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Digital Economy, China International Trade Potential, Industries of BRI countries: Evidence from Stochastic Frontier Gravity Model

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Abstract: The article investigates the impact of digital trade on China's trade efficiency, trade potential, and the possible influence factors of China to BRI nations under stochastic frontier gravity methodology framework. In this article, it follows previous studies and employ stochastic frontier gravity model to explore possible influence of digital trade and trade barriers on China's foreign trade potential at country-level. It evaluates the influence factor of China export potential to BRI countries via the aspect of digital commerce. Moreover, this article enriches the BRI literatures by employing stochastics frontier gravity model to examine the impact of digital trade on China trade potential and trade efficiency to BRI countries. The results of the study support the important role of BRI in facilitating digital trade among BRI countries and China. In addition to revealing the factors affecting digital trade (e.g., GDP and distance, bordering issue), the results highlight the importance of considering non-efficiency factors, in our case, the negative impact of digital trade restrictions on trade efficiency. The findings may provide some insight for policy makers (in China and BRI countries) into loosening the digital trade restrictions and improve trade efficacy along the BRI.

Keywords: Trade tariff, Digital trade, Belt and Road Initiative countries, Stochastic frontier gravity model.

1. Introduction

Nowadays, Chinese government has launched a global development strategy, "the Belt and Road Initiative (BRI)", covering infrastructure investment and development in more than 150 countries and international organizations, involving different nations and regions, such as Europe, Asia, Africa, the Middle East, and the Americas (Huang, 2016) (Jing, Zhihui, Jinhua, & Zhiyao, 2020). The targeted regions and countries are expecting to attract more Chinese foreign direct investment (FDI) with the development of BRI. Specifically, due to geopolitical advantages, West and Central Asia and Russia are favourable destinations of Chinese outward FDI (Du and Zhang, 2018). Intuitively, along with this ambitious strategy, China has surpassed the USA and ranked the second place regarding its outward FDI by 2018. A "new world order" is being built by China (Griffiths, 2017).

It is noted that there has not being without challenges for the BRI, where concerns come from potential clash of different political regimes and cross-border projects' financial viability and the lack of central coordination mechanism (Thøgersen, Zhou, & Huang, 2016). Meanwhile, the growth of Chinese outward FDI has been challenged by political uncertainties, for instance the current trade war between China and the USA. Notably, being the traditionally political partners to the USA, some countries in the Europe such as France, the UK, and Germany, have to balance the political pressure from the US and the direct investment from China most of which have been dominated by China's state-controlled companies (Du and Zhang, 2018). Despite the emergence of active non-state acquirers in non-infrastructure sector, the magnitude of the investment may be small or the large amount investment may come from the information and communication technology (ICT) companies, for example Huawei. The European countries are concerned about whether or not they would get trade gain in this process compared to the Asian countries (Herrero and Xu, 2017).

Another challenge comes from the underestimating the role of digital trading in the development of BRI. (Kozłowski, 2018) point out that BRI includes the establishment of digital industries and infrastructures. Compared to potential different political regime issue, few attentions have been paid on the development of Internet in BRI (Shen, 2018). However, recently, with the rise of giant Chinese internet companies, to build digital economy seems urgent for BRI development. Since 2015, "information Silk Road" and "digital Silk Road" or related concepts become more and more popular. Moreover, President Xi confirmed that building the digital Silk Road was the essential task in the overall development of BRI (Shen, 2018). In the published "13th Five-Year Plan", there was a separated section to discuss the building of digital or information Silk Road in 2016. Furthermore, the outline of the 2035 long-term goals and the "14th Five-Year Plan" clearly state that it is the crucial to promote the deep integration of the digital economy and the real economy. Therefore, digital economy is becoming more and more important among BRI countries.

