Exploring the Effect of ASEAN's Digital Economy on China's Export Trade Efficiency

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Abstract. With the popularization of big data, the Internet and communication technologies such as 5G, the digital economy has extended to all aspects of social life and has become a new engine for international trade. ASEAN is China's number one trading partner, and its digital economy has become an important factor in driving China's trade and economic development with ASEAN. Using 2010-2022 panel data on China's exports to ASEAN, this study examines ASEAN nations. It applies the Stochastic Frontier Gravity Model to explore the relationship between ASEAN's digital economy development and China's export efficiency, conducting empirical analyses. The results of the study show that advancement in digital economy in ASEAN countries can significantly improve the trade efficiency of China's exports to ASEAN.

Keywords: ASEAN, Digital Economy, Trade Efficiency, Stochastic Frontier Gravity Modelling.

1 Introduction

By 2024, ASEAN has maintained the status of China's top trading partner for five consecutive years. Although the development of the digital economy in ASEAN countries is still at a medium level in the global context, it is nevertheless growing at a significant rate. In this context, a study exploring the effect of the ASEAN digital economy on the efficiency of China's export trade is of significant importance for enhancing China's efficiency in exports to ASEAN.

In recent years, many researchers have attempted to develop an index system tailored to measure the digital economy development level. Zhao and Chu (2023) [1]select 15 representative indexes from the four dimensions of digital infrastructure construction, ICT primary application, Digital industrialization and industrial digitization. Zhang and Xu(2024)[2] summarize the existing indexes into four types: one-dimensional perspective based on digital industrialization and digital social impact, and composite perspective based on narrow field and wide field. With regard to the study of export trade, scholars have generally adopted the traditional gravity model and the stochastic frontier gravity model as their main analytical tools. Specifically, V.R. Renjini et al. (2017)[3] and Majid Lateef et al. (2018) [4]respectively utilized the gravity model in their analyses

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and found that India has significant export potential with countries such as Brunei and Laos. Manu Christiana (2020) [5]used the gravity model for an in-depth exploration and found that the volume of Ghana's bilateral exports is positively correlated with the wage levels of the country and its trading partners. Pandey Pranesh et al. (2021)[6]employed the gravity model to demonstrate that a common border is positively correlated with the trade volume between ASEAN and India, while geographical distance is negatively correlated with the trade volume. Jiang, W.et al(2021) [7]constructed an SFGM model and concluded that there is a big gap between China's export potential and the real level to the countries along the 'Belt and Road'. Zhao and Li(2023)[8] empirically analyzed the trade efficiency between China and the US by using the SFGM model. They found that in addition to traditional factors such as economic size and geographical location, non-economic factors such as policy barriers and tariff barriers between the two countries have a significant impact on the actual trade flows. Koshkarev A.V (2019) [9]The development of the digital economy rapidly reduces the cost of information communication. An empirical analysis conducted by Fan (2020) [10] reveals that advancements in the digital economy of importing countries enhance the efficiency of China's export trade.

2 Data Source

According to the needs of the study, considering the continuity and completeness of the panel data and the availability of data, 10 countries, namely Singapore, Malaysia, Thailand, the Philippines, Brunei, Indonesia, Vietnam, Myanmar, Laos, and Cambodia, were finally identified as the sample of the study, spanning the period of 2010-2022.

Among them, the data on China's exports to ASEAN are obtained from the UN Comtrade database, the data on GDP per capita and population size of each country are obtained from the World Bank database, and the data on whether there is a common border between countries and the distance are obtained from the Centre for Economic Prospects and International Information (CEPII). The core explanatory variables of this paper, data on the level of digital economy development in ASEAN countries were measured by author. Data on trade openness and transportation capacity index of ASEAN countries were obtained from UN Comtrade database, while government efficiency index was taken from the Worldwide Governance Indicators (WGI) database, and lastly, data on freedom of investment and freedom of commerce were obtained from the Heritage Foundation. For any missing data for certain indicators, the paper uses linear interpolation to fill them in.

3 Empirical Analysis

3.1 Model Setup

The stochastic frontier gravity model can better solve the problem of trade resistance factors being ignored and leading to the bias of the results, and break through the

limitations while being able to better measure the trade efficiency. Based on the existing research results, the stochastic frontier gravity model is set as Equation (1):

$$lnT_{ijt} = \beta_0 + \beta_1 lnPGDP_{it} + \beta_2 lnPGDP_{jt} + \beta_3 lnPOP_{it} + \beta_4 lnPOP_{jt} + \beta_5 lnDIS_{ij} + \beta_6 Border + v_{ijt} - u_{ijt} \quad (1)$$

v_{ijt}, u_{ijt} represent the random error term and the trade inefficiency term. The trade inefficiency model is set up as Equation (2):

$$u_{ijt} = \alpha_0 + \alpha_1 DIG_{jt} + \alpha_2 TO_{jt} + \alpha_3 GOVER_{jt} + \alpha_4 TRAN_{jt} + \alpha_5 IF_{jt} + \alpha_6 BF_{jt} + \varepsilon_{ijt} \quad (2)$$

In Equation(1),T_{ijt} represents the export volume of China to country j in period t. $PGDP_{it}, PGDP_{jt}$denote the per capita GDP of China and country j in period t, respectively. POP_{it}, POP_{jt}indicate the population size of China and the trading country in period t. DIS_{ij} is the distance between China and country j, and the variable Border indicates whether China and the trading country share a common border.

