47
2016	8.48	10.82	53.04	21.36	169.57	155.93	58.67
2017	8.84	12.53	62.61	23.34	166.33	162.66	60.48
2018	9.45	15.41	71.76	26.72	172.45	170.54	63.40
2019	9.94	16.51	78.6	28.42	168.61	164.09	64.28
2020	9.95	12.95	73.83	25.87	170.00	155.63	136.12
2021	11.84	16.86	101.43	34.08	211.76	166.96	102.51
2022	13.36	19.79	109.03	37.34	240.42	192.23	106.75
average	9.76	13.20	65.07	25.58	202.56	168.83	75.88

Source: United Nations commodity trade statistics database.

products is less than 1 billion US dollars, indicating that there is a lot of room for improvement in the export market share of these products.

At the same time, the export value of China's silk products, from 2012 to 2022, not only did not rise, but showed a downward trend, which may be due to the backward traditional technology of silk production in China since modern times, the lack of organizational and joint mechanisms among silkworm farmers, and

the defects in silk quality inspection technology, resulting in the quality of China's silk is not as good as before, and the international competitiveness is gradually weakening, resulting in the gradual decline of China's total silk exports (Fang, 2023). In addition, China's total exports of cotton, wool, Vegetable textile fibers and carpet products in the past 11 years have not made a big breakthrough, the total export volume has stagnated, and even in 2020, the total export volume has a temporary decline, which may be affected by the "Xinjiang cotton incident" and the comprehensive impact of the COVID-19 epidemic, resulting in serious restrictions on the trade and export of cotton products in China, and at this time, the signing of the RCEP agreement will bring new opportunities for the export growth of these textile products.

3. Methodology

3.1. Research Design

Based on the stochastic frontier production function established by Battese and Coelli (1995), this paper adopts the stochastic frontier gravity model improved by Armstrong (2007) and applies the "one-step method" for empirical analysis, and the specific function form is as follows:

$$T_{ijt} = f\left(X_{ijt},\beta\right)\exp\left(v_{ijt}\right)\exp\left(-\mu_{ijt}\right),\mu_{ijt} \geq 0 \tag{1}$$

$$\ln T_{ijt} = \ln f\left(X_{ijt},\beta\right) + v_{ijt} - \mu_{ijt},\mu_{ijt} \geq 0 \tag{2}$$

$$T_{ijt}^{*} = f\left(X_{ijt},\beta\right)\exp\left(v_{ijt}\right) \tag{3}$$

In Equation (2), T_{ijt} represents the actual export value of exporting country i to importing country j in period t, X_{ijt} represents the independent variables that affect export trade, such as GDP, population, geographical distance, etc., β as an estimated parameter, v_{ijt} represents random factors, and u_{ijt} represents trade inefficiencies due to human factors and other factors.

When u_{ijt} is zero, it means that there is no resistance factor in the export trade, so there is Equation (3), T_{ijt}^{*} represents the trade potential, which indicates the maximum trade level that can be achieved in the absence of trade resistance. Trade efficiency can be expressed as the ratio of export trade potential to actual export levels:

$$TE_{ijt} = \frac{T_{ijt}}{T_{ijt}^{*}} = \frac{f\left(X_{ijt},\beta\right)\exp\left(v_{ijt}\right)\exp\left(-\mu_{ijt}\right)}{f\left(X_{ijt},\beta\right)\exp\left(v_{ijt}\right)} = \exp\left(-\mu_{ijt}\right) \tag{4}$$

Since the non-efficiency terms in trade will change over time, this paper adopts the time-varying trade inefficiency model, and its main forms are as follows:

$$\mu_{ijt} = \exp\left(-\eta\left(t-T\right)\right)\mu_{i} \tag{5}$$

In Equation (5), η is an estimated parameter, and its sign reflects the trend of trade inefficient terms over time, when η is zero, it means that the non-efficient terms in trade do not change with time, and a time-invariant model is established. When $\eta > 0$, it indicates that the trade inefficiency term decreases with time, and

vice versa, and increases with time, T is the total number of periods, $t = 1, 2, 3, \cdots, T$.

