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DRIVING SUSTAINABLE TRADE: GREEN TECHNOLOGY IMPACT ON CHINA-ASEAN CROSS-BORDER TRADE

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Abstract:

The growing cross-border economic ties between China and ASEAN countries has highlighted the importance of their respective trade landscapes. This study looks into this dynamic by studying panel data for both regions from 2000 to 2021. The study uses a fixed effects and gravity model to investigate the impact of green technology determinants on cross-border trade between China and ASEAN. The study's findings provide important insights. Adoption of Green technology appears as a stimulus for ASEAN imports and export from China, with statistical significance. Nevertheless, the new innovation of green tehnology found to be delivering contradictory outcomes. In light of these findings, the paper offers policy recommendations based on the research findings. Recognizing the impact of green technology on Chinese imports, governments may consider measures to strengthen the integration of green technologies into ASEAN's sectors. Similarly, insights into the export dimension could guide policies targeted at increasing ASEAN's position in the Chinese market through green technology routes.

Keywords:

China-ASEAN, Cross-Boder Trade, Green Technology, Panel Data, Gravity Model

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Introduction

In today's globalized world, cross-border trade is a crucial driver of economic growth and progress. Cross-border trading has become more accessible and cost-effective for businesses of all sizes as e-commerce and digital technologies have grown in popularity. Trade is widely regarded as one of the most important drivers of economic growth and development in countries. Over the last three decades, trade has contributed an average of 2.5% per year to global economic growth (World bank,2021). Trade fosters competition, innovation, and specialization while enabling countries to acquire resources and things that may not be readily available locally. Consequently, trade has been a key driver of economic growth and development throughout history, reducing poverty and raising living standards (Rodrik ,2014).

An outstanding illustration of an area that profited from trade is the Association of Southeast Asian Nations (ASEAN). Data from the ASEAN Secretariat (2020) show that from 2010 to 2019, intra-ASEAN commerce increased at a rate of 6.2% annually, reaching a total of US $609 billion in 2019. This shows the significance of trade in fostering regional economic growth as it represents a significant increase from US $253 billion in 2005. China and the ASEAN nations have gradually strengthened their cross-border trade cooperation in recent years. China is the major commercial partner of Vietnam, Malaysia, Thailand, Indonesia, Singapore, the Philippines, Cambodia, and Myanmar, the second largest trading partner of Laos, and one of Brunei's top three trading partners, according to the China General Customs Administration (2022).

However, Yang *et al*. (2020) claim that the expansion of the global supply chain has significantly changed how raw materials are gathered, goods are produced, sold, and consumed, leading to environmental concerns. In fact, China, a notable example of rapid economic expansion in the face of escalating environmental harm, has declared that scientific innovation will lead to "leap-frog development" and a "historic transformation of environmental protection" (Lovely & Popp,2011). Trade business operations need to adopt a more sustainable strategy, according to Wu and Dunn, S. (2018). Although there has been previous study on the connection between technological innovation and commerce, there were few studies looking at how cleaner, more energy-efficient, or green technology innovation affects trade growth. According to Alam and Alam (2021), the green innovation strategy is one of the most crucial ones in the era of environmental pressure. The entire system of cross-border trade could suffer from a lack of appreciation of the critical role that green innovation plays. However, according to Yassin *et al*., (2022), it is surprising that so little research has been done the estimate the impact of green technology on the economy. Hence, this study aimed to investigate the effects of green technology innovation on international trade between China and ASEAN nations.

The remaining sections of this study are structured as follows. First, in section 2, several related literatures that discusses the cross-border trade and green technology. Next, the methods used in estimating and analyze the effect of green technology factors on China-ASEAN countries highlighted in Section 3. Then, the conclusions estimated and suggestions will be discussed in Section 4.

Literature Review

A review of the literature reveals academic gaps. Many scholars have conducted research on cross-border trade between China and ASEAN, but most of it is done through qualitative

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methods, such as descriptive statistics or comparative research. The quantitative analysis of cross-border trade between China and ASEAN mainly focuses on research on GDP, population size, exchange rate, trade facilitation, and other aspects, while the impact of green technology on trade is almost not involved.