The literature on the BRI focuses on the political perspectives regarding the potential impact of BRI on the targeted countries and regions (Pu, 2016). In particular, attentions have been given to the special role of China could play in this process politically and economically, as the BRI region could incorporate successful experiences of emerging market economies (Huang, 2016), and some believed that it may bring in new financial orders to the BRI region (Tsui et al., 2017). Therefore, the majority of the studies on BRI have focused on its potential economic impact on "Belt and Road" countries. To my best knowledge, so far, rarely have studies attempted to explore the impact of BRI on Chinese economy itself. The possible reason maybe it is too early to estimate the influence of BRI which has the potential ability to deeply integrate China and "Belt and Road" countries (Chan, 2017).

(Li, 2018; Tan & Zhou, 2015) point out that very few scholars investigate trade efficiency and potential among BRI countries and China. Moreover, to my best knowledge, few studies focus on exploring the impact of digital trade of BRI on Chinese economy, especially the potential of Chinese international trade. In this article, I will fill the gap and estimate the impact of digital economy on China international trade potential under the BRI framework.

The paper aims to provide the contribution of existing literature on the impact of BRI in two main ways. First, it evaluates the possible influence of BRI on China's foreign trade potential via the view of digital trade and barriers. Although at the early stage of BRI it may be hard to assess the impact of "Digital Silk Road", the article provides valuable information regarding to Chinese economy especially international trade potential. Second, the article employs the stochastic frontier gravity model and provide empirical results at country-level regarding to the influence of digital trade barriers on international trade potential under BRI framework.

2. Literature Review

Three streams of literature are closely associated with my research. The first stream of research provides the basis study of trade potential among "Belt and Road Initiative" countries and China. The second stream of research explore the impact of digital trade on Chinese economy and BRI countries. "Digital Silk Road" and "Online Silk Road" are the crucial components in the development of BRI. The last stream of the research help builds the empirical analysis models. The stochastic frontier gravity models are often applied in analysing the impact of trade barriers on international trade potential, exploring trade determinants, and investigating trade patterns.

Currently, studies on the international trade potential mainly focus on the level of traditional industries. (Cieślik, 2020) investigate 19 European BRI countries and find that the there is a significant positive relationship among Chinese exports of using the potential of European trading markets and the dependence on Chinese value added of European countries' exports. The research covers 54 industries including textiles, electronical equipment manufacturers, transport equipment, rubber and plastic products, electronic and optical products and so on. They also conclude that the level of export to the 19 European BRI countries is still low, and China has high export potential value to the European markets. However, a few qualitative studies focus on the association of the BRI and China-Europe trade provided less confidence of the economic contribution of BRI to the European countries' economies (Herrero & Xu, 2017; Zeng, 2017). (Cheng & Qi, 2021) collect data from 2008 to 2017 which covers 132 countries in total, of which 98 are BRI countries. Their empirical findings indicate that potential of Chinese Foreign Direct Investment (FDI) in low carbon field is greater than carbon intensive. field. Moreover, there are significant differences in determining FDI in the two fields.

In existing literature, digital silk road and communication sector are often undervalued and are given less attention (Ly, 2020; Shen, 2018). The centre of BRI is commonly considered as building infrastructure, such as gas pipeline, roads, and railways and so on (Kennedy & Parker, 2015). While, recently, digital infrastructure and e-commerce are becoming more and more popular. (Shen, 2018) point out that one of the most important purposes of BRI is to build a global political economy network to join China and BRI countries via infrastructure investment as well as digital infrastructure. By 2020, the total volume of China's cross-border digital trade will reach CNY 12 trillion which is more than one-third of total Chinese foreign transactions (Liang & Zhang, 2019). In addition, digital trade enhances the connection between China and BRI countries, as well as increases trade efficiency (Liang & Zhang, 2019). In the future, it seems to be crucial that "Digital Silk Road" will develop in a sustainable way (Guo et al., 2018).