In Equation(2), DIG_{jt} represents the digital economy development level of country j in period t. TO_{jt}, $GOVER_{jt}$, $TRAN_{jt}$, IF_{jt}, BF_{jt}refer to trade openness, government efficiency index, transportation capacity index, investment freedom, and business freedom, respectively. The core explanatory variable is DIG_{jt}. This paper uses the Entropy Weight Method to construct a measurement system for the level of digital economy that includes three dimensions, namely digital infrastructure construction, digital technological talents and digital industry competitiveness. All data can be found in the ITU and World Bank, and for the missing data of some indicators, this paper uses linear interpolation to fill them in. The data were analyzed using Stata software, resulting in the scores as shown in **Table 1**.

Table 1. Comprehensive Score and Ranking of Digital Economy of ASEAN Countries (from 2010 to 2022).

Country	2010	2014	2018	2022	mean	ranking
Singapore	0.4070	0.4327	0.6151	0.7759	0.5525	1
Malaysia	0.2834	0.3143	0.4082	0.5097	0.3745	2
Indonesia	0.1169	0.1187	0.3335	0.5457	0.2739	3
Thailand	0.1940	0.1972	0.2575	0.3365	0.2418	4
Vietnam	0.1056	0.1500	0.2648	0.4575	0.2328	5
Philippines	0.1560	0.1955	0.2284	0.2896	0.2229	6
Brunei	0.0901	0.1072	0.1399	0.2026	0.1323	7
Laos	0.0196	0.0512	0.0710	0.1037	0.0604	8
Cambodia	0.0274	0.0293	0.0434	0.0700	0.0422	9
Myanmar	0.0096	0.0394	0.0365	0.0702	0.0393	10

Note: Measured by the author.

Overall, the comprehensive development level of the digital economy in ASEAN countries has significantly improved from 2010 to 2022.However, there are also serious challenges for individual countries, as the advancement of the digital economy in ASEAN countries is imbalanced. The countries with the highest overall scores in digital economy development are Singapore, Malaysia and Indonesia, with Laos, Cambodia and Myanmar at the bottom of the list.

3.2 Descriptive Statistics

Table 2 presents the descriptive statistics of the variables. In the empirical study, natural logarithms were taken for some of the variables in order to attenuate the heteroskedasticity of the data. The software Frontier 4.1 was used as a tool for regression analysis in this study.

Table 2. Descriptive statistics results for variables.

Variable	Number of samples	Minimum	Maximum	Mean
lnT_{ijt}	130	10.513	16.503	14.138
$lnPGDP_{it}$	130	8.423	9.446	9.018
$lnPGDP_{jt}$	130	6.663	11.390	8.548
$lnPOP_{it}$	130	21.014	21.069	21.048
$lnPOP_{jt}$	130	12.889	19.434	17.007
$lnDIS_{ij}$	130	11.537	13.167	12.373
Border	130	0.000	1.000	0.300
DIG_{jt}	130	0.009	0.776	0.217
TO_{jt}	130	0.057	0.628	0.224
$GOVER_{jt}$	130	-1.680	2.320	0.204
$TRAN_{jt}$	130	12.370	70.890	38.905
IF_{jt}	130	0.000	85.000	47.730
BF_{jt}	130	20.000	98.000	63.500

Note: Measured by the author.

3.3 Applicability Test

In order to enhance the objectivity of the regression results, it is essential to verify the model's applicability prior, and the method used is the likelihood ratio test. The results of the hypothesis testing are shown in **Table 3** below.

Table 3. Applicability test results.

Null Hypothesis	Constrained Model	Unconstrained Model	LR	Degrees of Freedom	1% Critical Value	Test Result
No Inefficiency Terms	-106.485	-8.408	196.154	4	12.483	Reject
Inefficiency Terms Do	-8.408	4.306	25.428	3	10.501	Reject

Not Vary Over Time						
No Border Variable	4.400	4.306	-0.188	2	8.273	Accept

Note: Measured by the author.

The results show that the model has non-efficiency terms that do not vary over time and that the model should not introduce common border variables. Therefore, the Equation (1) of the stochastic frontier gravity model is reformulated as Equation (3):

$$lnT_{ijt} = \beta_0 + \beta_1 lnPGDP_{it} + \beta_2 lnPGDP_{jt} + \beta_3 lnPOP_{it} + \beta_4 lnPOP_{jt} + \beta_5 lnDIS_{ij} + v_{ijt} - u_{ijt} \quad (3)$$

3.4 Analysis of Stochastic Frontier Gravity Model results

Table 4 below demonstrates the empirical results for the linear regression (OLS), time-invariant stochastic frontier model (TI) and time-varying stochastic frontier model (TVD).