Definition of Cross-Border Trade

Cross border trade refers to the transaction of goods and services across borders. The scope of cross-border trade is very broad, including imports, exports, foreign investment, cross-border procurement, etc. The research on cross-border trade in this article is based on the narrow concept of cross-border trade in goods. Usually, both sides of the trade belong to different economic systems, each with its own economic behavior characteristics and policy regulations.

Although Europe and the United States are still the main markets for cross-border e-commerce in China, ASEAN has surpassed the European Union as China's largest trading partner since 2020 and has been China's largest trading partner for three consecutive years. China ASEAN has enormous development potential in cross-border trade development. Therefore, studying the cross-border trade between China and ASEAN has important practical significance.

Kurihara Fukushima (2013) compared the relationship between internet penetration and cross-border trade in OECD countries and found that internet penetration in developing countries has a stronger promoting effect on cross-border trade than in developed countries. At the same time, whether in developed or developing countries, cross-border trade is mainly promoted by internet technology through exports rather than imports. According to Truong et al. (2019), cross-border trade between China and ASEAN is significantly concentrated in high-tech and medium-sized products, indicating that production capacity in China and ASEAN countries is improving, because high-tech products often have a higher added value than products with little technical content. Pingliqun (2020) comprehensively analyzed the beneficial effects of RCEP signing on China ASEAN economic integration from the perspectives of stabilizing the predictable economic environment in the Asia Pacific region and enhancing confidence in building production networks. Du Fangxin and Zhi Yupeng (2021) analyzed the competitive complementarity of service trade between China and ASEAN countries based on classified data from the United Nations database and proposed targeted recommendations. Wang Jun and Wang Qingsong (2021) analysed the trade efficiency and potential between China and ASEAN countries based on the SFA model and proposed that China should encourage foreign trade enterprises to actively "go global", accelerate bilateral trade negotiations with ASEAN countries, and deepen connectivity with RCEP members. Li Guoqing et al. (2022) conducted an empirical study on the cross-border trade between China and ASEAN using panel data from 2012 to 2020 based on the trade gravity model. The results showed that factors such as the liner transportation index and the existence of a common border can affect the bilateral trade between China and ASEAN.

Definition of Green Technology

Green technology refers to a class of technical breakthroughs that are purposefully designed to promote environmental well-being and alleviate negative effects on the natural ecosystem. The increase in per capita economic development will not reduce greenhouse gas emissions (Liobikienė & Butkus,2018). Meanwhile, due to the impact of production scale and technology, economic expansion will inevitably affect the environment (Koondhar,2021). From the perspective of scale effect, more energy consumption and production emissions of pollutants

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are greater than the increase in greenhouse gas emissions. The technological effect indicates that as environmental quality improves, developed economies use more resources to replace dirty technologies with clean technologies (Bilgili et al, 2016).

Many research results have shown that green technological progress plays an important role in economics (Godil *et al*,2021). Foreign direct investment promotes technological improvement, thereby creating a cleaner environment (Halliru et al,2021). However, due to stricter global rules on environmental issues, rich countries have shifted their polluting sectors to poorer countries, and many industries have shifted from developed to developing countries. Green technology has a significant impact on international trade. Green technology adoption in manufacturing processes, according to researchers such as James and Smith (2018), leads to greater resource efficiency, lower emissions, and the promotion of eco-friendly products. This correlates with the growing global demand for sustainable goods and services (Johnson, 2019).

However, several academics have highlighted potential adverse trade factors. Critics, for example, believe that implementing green technology in the manufacturing process may raise the company's costs due to the need for professional equipment and the execution of harsher environmental standards (Diaz Reiney et al., 2017). These increased costs may reduce a company's competitiveness in the global market. One of the major issues associated with green technology and cross-border trade is the potential for trade barriers. Some governments impose tariffs or non-tariff measures on environmentally friendly products, which can reduce their competitiveness and market access. These impediments may have a disproportionate impact on underdeveloped countries, which frequently fail to achieve the stringent environmental requirements set by affluent countries.