In order to include the factors influencing trade inefficiency into the analysis, the one-step method proposed by Battese and Coelli (1995) is used to calculate trade efficiency, which is set in the following form:

$$\mu_{ijt} = \varepsilon Z_{it} + \omega_{ijt} \tag{6}$$

$$\ln T_{ijt} = \ln f\left(X_{ijt}, \beta\right) + v_{ijt} - \left(\varepsilon Z_{it} + \omega_{ijt}\right) \tag{7}$$

Substituting Equation (6) into Equation (2) yields Equation (7), where Z_{it} is the independent variable affecting trade efficiency, ε is the parameter to be estimated, and ω_{ijt} is the random error term. When $\varepsilon > 0$, the independent variable has a negative effect on the trade efficiency, and when $\varepsilon < 0$, the independent variable has a positive effect on the trade efficiency parameter.

3.2. Stochastic Frontier Gravity Model and Variable Description

In the design of the stochastic frontier gravity, this paper draws on the practice of Armstrong (2007), which includes factors that are not easy to change in the short term, such as economic scale, population size, geographical distance, language, and boundaries, and takes human factors such as free trade agreement, economic freedom, and tariff rate as the content of the non-efficiency model, and constructs the following model:

$$\begin{aligned} \ln exp_{ijt} = {} & \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln POP_{it} + \beta_4 \ln POP_{jt} \\ & + \beta_5 \ln DIS_{ij} + \beta_6 \ln CML_{ij} + \beta_7 \ln CMB_{ij} + v_{ijt} - u_{ijt}, u_{ijt} \geq 0 \end{aligned} \tag{8}$$

In Equation (8), *i* represents China, *j* represents RCEP countries. $\ln exp_{ijt}$ represents China's textile and apparel product exports to country *j* in year *t*. GDP_{it} represents the economic scale of China in year *t*. GDP_{jt} represents the economic scale of importing countries in year *t*. POP_{it} represents the population size of China in year *t*. POP_{jt} represents the population size of importing countries in year *t*. DIS_{ij} represents the distance between China and the capital of the importing country. And CML_{ij} and CMB_{ij} are both dummy variables, It indicates whether China and the importing country have a common language and a common border, if so, the value is 1, otherwise it is 0.

3.2.1. Set Up of Trade Inefficiencies

In this paper, a one-step method is used to establish the following trade inefficiency model:

$$\begin{aligned} u_{ijt} = {} & \alpha_0 + \alpha_1 \ln GS_{jt} + \alpha_2 TAF_{jt} + \alpha_3 BF_{jt} + \alpha_4 FTA_{ijt} + \alpha_5 MON_{jt} \\ & + \alpha_6 OPEN_{jt} + \alpha_7 TF_{jt} + \alpha_8 GEE_{jt} + \alpha_9 FIN_{jt} + \varepsilon_{ijt} \end{aligned} \tag{9}$$

Among them, GS_{jt} represents the final government expenditure of the importing country in the T period (constant US dollar in 2015), reflecting the public financial expenditure of the government of the importing country, so the expected sign is negative. TAF_{jt} stands for the weighted average tariff rate (%) levied on

imported primary products by RCEP countries in the t-period, and the higher the tariff levied by the importing country, the less favorable it is for the development of trade, so the expected sign is positive. The BF_{jt}, MON_{jt}, TF_{jt}, and FIN_{jt} variables represent the economic freedom of the importing country in the t period, which are commercial freedom, monetary freedom, trade freedom and financial freedom, respectively, the higher the economic freedom of the importing country, the smaller the trade barrier, the more conducive to the development of trade, and the expected sign is negative. FTA_{ijt} stands for whether or not there is a free trade agreement signed and effective between China and RCEP countries in the t period. The variable is a dummy variable. If it exists, the value is 1. Otherwise, it is 0. The signing of a free trade agreement is conducive to improving the trade environment and bringing favorable policies. Thus, promoting the development of bilateral trade, so the expected sign is negative. $OPEN_{jt}$ represents the ratio of the import and export trade volume of the RCEP countries in the gross national product (GDP) in the t period, reflecting the openness of the importing country to the international market and the dependence on foreign trade, and the expected sign is negative. GEE_{jt} represents the government effectiveness of RCEP countries in the t period, reflecting the quality of public services, policy formulation and implementation of the government of the importing country, and the credibility of the government's commitment to policy, so the expected sign is negative.

