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This paper is written by WANG Yue and YAN Binyang from Renmin University.

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Abstract

Despite certain consensus having been reached, Central Asian countries still face a depression in regional trade cooperation. As a crucial organization to promote trade cooperation, CAREC involves most of the major countries situated at the border of the European continent and the Asian continent. To further forecast the trade development prospect of Central Asia and promote the formation of an action plan to remove trade resistance factors as soon as possible, this report uses the stochastic frontier gravity model to study the trade efficiency and influencing factors among CAREC countries. The results show that the trade efficiency of the CAREC region is generally low; 56% of countries have a trade efficiency lower than 0.2. There is still huge room for improvement concerning trade integration in this region, and the trade efficiency of the CAREC region generally declined from 2001 to 2020. The development of regional trade lags behind the expansion speed of ideal boundary. Transportation cost represented by geographic distance is a major constraint factor in the CAREC region, and the so-called 'interconnectivity' in Central Asia serves as an important link to drive the development of trade. The trade barrier of export countries is an important factor hindering trade efficiency. To further expand export, government regulation should be reduced and market forces should be used to realize the effective allocation of resources. The informatization difference between CAREC countries has a significant negative impact on trade efficiency, and the further expansion of informatization difference caused by COVID-19 may become a new hindering factor in the development of trade, which deserves policy attention.

Key words: CAREC region; Central Asia; trade efficiency; influencing factors; stochastic frontier gravity model

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Abbreviations

APTA	Asia-Pacific Trade Agreement
CAREC	Central Asia Regional Economic Cooperation
CRII	CAREC Regional Integration Index
EAEU	Eurasian Economic Union
GDP	gross domestic product
NTB	non-tariff barriers
SFA	stochastic frontier analysis
SPS	sanitary and phytosanitary standards

1 Introduction

Connecting Europe and Asia, Central Asia is geographically prominent. In the 13th century, Genghis Khan built the largest land empire in history, allowing long distance trade between East Asia and Europe, with Central Asia becoming known as the 'crossroads' of Eurasia (Findlay and O'Rourke, 2007). After its decline, Central Asia became unstable and lost its trading status. First it was absorbed into the Russian Empire, and subsequently became part of the Soviet Union (Pomfret, 2010). After the independence of the Central Asian countries in 1991, not only did these countries wish to become crossroads again, other countries in the world also adopted the layout of 'the Silk Road.' The New Silk Road Initiative of the United States, the Silk Road Diplomacy of Japan, and the Silk Road Economic Belt initiative of China all reflect their support of the development of central Asia and cooperation with the region.

The Silk Road focuses on trade issues, and the economic development of Central Asia depends on foreign trade. The foreign trade of central Asian countries has natural advantages in the form of energy and agricultural products, but obvious disadvantages in commodity transportation. Transportation in Central Asia met the needs of the Soviet Union in the past, but fell short of the requirements of commodity globalization; its transportation network could not adapt to the development of modern trade. During its 30 years of independence, Central Asia focused on national reconstruction and other economic fields in the first 20 years (Pomfret, 2010). In the past 10 years, it began to emphasize the importance of transportation, proactively sought capital investment, and upgraded hard and soft infrastructure to further reduce trade costs. As Central Asia is far away from most global economic centers and still lacks efficient cross border cooperation, trade cooperation among regional countries is particularly important (Mogilevskii, 2012) and is the main choice for the development of foreign trade in Central Asia (Kim and Mariano, 2020).

Multilateral institutions, bilateral donors, and non-government organizations play an active role in the development of trade in Central Asia, and the Central Asia Regional Economic Cooperation (CAREC) has the most extensive influence in promoting economic cooperation within the region (Qadir and Adriano, 2018). Founded in 2001, CAREC is a cooperation platform led by the Asian Development Bank to improve regional development and upgrade regional cooperation. It has also formed a negotiation mechanism (Pomfret, 2010) focusing on trade cooperation. It currently involves 11 countries—namely, Afghanistan, Azerbaijan, China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan.

In a word, despite certain consensus having been reached, Central Asian countries still face a depression in regional trade cooperation. As a crucial organization to promote trade cooperation, CAREC involves most of the major countries situated at the border of the European continent and the Asian continent. Member countries of CAREC have shown their willingness to promote trade cooperation. To further forecast the trade development prospect of Central Asia and promote the formation of an action plan to remove trade resistance factors as soon as possible, this report uses the stochastic frontier gravity model or stochastic frontier analysis (SFA) model to study trade efficiency and its influencing factors among CAREC countries. It also highlights the gap between the current trade status and its ideal level and identifies the key factors affecting the sustainable development of regional trade.