Theoretical Background and Model Construction
This article compiles China-ASEAN cross-border trade data from 2000 to 2021, using a panel data fixed effects model and a modified gravity model to evaluate the impact of green technology on China ASEAN cross-border trade, helping readers and policy makers have a broader perspective on the future.

The gravity model is widely used in studying the potential and influencing factors of international trade. In the 1960s, Tinbergen (1962) and Poyhonen (1963) first used the gravity model to explain the relationship between cross-border trade scale, market size of trading countries, and trade distance. They believed that the economic size of a country had a promoting effect on cross-border trade between the two countries, and the distance between the two countries would to some extent hinder the development of trade between the two countries. In the gravity model, a function is used to represent the relationship between export trade volume and the gross domestic product, geographical distance, and other trade-related variables of the two countries. The basic equation is as follows：

$$T_{ij} = A * \frac{Y_i Y_j}{D_{ij}} \tag{1}$$

In the equation, T_{ij} represents bilateral cross-border trade volume, Y_i represents the GDP of country i, Y_j represents the GDP of country j, D_{ij} represents the geographical distance between country i and country j, and A is a constant term.

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Due to the multiplicative nature of the above equations, for the convenience of calculation, when applying a gravity model, all variables are logarithmically processed to obtain the following linear estimation equation, and regression estimation is performed on this basis.

$$LnT_{ij}=\beta_0 + \beta_1 Ln(Y_i Y_j) + \beta_2 LnD_{ij}+\varepsilon_{ij} \quad (2)$$

β_0 is a constant term, β_1 and β_2 represents the elastic coefficients of Y_iY_j and D_{ij} respectively, with ε_{ij} as the error term.

The widespread application of the gravitational equation in empirical research has demonstrated its stability and explanatory power for bilateral trade flows. At the same time, scholars have continuously enriched the trade gravity model by adding variables such as population and proximity to the model, to better study the dependent variables and enhance the practicality of the model. Based on the research of domestic and foreign scholars, this article takes export and import as the dependent variables, green technology variables as the core explanatory variable, selects GDP, population, exchange rate, and trade distance as the control variables, and further expands the gravity model, designate Model 1 and Model 2 as follows:

Model 1:

$$import(i,j)_{it} = \beta_0 + \beta_1 dgt_{it} + \beta_2 pgt_{it} + \beta_3 GDP_{it} + \beta_4 pop_{it} + \beta_5 exr_{it} + \beta_6 dis_{it} + \varepsilon_{ex,it} \quad (3)$$

Model 2:

$$export(i,j)_{it} = \beta_0 + \beta_1 dgt_{it} + \beta_2 pgt_{it} + \beta_3 GDP_{it} + \beta_4 pop_{it} + \beta_5 exr_{it} + \beta_6 dis_{it} + \varepsilon_{im,it} \quad (4)$$

In model 1, $import(i,j)_{it}$ is the volume of cross-border trade goods ASEAN nation i import from China, and $export(i,j)_{it}$ represents the volume of cross-border trade goods that ASEAN country i export to China. dgt_{it} presents the relative advantage in environment-related technology of country i, pgt_{it} presents the patents on environment technology of country i, GDP_{it} indicates the GDP per capita of country i, pop_{it} represents the population size of country i, the real exchange rate is represented by exr_{it}, while the trade distance between China and the other ASEAN countries is represented by dis_{it}, $\varepsilon_{m,it}$ and $\varepsilon_{ex,it}$ indicates the white noise or errors.