Substituting Equation (9) into Equation (8) can further obtain the stochastic frontier gravity model:

$$\begin{aligned}\ln exp_{ijt} = {} & \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln POP_{it} + \beta_4 \ln POP_{jt} \\ & + \beta_5 \ln DIS_{ij} + \beta_6 \ln CML_{ij} + \beta_7 \ln CMB_{ij} + \beta_8 \ln GS_{jt} \\ & + \beta_9 TAF_{jt} + \beta_{10} BF_{jt} + \beta_{11} FTA_{ijt} + \beta_{12} MON_{jt} + \beta_{13} OPEN_{jt} \\ & + \beta_{14} TF_{jt} + \beta_{15} GEE_{jt} + \beta_{16} FIN_{jt} + v_{ijt} - \varepsilon_{ijt}\end{aligned} \tag{10}$$

3.3. Data Source

The textile and apparel products studied in this paper mainly include products with HS code chapters 50 - 63. In terms of trading partners, due to the serious lack of foreign trade dependence indicators of Laos and Myanmar, this paper excludes Laos and Myanmar from the sample. And then comprehensively considers the availability of all variables, and finally selects the time span from 2012 to 2022, and the sample is 12 RCEP member countries (including Australia, Brunei, Indonesia, Japan, Cambodia, South Korea, Malaysia, New Zealand, Philippines, Singapore, Thailand, and Vietnam). For some missing data, Stata17 software is used to complete the data based on the principle of linear interpolation. **Table 3** shows the expected symbols and data sources for each variable.

4. Model Estimation and Result Analysis

4.1. Model Suitability Test

In order to investigate the applicability of this study to the gravitational model of

Table 3. Expected symbols and data sources for each variable.

Variables	Variable name	Expect symbols	Data sources
exp_{ijt}	Exports of textile and apparel products		UN Comtrad
GDP_{it}, GDP_{jt}	gross domestic product	+	World Bank WDI Database
POP_{it}, POP_{jt}	total population	+	
DIS_{ij}	geographical distance of the two capitals,	–	CEPII database
CML_{ij}	common language	+	
CMB_{ij}	common border	+	
FTA_{ijt}	free trade agreement	–	China FTA Network
TAF_{jt}	weighted mean tariff rate of primary products	+	World Bank WDI Database
$OPEN_{jt}$	foreign trade dependence	–	
MON_{jt}	monetary freedom,	–	The Heritage Foundation
FIN_{jt}	financial freedom,	–	
TF_{jt}	trade freedom,	–	
BF_{jt}	commercial freedom,	–	
GEE_{jt}	government effectiveness	–	World Bank WGI database
GS_{jt}	government spending	–	

the immediate frontier, this paper uses the likelihood ratio test to verify it. For the content of this article. Five hypothetical tests are set in turn: one is to test whether the trade inefficiency term exists, the second is to test whether the trade inefficiency term changes with time, the third is to test whether the distance variable is introduced, the fourth is to test whether the language dummy variable is introduced, and the fifth is to test whether the boundary dummy variable is introduced. The test results are shown in Table 4.

The non-existent trade inefficient terms and the non-trade inefficient terms do not change with time both reject the null hypothesis at the significant level of 5%, and accept the alternative hypothesis. This indicates that the trade inefficient terms are significantly present in the export of China's textile and apparel products, and the trade inefficient terms will change over time. So this paper chooses the time-varying stochastic frontier gravity model.

The non-introduction of distance variables and the non-introduction of boundary dummy variables both reject the original hypothesis at the 5% significant level, which indicates that the influence of distance and boundary dummy variables on the export of textile and apparel products by RCEP countries cannot be

Table 4. Simulation likelihood ratio hypothesis testing results.