Gravity models are often applied in investigating international trade issues, such as trade potential, trade pattens and barriers, and influence factors during trade process (Jing et al., 2020). Pöyhönen (1963) and Tinbergen (1962) are considered the pioneers who first try to use gravity models in analysing international bilateral trade researches. Gravity models consists of frontier gravity model and conventional gravity model. For example, (Bi & Shi, 2010) employ conventional gravity model to analysis China's trade potential. (Sun, Edziah, Song, Kporsu, & Taghizadeh-Hesary, 2020) conduct a stochastic frontier analysis to estimate transient and persistent energy efficiency among BRI nations. Also, gravity models can be used at both country-level and industry-level. (Jiang, Zhang, & Lin, 2021) use frontier gravity model in exploring trade potential and efficiency among BRI countries and China at industry-level. While, (Li, 2018) conduct the similar analysis at country-level. In this article.

The traditional gravity model is often used in research field of studying trade potential and identify the determinants of constraining the trade flow, especially international trade potential and efficiency (Jiang et al., 2021). However, the traditional gravity model has its own limitations. The assumption of traditional gravity model is free of trade friction, thus, subjective resistances are not controlled correctly (Fan, Zhang, Liu, & Pan, 2016). (Armstrong, 2007) argue that since the mean effects of trade determinants are evaluated under the conventional gravity model framework, trade resistance issues are still unsolved properly. While trade resistance is a crucial factor which has important impact on international bilateral trade. To reduce the influence of trade resistance, (Meeusen & van Den Broeck, 1977) and (Aigner, Lovell, & Schmidt, 1977) firstly introduce and develop the stochastic frontier analyse technique in the study of trade potential.

3. Research Methods and Data

3.1. Theoretical framework

In this article, I follow previous studies and employ stochastic frontier gravity model to explore the possible influence of trade barriers and digital trade on China's foreign trade potential at country-level. The actual trade potential Y^*_{ijt}, trade volume Y_{ijt}, and trade efficiency TE_{ijt} of nation i to nation j in a year t can be specified as below:

$$Y_{ijt} = f(x_{ijt}, \alpha) \exp(v_{ijt}) \exp(-u_{ijt}), u_{ijt} \geq 0 \quad (1)$$

$$lnY_{ijt} = lnf(x_{ijt}, \alpha) + v_{ijt} - u_{ijt}, u_{ijt} \geq 0 \quad (2)$$

$$Y^*_{ijt} = f(x_{ijt}, \alpha) \exp(v_{ijt}) \quad (3)$$

$$TE_{ijt} = Y_{ijt}/Y^*_{ijt} = \exp(-u_{ijt}) \quad (4)$$

Where x_{ijt} is the variables that is established to represent the actual trade level in the gravity model, such as per capital GDP, economic and market size, distance between importing and exporting countries, population, and language and so on. α denotes a vector of unspecified parameters. v_{ijt} represents a random noise that follows the normal distribution with a mean value of zero. The random noise measures the estimation deviation cause by the uncontrolled influence factors, such as statistical error. u_{ijt} represents a trade non-efficiency term that is independent of the random noise v_{ijt}. Unlike conventional gravity model, stochastic frontier gravity model can take the trade resistance into account using the trade non-efficiency term u_{ijt}, which can control the impact of trade resistance and measure it. In stochastic frontier gravity model, u_{ijt} is used in measuring the trade resistance that are not considered in the model, such as government policy, and tariff level and so on. One of the assumptions is that u_{ijt} follows truncated normal distribution instead of the normal distribution. In the case of u_{ijt} larger than zero, there is trade non-efficiency in bilateral trade. In addition, when $TE_{ijt}$is larger than zero and less than one, the trade potential volume is greater than the actual trade level. While in the case of u_{ijt} is equal to zero, it indicates that bilateral trade does not have trade non-efficiency. And TE_{ijt} is equal to one, which means that the level of actual trade is the same to the potential trade volume.