Table 1: Description of Variables

Variables	Description	Source
import	Annual volume of cross-border trade goods that ASEAN nation i import from China	China Statistical Yearbook（2023）
export	Annual volume of cross-border trade goods that ASEAN country i export to China	China Statistical Yearbook（2023）
dgt	Relative advantage in environment-related technology, multiply dgt of each ASEAN countries by dgt of China in that year	OECD (2023)
pgt	Patents on environment technology, multiply pgt of each ASEAN countries by pgt of China in that year	OECD (2023)

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gdp	Per capita GDP	The World Bank (2023)
pop	The population statistics of ASEAN countries	The World Bank(2023)
exr	The bilateral real exchange rate data between China and ASEAN, calculated by CPI and name exchange rate	The World Bank(2023)
dis	A proxy for transport cost, multiply the distance between the two capitals by the Brent crude oil price of that year	CEPII,Energy Information Administration

This study used panel data to process all selected variables, with a data period from 2000 to 2021. The data sources and descriptions are shown in Table 1. The import and export situation between China and the ten ASEAN countries is shown in Figures 1 and 2, indicating a generally growth trend in both imports and exports between China and ASEAN countries.

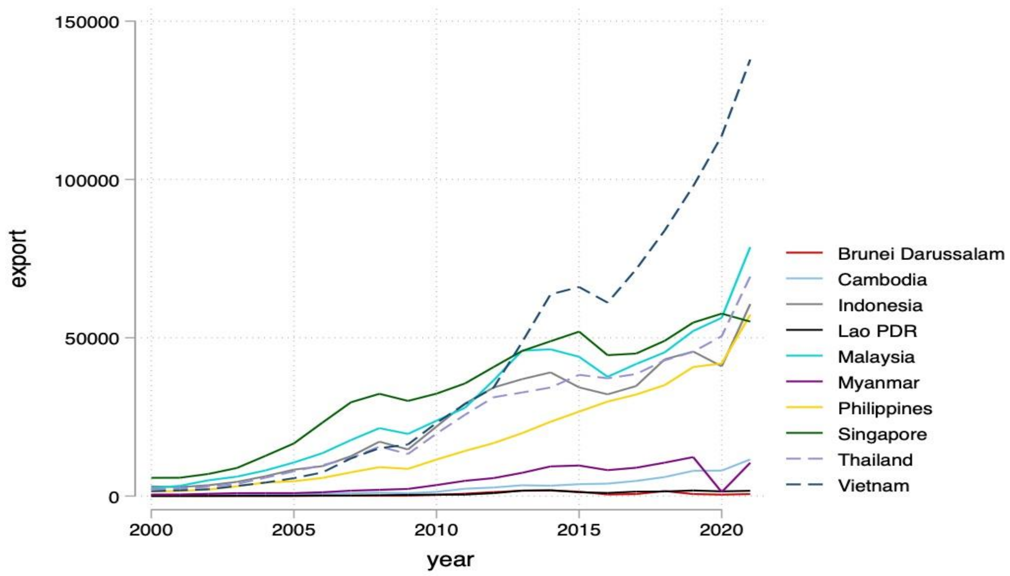

Figure 1: Annual Total Trade Volume of Each Ten ASEAN Countries Import from China during 2009-2021 (US $ 100mllion)

Source: China Statistical Yearbook（2023）

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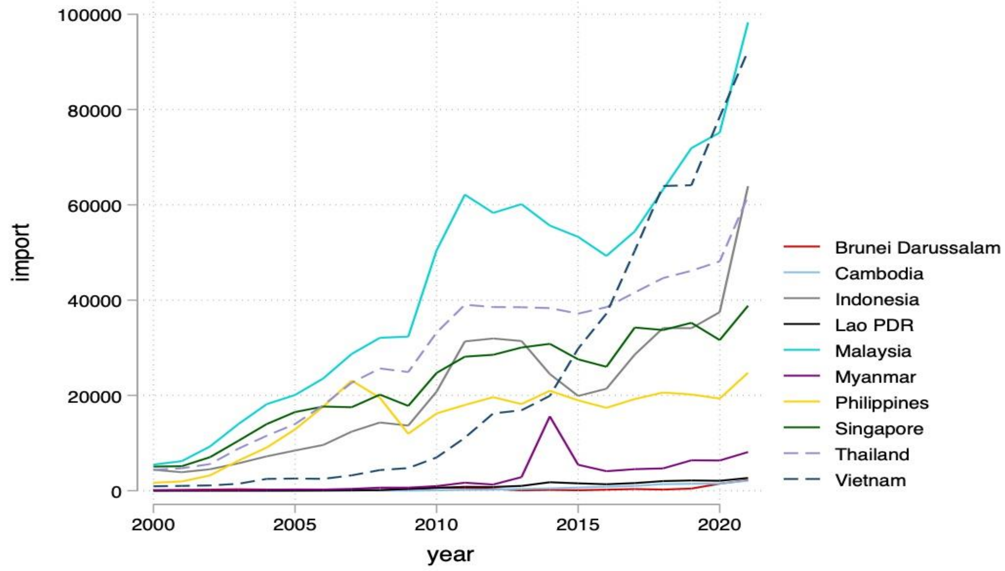