Null hypothesis	H0	H1	LR statistic	5% cut-off	Conclusions of the test
There are no trade efficiencies	−129.9278	−60.8399	138.17578	10.371	refuse
Trade efficiencies do not change over time	−60.8399	−35.2483	51.183182	8.761	refuse
Distance variables are not introduced	−39.2958	−35.2483	8.095094	7.045	refuse
Language dummy variables are not introduced	−35.9819	−35.2483	1.467202	7.045	accept
Boundary dummy variables are not introduced	−41.5876	−35.2483	12.678604	7.045	refuse

Note: LR statistic = −2 [ln (H0) − ln (H1)], H0 is the constrained model, and H1 is the unconstrained model.

ignored in this study. So it is appropriate to introduce distance and boundary dummy variables. Since it is impossible to reject the null hypothesis that language dummy variables are not introduced, the influence of language variables in the model is excluded in this study. This paper revises the frontier gravity model as follows:

$$\begin{aligned}\ln exp_{ijt} &= \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln POP_{it} + \beta_4 \ln POP_{jt} \\ &+ \beta_5 \ln DIS_{ij} + \beta_6 \ln CMB_{ij} + v_{ijt} - u_{ijt}, u_{ijt} \geq 0\end{aligned} \tag{11}$$

4.2. Stochastic Frontier Gravity Model Estimation Results and Analysis

According to the stochastic frontier gravity model established above, the data of 12 countries (excluding Laos and Myanmar) from 2012 to 2022 for China and other RCEP countries are regressed, and the regression results are shown in **Table 5**, and the specific analysis results are as follows:

1) $\gamma = \frac{u^2}{u^2 + v^2}$, The coefficients of γ in the time-invariant model and the time-varying model are 0.9668 and 0.9939, respectively, and both of them are significantly not 0 at the level of 1%, indicating that the artificial trade inefficiency term is the main factor leading to the gap between the actual export value and the optimal export value. In addition, the coefficient of η in the time-varying model is −0.0539, and it is significantly not 0 at the level of 1%, indicating that the export efficiency decreases with time.

2) The GDP of exporting countries and importing countries has a significantly positive effect on the export of China's textile and apparel products, indicating that the more the economic scale of exporting countries and importing countries grows, the production capacity of exporting countries and the consumption capacity of importing countries will increase each other.

3) The population size of the exporting country (POP_{it}) has a significantly negative impact on China's textile exports, indicating that the more exporting countries, the higher the domestic demand for textile and garment products, so that exports turn to domestic demand; The population size of the importing country (POP_{jt}) is significantly positive in the time-invariant model, but the

Table 5. Estimation results of the stochastic frontier gravity model.

Estimation methods variables	Time-invariant models		Time-varying models	
	Coefficients	t-values	Coefficients	t-values
β_0	778.1107***	767.3005	784.2360***	184.6142
$\ln GDP_{it}$	3.0871***	18.4136	3.9244***	18.8574
$\ln GDP_{jt}$	0.1689***	3.2580	0.3751***	6.2749
$\ln POP_{it}$	−40.9438***	−141.8482	-41.9245***	-87.3560
$\ln POP_{jt}$	0.5879***	4.3312	-0.0967	-0.6314
$\ln DIS_{ij}$	−0.1543	−0.7431	-0.6778***	-3.3588
CMB_{ij}	0.3262	1.1504	1.0393**	2.0978
σ^2	3.3079	0.7319	11.1969**	2.0147
γ	0.9668***	20.3971	0.9939***	300.1857
μ	−3.5767	−0.5906	-6.6719***	-3.4403
η			-0.0528***	-5.4866
Log likelihood	−60.8839		−35.9819	
LR test	138.4631		188.2672	

Source: Author, 2024.

coefficient sign is negative and not significant in the time-varying model, which may be due to the small growth rate of the population of most RCEP countries in recent years, and the population of countries showing a negative growth trend (South Korea, Japan, etc.), so in the time-varying model, the population of the importing country has a negative but not significant effect on China's textile and apparel exports to RCEP countries.

4) The geographical distance between the two countries (DIS_{ij}) has a significantly negative effect on China's textile and apparel exports, indicating that geographical distance is a factor hindering China's textile and apparel exports, and the farther the distance between the two countries, the higher the transportation cost, and thus the higher the trade cost, which is not conducive to the export of textile and apparel products.

5) Whether the importing and exporting countries have a common border (CMB_{ij}) has a significantly positive impact on China's textile and apparel product exports, indicating that having a common border can significantly promote the export of China's textile and apparel products, and neighboring countries mean closer geographical distance, and there may be similar cultural customs, which is conducive to promoting economic exchanges between the two countries, and helps to reduce trade costs, thereby promoting the import and export trade of the two countries.