2 Literature Review

In view of CAREC's important role in regional economic integration in Central Asia and in promoting trade cooperation in Central Asia, some scholars have carried out a series of studies on CAREC regional economic development. Regional economic integration in Central Asia is an important CAREC goal.

Qadir and Adriano (2018) proposed the CAREC Regional Integration Index (CRII), which measures cooperation among CAREC members. Qadir and Dosmagambet (2020) studied from the perspective of CAREC regional energy trade integration and concluded that the region should build cross border energy trade infrastructure and governance mechanism through regional public goods to optimize regional trade cooperation.

CAREC regional studies are more based on trade development and trade cooperation. The purpose of the CAREC regional economic integration path designed by Mehar (2020) was to obtain financing through short term foreign debt for the development of trade and transport related infrastructure, to increase the total volume of trade activities, and thus promote economic growth. International trade is considered to be a tool and driving force for economic development (Frankel and Romer, 1999). Both classical and neoclassical economists believe that foreign trade is an engine of economic growth, and that foreign trade can help a country promote economic reform, create jobs, and develop professional skills to achieve sustainable development goals (Gnangnon, 2019). Mogilevskii (2012) analyzed the trade development of CAREC countries.

Concerning trade research in the CAREC region, little has been written focusing on trade development and a gap remains in the study of trade efficiency and trade potential between CAREC countries, while the gap between trade and ideal trade is not clear either. Trade efficiency and potential is studied by using the SFA model, which has become the mainstream method of measuring trade efficiency estimation. For example, Stack, Pentecost, and Ravishankar (2018) calculated that Britain retreated after the members of the European Union's trade efficiency, focusing on the trade performance of the new EU member states; Jiang, Zhang, and Lin (2021) estimated China's export potential and trade efficiency to countries along the Belt and Road, and so on.

With the background of slow development in CAREC's regional trade, a number of scholars have analyzed trade resistance. Roy and Xiaoling (2020) pointed out that economic growth, foreign direct investment, and the labor force have a positive influence on CAREC's regional export performance; in addition, paperless trade policies and measures to increase aid for trade facilitation and communications department allocation can improve export trade in these areas. Yelena and Hans (2021) studied the strengthening of the connectivity and trade between CAREC and the rest of the world, emphasizing that transportation corridors and the reduction of trade costs are crucial to the development of foreign trade in CAREC countries. Kim and Mariano (2020) measured the impact of reducing border trade time and cost on CAREC regional trade and found that CAREC interregional trade increased by 1.41% when the time at import borders decreased by 10%. Factors affecting trade efficiency include many aspects, such as economic development, natural environment, cultural and social environment, and political environment. Currently, there is hardly any research into factors affecting trade in the CAREC region; it is limited mainly to economic aggregate, direct investment, trade facilitation, and so on.

In general, trade is an important direction of CAREC area studies, and is an important goal of CAREC regional cooperation. The literature review shows that there are several aspects that deserve more attention: first, trade efficiency and trade potential are an important direction of trade research and an important reference to predict trade development, while it is not clear about the specific analysis result concerning intra-regional trade in CAREC countries. In this report, the SFA model is used to measure the trade efficiency among CAREC countries. Second, CAREC regional trade cooperation needs to remove trade resistance, but currently, information technology development and political institution are rarely involved in the study of trade influencing factors. Based on the main factors such as economic scale, population scale, geographic distance, common language, and border situation, this report focuses on the influence of trade barriers, information difference, and institutional distance on export trade efficiency in the CAREC region.

3 Theoretical Model

3.1 Stochastic Frontier Gravity Model

A gravity model is a common way to estimate trade potential. The estimated amount of trade is the trade frontier level between countries. The bilateral trade fitted value is referred to as trade potential, while the ratio of actual trade volume to trade potential as trade efficiency. The gravity model proposed by Tinbergen (1963) assumes that trade flows between two countries are influenced mainly by market size and geographic distance. This method is widely used for identifying restrictive factors and estimating trade potential in international trade models.

The gravity model can account for only a few objective trade resistance factors, while other invisible factors that are hard to quantify are within the residual term, thus estimation from the gravity model can be biased (Anderson and Van Wincoop, 2003). To cure this problem, Amstrong (2007) proposed the SFA model, whose idea was derived from the production model to measure technical efficiency by Aigner, Lovell, and Schmidt (1977). Specifically, the method specifies a production boundary that represents the maximum output that can be produced from a given input level. The input-output combination on the boundary represents completely effective production activities, while the input-output combination within the boundary represents incomplete efficient production activities (that is, the actual output level is lower than the maximum possible output level). Here the disturbance term can be decomposed into a random disturbance term reflecting statistical noise and a technical inefficiency term, which is used mainly to measure production efficiency and its influencing factors. The steps of the production boundary model to estimate technical efficiency are as follows.