Figure 1: Annual Total Trade Volume of Each Ten ASEAN Countries Export to China during 2009-2021 (US $ 100mllion)

Source: China Statistical Yearbook（2023）

Econometric Approach

To estimate the impact of green technology on cross-border trade between China and ASEAN, this article uses panel data from China and ten ASEAN countries from 2000 to 2021. This study estimated the impact of green technology on the China ASEAN cross border trade under the assumption of homogeneous slope and considered the heterogeneity between countries. The discovery of homogeneous parameter estimation methods was later compared with the discovery of heterogeneity estimation programs to improve the robustness of the discovery. In the homogeneous estimator, this paper selects fixed effects regression with robust standard error to overcome cross-sectional and time dependencies.

Estimation Results

Before estimating the model, for the convenience of calculation, all variables are converted into natural logarithms to standardize the data and generate accurate estimates. A description of the variables is presented in Table 2. Learn from the available data, averages are quantified as lnimport(8.552), lnexport(8.182), lndgt(-0.172), lnpgt(4.604), lngdp (8.082), lnpop (5.421), lnexr (3.119) and lndis (2.998).

Table 2 Descriptive Statistics of Variables

Variable	Mean	Std.dev.	Min	Max
lnimport	8.552	2.038	2.566	11.83
lnexport	8.182	2.378	1.859	11.50
lndgt	-0.172	0.526	-2.060	1.987
lnpgt	4.604	0.779	2.021	6.510
lngdp	8.082	1.525	4.879	11.26
lnpop	5.421	1.795	1.206	7.915
lnexr	3.119	3.700	-1.728	8.016
lndis	2.998	0.527	1.739	4.064

Source: Author

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Use LLC and IPS stability test on the Panel data to conduct the panel unit root test. Results in Table 3 shows that all data reject the original hypothesis, which means the panel data sequence is stable and there is no Root of unity issue.

Table 3: Results of Unit Root Test

	LLC		IPS	
	Level	**1st difference**	**Level**	**1st difference**
lnimport	-2.4024***	-2.0406**	0.0728	-6.9964***
lnexport	-3.7514***	-3.9173***	-1.4969*	-5.9381***
lndgt	-2.1758**	-6.5577***	-7.1356***	-9.5771***
lnpgt	-0.7742	-5.7291***	-5.0159***	-8.9028***
lngdp	2.5003	-3.5659***	3.4350	-6.2487***
lnpop	-0.9931	-1.6374*	5.3771	-7.135***
lnexr	-2.9330***	-4.2172***	-1.4049*	-6.5933***
lndis	-2.0213**	-2.7276***	-0.7394	-6.4962***

Nota bene: (*) significant at the 10% level, (**) significant at the 5% level, and (***) significant at the 1% level.
Source: Author

As shown in Table 4, the diagnostic test is used to examine the problem of serial correlation and the presence of heteroscedasticity. The Breusch Pagan LM test was then used to identify cross-sectional dependencies in the data, as shown in Table 4, the model in this paper has issues with inter group synchronicity. The results show that while examining China ASEAN panel data, the error structure is expected to be heteroscedasticity, autocorrelation and synchronicity due to probable correlation between groups (Hoechle, 2007).