Table 4. Estimation Results of the Stochastic Frontier Gravity Model.

	OLS		TI		TVD	
Variable	Coeffi-cient	t-Sta-tistic	Coeffi-cient	t-Sta-tistic	Coeffi-cient	t-Statis-tic
Constant Term	944.280**	2.635	350.793**	2.319	276.354**	2.406
$lnPGDP_{it}$	3.368*	3.312	1.739***	4.089	2.047***	6.376
$lnPGDP_{jt}$	0.945	16.732	1.039***	10.270	1.033***	11.865
$lnPOP_{it}$	-46.498**	-2.677	-17.920**	-2.449	-14.275**	-2.558
$lnPOP_{jt}$	0.991***	27.730	1.039***	12.685	0.755***	8.035
$lnDIS_{ij}$	-0.548**	-2.430	-0.066	-0.618	-0.058	-0.736
σ^2	0.325		0.518	1.503	21.943***	6.243
γ	/		0.913***	15.373	0.998***	2500.87
μ	/		0.722*	1.661	-9.361***	-4.643
θ	/		/		-0.033***	-4.829
Log - Likelihood Value	-108.289		-4.647		4.400	
LR Test	/		207.283		225.378	

Note: *** p<0.01, ** p<0.05, * p<0.1

The results show that: China's export trade flows are significantly and positively affected by the size of the economies of China and ASEAN countries, as well as the size of the population of ASEAN countries, the population size of China has a significant negative impact on China's export trade volume; the coefficient of the geographic distance between China and ASEAN countries is not significant, probably because with the advancement of the logistics technology, the impediment of the geographic distance to the trade has gradually weakened.

3.5 Analysis of the Results of the Trade Inefficiency Model

In constructing the trade inefficiency model, we consider the level of the digital economy as a key trade impediment and use a "one-step approach" to directly observe the empirical results of the model, as shown in the **Table 5**.

Table 5. Estimation Results of the Trade Inefficiency Model.

Model	Variable	Coefficient	Standard Error	t-Statistic
(1)	Constant Term	942.530***	1.658	568.357
	$lnPGDP_{it}$	2.758***	0.115	24.025
	$lnPGDP_{jt}$	0.753***	0.028	27.313
	$lnPOP_{it}$	-46.014***	0.151	-303.750
	$lnPOP_{jt}$	0.929***	0.026	36.169
	$lnDIS_{ij}$	-0.479***	0.105	-4.569
(2)	Constant Term	3.251***	0.297	10.932
	DIG_{jt}	-2.012***	0.428	-4.703
	TO_{jt}	-5.292***	0.422	-12.547
	$GOVER_{jt}$	0.278**	0.109	2.537
	$TRAN_{jt}$	-0.023***	0.005	-4.508
	IF_{jt}	-0.009***	0.002	-3.958
	BF_{jt}	0.010***	0.003	3.232
	σ^2	0.078***	0.009	8.257
	γ	0.999***	0.027	37.593
	Log - Likelihood Value		0.863	
	LR Test		218.304	

Note: *** p<0.01, ** p<0.05, * p<0.1

Based on the regression outcomes,the value of γ is 0.999, indicating a good fit of the trade inefficiency model. Moreover, the values of σ² and γ are both significant at the 1% level. Serving as the primary explanatory variable in this research, the coefficient of DIG_{jt} is -4.703, which is negatively correlated with the trade inefficiency term. It shows that the advancement of digital economy in ASEAN countries can significantly improve the efficiency of China's exports. For every 1 percentage point increase in the level of digital economy in ASEAN countries, the estimated inefficiency of China's export trade to them is expected to decrease by 4.703%. Furthermore, even after including five influencing factors—trade openness, government efficiency index, transportation capacity index, investment freedom, and business freedom—the variable still significantly suppresses trade inefficiency.

4 Conclusions and recommendations

This study utilizes panel data from ASEAN countries spanning 2010 to 2022 to calculate the digital economy levels. Subsequently, We used the stochastic frontier gravity

model to assess the role of the degree of digital economy development in ASEAN countries on the efficiency of China's export trade, and came to the following specific conclusions: Firstly, the overall trend of the development of the digital economy in the ASEAN countries is on an upward trend. At the national level, however, a digital divide exists among these countries. Secondly, the economic scale of both China and ASEAN countries, as well as the population size of ASEAN countries, have a significant positive impact on China's export trade volume. In contrast, China's population size exerts a significant negative influence on its export trade volume. Third, Upgrading the digital economy of ASEAN countries can effectively promote the efficiency of China's export trade with ASEAN.

In light of this conclusion, this paper proposes the following policy recommendations as primary considerations: Firstly, the further strengthen cooperation with ASEAN countries, particularly those lagging in digital economy development. Secondly, enhance collaboration with ASEAN countries in digital technology talent cultivation and innovation to create a more favorable technical environment for improving export trade efficiency.

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