In the early stage of the development of stochastic frontier analysis, the trade non-efficiency term is usually assumed to be constant and not changed with time. The model is called the time-invariant model. However, when the data set is constructed in the form of panel data, the assumption would not hold. Because one of the features of panel data is that the time dimension is long in data set. To solve the issue, the time-varying stochastic frontier gravity model is introduced into the analysis of trade potential, especially dealing with unbalanced panel data (George E Battese & Coelli, 1992). The form of time-varying stochastic frontier gravity model is as follows:

$$u_{ijt} = u_{ij}\exp\left(-\eta(t-T)\right) \quad (5)$$

Where u_{ijt} still follows the semi-normal distribution with $\exp\left(-\eta(t-T)\right)$ larger that zero. In equation (5) η denotes an estimated parameter which takes the time effect into account. The value of η can be larger, smaller, and equal to zero. In the case of larger than zero, the trade non-efficiency term u_{ijt} declines, which means that the trade resistance decreases with time. If η is less than zero, then the term u_{ijt} move up, which indicates that the trade resistance increases with time. And when the parameter η is equal zero, u_{ijt} becomes a constant and the effect of time is zero. Therefore, the model turns to be a time-invariant model.

Regarding to the determinants of trade non-efficiency, a one-step method is proposed by (George Edward Battese & Coelli, 1995). The method requires the trade inefficiency components and its determinants regress in the stochastic frontier model simultaneously. The basic form is as follows:

$$u_{ijt} = f\left(k_{ijt}, \alpha\right) + \varepsilon_{ijt} \quad (6)$$

Where α denotes an unknown vector of parameter, k_{ijt} represents the variables that influence trade inefficiency exogenously, and ε_{ijt} is a random disturbance term. We substitute Equation (6) into Equation (2) and the new formula is as follows:

$$lnY_{ijt} = lnf\left(x_{ijt}, \alpha\right) + v_{ijt} - [f\left(k_{ijt}, \alpha\right) + \varepsilon_{ijt}] \quad (7)$$

3.2. Data Description and Methodology

3.2.1. Time-varying Stochastic Frontier Gravity Model

First, in order to estimate Chinese trade potential (exporting country) to the industries of BRI countries, I build a time-varying stochastic frontier gravity model. The details are as below:

$$lnY_{ijt} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{jt} + \beta_3 lnPOP_{it} + \beta_4 lnPOP_{jt} + \beta_5 lnDIS_{ij} + \beta_6 lnict_t + \beta_7 jr_t + \beta_8 X_{ijt} + v_{ijt} - u_{ijt} \quad (8)$$

Where Y_{ijt} is the dependent variable that represent the total volume of China's export to country j in year t. The independent variables are GDP, per capital of GDP, the ratio of digital trade volume to GDP, distance, and other factors, such as language, border, and landlock. The details of independent variables are as follows in Table 1.

Table 1. Description of variables included in the stochastic frontier gravity model

Independent variables	Description	Data sources	Expected sign
GDP_{it}, GDP_{jt}	The GDP of China and BRI nations (importing countries)		+
POP_{it}, POP_{jt}	The size of population of China and BRI nations (importing countries)		+
DIS_{ij}	Geographical distance among China and BRI countries (importing countries)		-
jr_t	BRI countries (importing countries) bordering with China or not		+
ict_t	Bilateral trade flows by ICT goods categories		+
X_{ijt}	Other factors that influence actual trade level		+

3.2.2. Trade Non-efficiency Model

To further explore the impact of digital trade barriers on trade non-efficiency among BRI countries and China, this article employs one-step trade non-efficiency model. The specific model equation is as follows:

$$u_{ijt} = \alpha_0 + \alpha_1 stri_{jt} + \alpha_2 fdi_{jt} + \alpha_4 fta_{jt} + \alpha_5 ita_{jt} + \varepsilon_{ijt} \quad (9)$$

Where u_{ijt} is trade non-efficiency. The details of independent variables are given in Table 2.

Table 2. Description of variables included in the stochastic frontier gravity model

Independent variables	Description
$stri$	Digital services trade restrictiveness index
fdi	The ratio of net FDI inflow to GDP
fta	Existence of free trade agreement between China and the other country
ita	Whether or not the china has a ITA with the targeted country

The final sample used in the study includes 322 observations. Key variables' descriptive statistics covered in the models above (equation 8 and equation 9) are presented in Table 3.