Table 4: Diagnostic Tests

Modle	**1**	**2**
Wooldridge test	0.756	43.875***
Modified Wald	1616.00***	1064.05***

Nota bene: (*) significant at the 10% level, (**) significant at the 5% level, and (***) significant at the 1% level.
Source: Author515.3

Table 5: Cross-Sectional Dependence Tests

		Breusch-Pagan LM test	**Pesaran's test**	**Frees test**
Model 1	FE	218.866***	1.026	1.657
	RE	257.338***	8.41***	1.810
Model 2	FE	194.484***	0.783	1.594
	RE	189.962***	0.803	1.545

Nota bene: FE and RE presents fixed and random effect estimations respectively. (*) significant at the 10% level, (**) significant at the 5% level, and (***) significant at the 1% level.
Source: Author

According to the Hausman test results, this study is applicable to fixed effects models. To produce a convincing result, models 1-2 will be tested using fixed-effect estimation with robust standard error, which is resilient to heteroscedasticity across panels, serial correlation, and cross-sectional dependence within panels. Table 6 and table 7 show the empirical results for Model 1 and Model 2 respectively, employing the homogeneous estimators based on robust standard error.

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Table 6: Measurement Results of Extended Gravity Model 1

	OLS	FE	RE	FE Robust
lndgt	-0.182	0.179**	0.0596	0.179**
	(0.150)	(0.0762)	(0.109)	(0.0707)
lnpgt	0.286***	-0.0639	0.182**	-0.0639
	(0.107)	(0.0614)	(0.0786)	(0.069)
lnPerGDP	1.053***	0.996***	1.223***	0.996**
	(0.0619)	(0.0976)	(0.0617)	(0.3227)
lnpop	1.134***	5.505***	1.201***	5.505**
	(0.0440)	(0.536)	(0.0547)	(2.1077)
lnexr	0.0173	-0.0257	0.0484*	-0.0257
	(0.0218)	(0.0419)	(0.0250)	(0.0568)
lndis	0.277**	0.302***	0.362***	0.302*
	(0.131)	(0.0769)	(0.103)	(0.1391)
_cons	-8.339***	-29.84***	-9.910***	-29.84**
	(0.771)	(2.370)	(0.652)	(9.6284)
Hausman	chi2(6) = 117.07, Prob > chi2 = 0.0000			
R-sq	0.837	0.892	0.8504	0.8916
F	182.0	279.6		

Nota bene: FE and RE presents fixed and random effect estimations respectively. (*) significant at the 10% level, (**) significant at the 5% level, and (***) significant at the 1% level.
Source: Author

To facilitate the comparison of estimation results, this article reports the mixed OLS effect model, fixed effect model, random effect model, and fixed effect model data under cluster robustness error in Table 6. The regression results in Table 6 show a positive correlation between lndgt and lnimport and statistically significant. As expected, the green technology advantages of the two countries reflect their level of advantages in green technology, which in turn promotes ASEAN countries' imports from China, and every 1% increase in lndgp will drive ASEAN's imports from China to increase by 0.179%. However, lnpdt showed a negative correlation with lnimport, but not statistically significant. These results indicate that when a country develops and patents green technologies, it becomes more self-sufficient in their production and implementation. This decreases the need for similar technologies to be imported from other countries. In line with the diffusion theory, where this hypothesis proposes that innovations created in one location, such as green technologies, can be transmitted and dispersed to other regions. When a country obtains patents for certain technologies, it may result in lower imports as other countries adopt and implement the patented inventions (Santacreu,2015)

Table 7: Measurement Results of Extended Gravity Model 2

	OLS	FE	RE	FE Robust
lndgt	-0.133	0.0155	-0.0277	0.0155
	(0.137)	(0.104)	(0.105)	(0.1614)
lnpgt	0.0439	-0.0883	-0.0227	-0.0883
	(0.0973)	(0.0841)	(0.0784)	(0.1809)
lnPerGDP	1.433***	1.876***	1.731***	1.876***
	(0.0566)	(0.134)	(0.0713)	(0.3209)
lnpop	1.317***	1.407*	1.406***	1.407