4.3. Analysis of the Estimation Results of the Trade Inefficiency Model

Table 6 shows the regression results of the trade inefficiency model, in which the γ coefficient is 0.6945 and significantly not 0 at the 1% level, indicating that there is a gap between the actual export value and the potential export value, and the gap is mainly caused by trade inefficiency factors.

Table 6. Estimation results of the trade inefficiency model.

	Variables	Coefficients	t-values
Stochastic frontier gravitational model	β_0	777.9929***	778.9690
	$\ln GDP_{it}$	3.5958***	16.2295
	$\ln GDP_{jt}$	0.3322***	11.4734
	$\ln POP_{it}$	−41.3465***	-128.7337
	$\ln POP_{jt}$	0.0185	0.3057
	$\ln DIS_{ij}$	−0.3360***	-4.1776
	CMB_{ij}	1.2262	1.5988
Trade inefficiency model	GS_{jt}	−0.9105***	-8.7660
	TAF_{jt}	0.0913*	1.7369
	BF_{jt}	0.0517***	3.6505
	FTA_{ijt}	−1.4129***	-3.3662
	MON_{jt}	−0.0630**	-2.4878
	$OPEN_{jt}$	−0.0042***	-3.2082
	TF_{jt}	0.2423***	8.4090
	GEE_{jt}	2.6197*	1.9074
	FIN_{jt}	−0.0149	-1.2375
	σ^2	0.3582***	4.8656
	Γ	0.6945***	18.1836
	Log likelihood	−64.8922	
	LR test	130.4466	

Source: Author, 2024.

As can be seen from Table 6, the human factors that significantly affect trade efficiency are:

1) The impact of government spending (GS_{jt}) on trade inefficiencies is significantly negative, and the impact on trade efficiency is significantly positive, which is consistent with the expected sign. It shows that the more the government spends on public finance, the more complete the national infrastructure will be, which is

more conducive to promoting the development of trade.

2) The coefficient of the Weighted Average Tariff Rate of Primary Products (TAF_{jt}) variable is significantly positive, which is in line with expectations, indicating that the increase in the average tariff rate of importing countries will inhibit the development of trade and reduce the export efficiency of China's textile and apparel products.

3) Among the indicators of economic freedom, the coefficient of commercial freedom (BF_{jt}) and trade freedom (TF_{jt}) variables is significantly positive, that is, the impact on trade inefficiency is significantly positive, indicating that the increase of business freedom and trade freedom will reduce trade efficiency. The improvement of commercial freedom and trade freedom in importing countries is theoretically conducive to the export efficiency of China's textile and apparel products. However, the improvement of commercial freedom and trade freedom in importing countries also means lowering the market access threshold and relaxing import restrictions, and more international enterprises and export products will pour into the markets of importing countries, thereby increasing the competitive pressure of China's textile and garment products in importing countries. As there is still a certain gap between China's textile and apparel enterprises in terms of technology, brand, marketing and some international advanced enterprises, this gap may be further amplified in the highly competitive market environment, thereby affecting export efficiency.

4) Among the indicators of economic freedom, monetary freedom (MON_{jt}) and financial freedom (FIN_{jt}) will significantly reduce trade resistance, that is, promote trade efficiency, which is consistent with the expected symbol. It shows that the higher the degree of financial and monetary freedom, the better the financial and capital market environment of the importing country, and the higher the value and liquidity of the currency, which greatly improves trade facilitation, reduces trade costs and promotes trade development.

5) The signing of free trade agreements (FTA_{ijt}) can usually reduce trade frictions, simplify trade procedures and reduce trade barriers such as tariffs, thereby effectively promoting the development of import and export trade between China and RCEP countries, thereby improving the export efficiency of China's textile and apparel products.

6) The coefficient sign of foreign trade dependence ($OPEN_{jt}$) is significantly negative, which has a positive impact on trade efficiency and is consistent with the expected symbol, indicating that the higher the dependence of the importing country on the international market, the more conducive to the export of China's textile and apparel products.