Table 3. Descriptive statistics of key variables in frontier gravity model

Variable	Mean	Std. Dev.	Min	Max	Observations
gdpj	828000	1048135	17517.21	5148782	322
pgdpi	9006.837	1061.807	7636.12	10434.78	322
pgdpj	30298.59	24426.87	1573.886	124000	322
popj	69.602	197.246	0.327	1380.004	322
popi	1393.88	13.574	1371.86	1410.929	322
dis	8350.662	3988.25	956.28	19261.93	322
exp	40968.32	61829.65	589.724	312641	322
dis	8350.664	3988.251	956.28	19261.9	322
ict	5298.873	8680.019	9	39653	322
jr	0.065	0.247	0	1	322
stri	0.177	0.096	0.043	0.647	322
fdi	3.329	10.476	-40.291	81.335	278
fta	0.127	0.334	0	1	322
ita	0.87	0.337	0	1	322

4. Results and Discussion

4.1. Findings of Time-varying Stochastic Frontier Gravity Model

The dependence of stochastic frontier gravity model on form of model function cannot be ignored. Therefore, the appropriate form of function is tested and needed by generalized likelihood ratio before conducting empirical analysis. There are two tests in the article. One is the existence test, that is, whether there is trade inefficiency. The other one is the time-varying test of trade inefficiency, that is, whether trade inefficiency changes with time. The tests results (seeing Table 4) show that at 1% significant level, trade non-efficiency changes with time and no existence of trade non-efficiency is rejected. Therefore, the selection of time-varying stochastic frontier gravity model is appropriate.

Table 4. Test findings of model selection

Hypothesis	Constraint model	unconstrained model	LR statistic	Results
No existence of trade non-efficiency	-417.3955	114.2469	1063.28	Reject*
No change of trade of non- efficiency with time	114.2469	135.166	41.84	Reject

* At 1% significant level

Table 5 presents the results of time-varying stochastic frontier gravity model. According to the regression results, η is significant at 1% significant level, which means that trade inefficiency changes with time. Moreover, the significance of η also shows that the selection of time-varying model is more appropriate than time-invariant model. Moreover, η has a positive value which shows that trade non-efficiency decreases with time. The independent variable GDP (lngdpj) is significant and positive at 1% significant level, which indicates that there is a positive impact of economic development of BRI countries on trade. Similarly, (Fadun, 2014) shows that there is a positive effect of the GDP (economic size) on agri-food export in Nigeria. The variable lndis is significant and negative at 10% significant level, which shows that distance impedes trade. The result is consistent with (Chaney, 2018) and (Tinbergen, 1962)'s conclusion that the transport cost reflected by distance has a negative influence on trade. The coefficient lnpopj is significant with negative value, which means that smaller market size of BRI countries needs more imports. The negative coefficient sign is not consistent with expectation, which may be due to the internal demand of BRI countries that impedes the export (Jiang, Zhang, & Lin, 2021; Martínez-Zarzoso & Nowak-Lehmann, 2003). Finally, γ is the ratio of trade non-efficiency to disturbance term with the value 0.992 in both time-invariant and time-varying models. The significancy of γ shows that optimal frontier trade volume and actual trade level are significantly different. Furthermore, the difference is caused by trade non-efficiency, which is consistent with (Jiang et al., 2021)'s result.