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	(0.0402)	(0.735)	(0.0936)	(1.6710)
lnexr	-0.0248	-0.0287	0.0296	-0.0287
	(0.0199)	(0.0574)	(0.0353)	(0.1054)
lndis	-0.202*	-0.231**	-0.171*	-0.231
	(0.120)	(0.105)	(0.103)	(0.1707)
_cons	-10.08***	-13.42***	-12.91***	-13.42*
	(0.704)	(3.249)	(0.759)	(7.260)
Hausman	chi2(6) = 16.41, Prob > chi2 = 0.0117			
R-sq	0.900	0.818	0.8172	0.8185
F	319.4	153.3		

Nota bene: FE and RE presents fixed and random effect estimations respectively. (*) significant at the 10% level, (**) significant at the 5% level, and (***) significant at the 1% level.
Source: Author

Meanwhile, as shown in Table 7, the regression results show a positive correlation between lndgt and lnimport but found to be not statistically significant. Interestingly, lnpdt showed a negative correlation with lnimport.

Conclusions and Ssuggestions

Based on the current research results, the ASEAN countries the adoption of new technologies and practices found to significantly positive impact on import from China, but no significant impacts on its export to China. However, as ASEAN country's new green pattern patents increase, it is found to negatively influence import and export. Although it is not statistically significant, it is critical to analyse the larger context and probable contributors to this phenomenon. First, ASEAN countries may become less reliant on imports for similar technology as they develop and implement new green technologies. This could result in lower imports, particularly if the green technologies they produce are employed in industries that formerly relied heavily on imports. Secondly, adoption of new technology may necessitate a high initial investment (Li *et al*.,2021). If ASEAN countries are still in the early stages of adopting green technologies, they may prioritize domestic implementation above exports, resulting in possible trade imbalances. Thirdly, If ASEAN countries implement policies that promote domestic green technology research and adoption, trade dynamics may change. Certain policies, for example, may make non-green technology imports less appealing, resulting in lower imports.

Meanwhile, we also noticed that lnGDP and lnpop are positively correlated with lnimport. Both lnGDP and lnpop are positively correlated with lnexport, but lnpop is not significant. This indicates that the higher per capita GDP and population size of the two trading countries have a positive promoting effect on cross-border trade imports and exports between ASEAN countries and China, because the stronger of the consumption capacity of its residents, and the greater the demand for import trade,which is consistent with the expectations of this article. In the traditional gravity model, logistics cost is one of the main factors affecting imports and exports between the two countries. The farther the transportation distance, the higher the logistics cost, and the less competitive the product price. However, in the results of this study, the impact of logistics cost on imports and exports between China and ASEAN is opposite and not significant, possibly due to other factors such as language distance and whether the two countries are adjacent.

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Suggestions

Sustainable development is a key global issue. This study analyzes the impact of green technology development and green technology patents on cross-border trade between China and ASEAN countries. The results show that green technology development will promote cross-border trade between ASEAN and China, while green technology patents may hinder cross-border trade between ASEAN and China, possibly due to ASEAN countries setting high standards for product green technology access, trade restrictions have been imposed on some products through green trade barriers.

Therefore, the governments of China and ASEAN countries should formulate incentive policies in the development of green technology and encourage the research and development of green technology patents, promote the development of green technology in various industries and benefit from relevant policies, improve product competitiveness while improving the environment. For example, tax incentives for green technology development in enterprises, incentive measures for researchers to conduct green technology research and development, and grants and subsidies for infrastructure expansion related to green technology development.

This article provides some innovative insights into the factors influencing cross-border trade between China and ASEAN, but it also has significant limitations and opens up new areas for further research. The development of green technology and the impact of green technology patents on cross-border trade between the two countries are influenced by various policies, societies, and cultures, and can be further explored. It also provides research direction for the future development trend of cross-border trade of green technology in other developing and developed countries, using specific countries and panel data analysis to provide more accurate information.

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