7) The effect of government efficiency (GEE_{jt}) on trade inefficiency is significantly positive, that is, the higher the government efficiency, the negative impact on trade efficiency, which is the opposite of the expected sign. Efficient governments tend to be accompanied by stricter integrity, which may reduce the scope for rent-seeking by some individuals to facilitate deals. At the same time, although

the higher government efficiency will increase trade facilitation, it will also enhance the competitive pressure of China's textile and garment products.

5. Correlation Analysis

5.1. Analysis of China's Export Efficiency of Textile and Apparel Products to RCEP Countries

In this paper, Frontier 4.1 software is used to calculate the export efficiency of China's textile and apparel products to RCEP member countries from 2012 to 2022 based on the time-varying stochastic frontier gravity model and the one-step trade inefficiency model, as shown in Table 7. According to the above Equation (4), it can be seen that the export efficiency is the ratio of the actual export value to the export potential, then the value is between (0, 1), the larger the value, the actual export value is about close to the export potential, and the export resistance is smaller, conversely, the greater the resistance to exports, the greater the growth potential and space for trade.

As can be seen from Table 7, the average efficiency of China's overall exports to RCEP countries is around 0.7, which is at an average level. Among them, the export efficiency of textile and garment products to Indonesia, Japan, Cambodia and Philippines is relatively high, indicating that these three countries are important export markets for China's textile and garment products, and China's export of textile and apparel products to these countries has relatively little resistance to human factor trade, while Brunei, New Zealand and Singapore show low export efficiency, indicating that there is greater export potential in the future. With the entry into force and full implementation of the RCEP agreement, China's

Table 7. China's export efficiency of textile products to RCEP countries from 2012 to 2022.

Country	2012	2015	2018	2021	2022	Mean
Australia	0.7913	0.8921	0.9036	0.8714	0.8719	0.8607
Brunei	0.0700	0.0787	0.0125	0.0185	0.0174	0.0505
Indonesia	0.9359	0.9379	0.9090	0.8679	0.8876	0.9002
Japan	0.9444	0.9262	0.9284	0.9235	0.9459	0.9331
Cambodia	0.9285	0.9206	0.8909	0.9560	0.9412	0.9260
South Korea	0.8464	0.9397	0.8806	0.8627	0.9239	0.8859
Malaysia	0.9151	0.8961	0.6485	0.8786	0.9134	0.8569
New Zealand	0.3131	0.3957	0.4316	0.3215	0.3108	0.3495
Philippines	0.8777	0.9174	0.8834	0.9173	0.9125	0.8977
Singapore	0.4849	0.5069	0.3565	0.3052	0.5219	0.4345
Thailand	0.8170	0.8368	0.6352	0.7256	0.9274	0.7564
Vietnam	0.8170	0.8281	0.8593	0.8268	0.7891	0.8129

Source: Author, 2024.

export market share of textile and apparel products to RCEP countries is expected to further increase.

5.2. China's Analysis of the Export Potential and Expansion Space of Textile and Apparel Products of RCEP Countries

Export potential is the ratio of actual export value to export efficiency, representing the amount of trade that can be theoretically achieved without any trade resistance. The formula for calculating the expansion space is: export expansion space = (export potential − actual export value)/actual export value * 100%. This indicator reflects the opportunities for potential trade growth at the current level of trade. Table 8 shows the estimated results of China's export potential of textile and apparel products to RCEP countries from 2012 to 2022.

As can be seen from Table 8, in 2022, the top five countries with the export potential of China's textile and apparel products to RCEP countries are: Vietnam, South Korea, Malaysia, Indonesia and Australia, and the top five countries with export expansion space are: Brunei, New Zealand, Singapore, Vietnam and Indonesia.

Table 8. China's export potential and expansion space of textile and apparel products to RCEP countries from 2012 to 2022 (unit: US$100 million).