Table 5. Regression findings of OLS, time-invariant, and time-varying model

	OLS	time-invariant	time-varying
lngdpi	0.183	0.557***	0.0515
	(0.52)	(11.81)	(0.48)
lngdpj	1.506***	0.790***	0.891***
	(19.03)	(11.63)	(12.26)
lndis	0.0948	-0.446	-0.446*
	(0.86)	(-1.29)	(-1.76)
lnpopj	-1.061***	-0.299***	-0.342***
	(-15.39)	(-3.26)	(-4.78)
lnpopi	40.27	3.263	1.412
	(0.90)	(0.58)	(0.26)
lnict	0.380***	-0.00293	-0.0412
	(6.24)	(-0.10)	(-1.43)
jr	0.692***	-0.427	-0.454
	(2.89)	(-0.62)	(-0.85)
_cons	-870.3	-85.70	-33.17
	(-0.92)	(-0.72)	(-0.29)
lnsigma2			
_cons		0.370	0.218
		(1.30)	(0.80)
gamma			
_cons		0.992***	0.992***
		(16.17)	(16.69)
mu			
_cons		2.273***	2.217***
		(6.20)	(6.56)
eta			
_cons			0.0156***
			(6.50)
N	322	322	322
ll	-417.4	114.2	135.2
chi2		445.0	235.8
p	1.66e-77	5.20e-92	2.90e-47

t statistics in parentheses; ** $p < 0.05$, * $p < 0.1$, *** $p < 0.01$

Table 6. Time-varying stochastic model with trade non-efficiency considered

Time-varying Stochastic Frontier Gravity Model		Trade Non-efficiency Model	
Frontier		Mu	
lngdpi	0.347	stri	23.56**
	(1.03)		(2.42)
lngdpj	1.542***	fdi	-0.0432
	(22.56)		(-0.88)
lndis	0.454***	wdi	-0.00839
	(3.41)		(-0.05)
lnpopj	-1.186***	fta	2.778
	(-19.91)		(1.55)
lnpopi	31.80	ita	0.391
	(1.20)		(0.29)
lnict	0.427***	_cons	-8.948
	(8.44)		(-1.49)
jr	2.991***		
	(9.36)		
_cons	-698.6		
Usigma		1.359**	
_cons		(2.31)	
Vsigma		-1.774***	
_cons		(-8.88)	
N		254	
ll		-281.5	
chi2		1188.8	
p		0	

t statistics in parentheses; ** $p < 0.05$, * $p < 0.1$, *** $p < 0.01$

4.2. Trade non-efficiency model

In the article, it uses one-step method to develop the trade inefficiency mode. As shown in Table 6, although only one variable (stri) is found to be significant in the non-efficiency model, the time-varying stochastic frontier gravity model performs better when the non-efficiency part is considered. Note that, the variable stri (digital services trade restrictiveness index) is an important variable in measuring restrictions of digital trade. The associated coefficient is significant with a positive value, which means that the less restriction on digital trade, the more promoting effect on the development of digital commerce. These results are consistent with the previous studies on, for example the effect of tariff and trade restriction on trade efficiency (Jiang et al., 2021). In addition, more independent variables are significant in the stochastic frontier function after taking the trade inefficiency into account. For example, the coefficient of lnict (bilateral trade flows by ICT goods categories) is significant now with positive value, which indicates that the larger volume of bilateral trade, the more prompting the digital commerce development. Another independent variable jr (border) also becomes significant with positive value, which means that bordering with China has a positive effect on China's export to BRI nations.

5. Conclusion

The article investigates the impact of digital trade on China's trade efficiency, trade potential, and the possible influence determinants of China to BRI nations under the stochastic frontier gravity methodology framework. There are two main contributions of the study. First, it evaluates the influence factor of China export potential to BRI countries via the aspect of digital commerce. Second, the article enriches the BRI literatures by employing stochastics frontier gravity model to examine the influence of digital trade on China trade potential and trade efficiency to BRI countries.

The results of the study support the important role of BRI in facilitating digital trade among China and BRI nations. In addition to revealing the factors affecting digital trade (e.g., GDP and distance, bordering issue), the results highlight the importance of considering non-efficiency factors, in our case, the negative influence of digital trade restrictions on trade efficiency. The findings may provide some insight for policy makers (in China and BRI countries) into loosening the digital trade restrictions and improve trade efficacy along the BRI.

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