Country	2012			2018			2022		
	Actual export value	Export potential	Export expansion space (100%)	Actual export value	Export potential	Export expansion space (100%)	Actual export value	Export potential	Export expansion space (100%)
Australia	45.83	57.92	26.37	51.02	56.46	10.67	76.62	87.88	14.69
Brunei	0.84	11.99	1328.22	0.2	15.68	7900	0.26	14.83	5647.13
Indonesia	43.63	46.62	6.85	50.64	55.7	10.01	65.02	73.26	12.66
Japan	264.25	279.82	5.89	202.14	217.73	7.71	195.57	206.76	5.72
Cambodia	13.79	14.85	7.70	32.12	36.05	12.25	47.04	49.97	6.25
South Korea	57.83	68.32	18.15	77.23	87.7	13.56	99.61	107.81	8.24
Malaysia	43.00	46.98	9.28	25.72	39.67	54.20	67.39	73.78	9.48
New Zealand	7.14	22.80	219.41	8.61	19.95	131.70	9.58	30.81	221.75
Philippines	26.90	30.64	13.93	54.93	62.19	13.20	65.52	71.80	9.59
Singapore	18.81	38.80	106.24	10.66	29.9	180.50	34.69	66.46	91.61
Thailand	20.96	25.66	22.40	27.49	43.28	57.43	53.39	57.57	7.83
Vietnam	91.38	111.86	22.40	160.25	186.49	16.37	192.07	243.40	26.73

Source: Author, 2024.

6. Conclusion and Suggestion

6.1. Conclusion

In this paper, the stochastic frontier gravity model and the trade inefficiency

model are used to measure the export efficiency of China's textile and apparel products to RCEP countries. By using one-step method, the export efficiency of China's textile and apparel products to RCEP member countries is calculated, the main factors affecting the export trade of textile and apparel products are analyzed, and the growth potential and expanding space of China's textile and apparel products to RCEP member countries are predicted. Based on the findings, the study concludes as follows:

First, from 2021 to 2022, China's exports of textile and apparel products to RCEP countries will show a steady growth trend, and the export markets are mainly concentrated in ASEAN and Japan, followed by South Korea and Australia, and the export categories of textile and apparel are mainly knitted apparel and non-knitted apparel.

Second, geographical distance and the total number of Chinese population have a significant negative impact on the export trade of textile and apparel products, and the scale of RCEP countries and China's economy have a significant positive impact on the export of textile and apparel products in China.

Third, from the perspective of the main factors affecting the non-efficiency of China's textile and apparel products, the government spending, monetary freedom, financial freedom, foreign trade dependence and free trade agreements of importing countries have significantly improved the export efficiency of China's textile and apparel products, while the average tariff level of primary products, commercial freedom, trade freedom and government efficiency of importing countries have significantly hindered the improvement of the export efficiency of textile and apparel products.

Fourth, from 2012 to 2022, the average export efficiency of textile and apparel products between China and RCEP member countries is 72.2%, and the export efficiency of Chinese Brunei, New Zealand and Singapore is low, but its export potential and expansion space are large, indicating that China's export potential of textile and apparel products to these three countries needs to be further explored.

6.2. Suggestion

In view of the findings, the following suggestions are made for policy implications:

1) Optimize the export trade structure of China's textile and garment products. China's textile and garment exports are mainly concentrated in the clothing and its accessories, while the export of textile raw materials and textile products are relatively concentrated in a few types of products, which may lead to increased market risks, while limiting the diversity and flexibility of export trade. The government and enterprises should work together to maintain the export of the original advantageous products, increase the export of other categories of products, and build a more diversified and balanced export trade structure of textile and garment products.

2) We need to work with RCEP countries to advance trade facilitation.

Continuously improve the construction of transportation infrastructure between China and RCEP countries, and weaken the obstacles to the export of textile and apparel products due to geographical distance. China's overall export efficiency of textile and apparel products to ASEAN countries is low, for countries with relatively weak transportation infrastructure construction, Chinese enterprises should be encouraged to increase investment in infrastructure construction, further improve their transportation network, and create more convenient trade conditions for the export of textile and garment products.

3) We should establish good trade relations with countries with high export efficiency, and dig deeper into the markets of countries with low export efficiency and greater trade potential. For example, China's textile and apparel exports to Vietnam, Australia and other countries have high efficiency, large trade scale and still have more than 10% growth potential, and it is very important to continue to tap and deepen bilateral trade relations; At the same time, for countries with relatively low export trade efficiency but huge trade potential, such as Brunei, Singapore and New Zealand, by actively exploring and digging into the market demand and opportunities of these countries, it will further enhance the export trade level and international competitiveness of China's textile and garment products.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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