Assume that the production efficiency is 100%, the output function is as follows.

$$Y^* = f(z,b) \tag{1}$$

In actual production process where efficiency loss often exists, the output function is as follows.

$$Y = f(z,b) * \omega \tag{2}$$

Here ω ($0<\omega\leq 1$) represents the efficiency level. When ω equals 1, it means that the existing production technology has reached the theoretical optimal output level. Whereas $\omega<1$ indicates the existence of efficiency loss, which is used to identify the deviation from the maximum possibility of actual transaction level and the degree of potential transaction.

It is assumed that the production may be affected by the random interference term v which follows the normal distribution $\mathrm{N}(0 \sim \sigma_v^2)$. The exponential form is adopted to ensure Y >0, and the output function is as follows.

$$Y = f(z,b) \times \omega \times e^v \tag{3}$$

The production efficiency level ω can be represented as follows.

$$\omega = e^{-u} \tag{4}$$

$$Y = f(z,b) \times e^{-u} \times e^v \tag{5}$$

Take the logarithm form of both sides of the above equation.

$$lnY = ln[f(z,b)] + v - \mu \tag{6}$$

In the stochastic production boundary model, the output index is replaced by bilateral trade volume and the input variable index is replaced by trade influencing factors. The transformation from the stochastic production boundary model to the SFA model can be expressed as follows.

$$ln\, Y_{ijt} = ln\left[f\left(x_{ijt}, \beta\right)\right] + v_{ijt} - \mu_{ijt} \tag{7}$$

Here x_{ijt} is the core variable affecting the actual trade level, and β is the unknown parameter vector. v_{ijt} represents the normal statistical error caused by measurement, which reflects the estimation deviation caused by uncontrollable factors such as statistical error, and follows the normal distribution with the mean value of 0. The trade inefficiency term μ_{ijt} refers to the gap between actual trade and ideal trade volume, and is irrelevant to v_{ijt}. It is generally considered to follow a semi normal distribution or truncated normal distribution.

Trade efficiency TE_{ijt} can be written as the following formula. [①]

$$TE_{ijt} = Y_{ijt}/Y_{ijt}^{*} \tag{8}$$

When $\mu_{ijt}>0$, bilateral trade has trade inefficiency, and $TE_{ijt} \in (0,1)$, which means that the actual trade level is less than the potential trade volume. When $\mu_{ijt}= 0$, there is no trade inefficiency in bilateral trade, and TE_{ijt} equals one, the actual trade level is equal to the potential trade volume.

3.2 Inefficiency Model

Anderson and Van Wincoop (2003) believed that the deviation between the actual value of trade and the ideal value is caused by multilateral trade resistance, which leads to low trade efficiency in bilateral and multilateral trading environments. The trade inefficiency term u_{ijt} can be expressed as follows.

$$u_{ijt} = \beta z_{ijt} + \varepsilon_{ijt} \tag{9}$$

β is the unknown parameter vector. z_{ijt} is the exogenous variable that affects trade inefficiency. ε_{ijt} is a random disturbance term.

Battese and Coelli (1995) put forward the basic form of one step method in the study of trade inefficiency, which makes the trade inefficiency terms u_{ijt} in stochastic frontier model and the influencing factors of principal model x_{ijt} be regressed simultaneously. According to the one step method, we have:

$$ln\, Y_{ijt} = ln\left[f\left(x_{ijt}, \beta\right)\right] + v_{ijt} - \left(\beta z_{ijt} + \varepsilon_{ijt}\right) \tag{10}$$

Here u_{ijt} follows the normal distribution subject to truncation, and the average value βz_{ijt} is irrelevant to v_{ijt}.

[①] The specific derivative process can be referred to in (Kang and Fratianni, 2006).

4 Model Specification, Variables, and Data Source

4.1 The Main Model

When measuring trade efficiency and trade potential based on the SFA model, the main model mainly considers objective variables that do not change over time in the short term, such as economic scale, population size, geographic distance, border and common language of bilateral countries, and so on. The main model specifications are shown in the following formula.

$$\ln T_{ijt} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln Pop_{it} + \beta_4 \ln Pop_{jt} + \beta_5 \ln Dist_{ij} + \beta_6 Border_{ij} + \beta_7 Lang_{ij} + v_{ijt} - \mu_{ijt} \quad (11)$$

Where T_{ijt} is the trade volume between exporter country i and export destination country j in period t; β_0 is the constant term of the model, and β_1, β_2, β_3, β_4, β_5, β_6, β_7 respectively represents the regression coefficient of explanatory variables. The specific descriptions of each variable in the model are as follows.

(1) Economic factors. There are many ways to measure economic scale in the empirical problems of international trade, and most researchers suggest using gross domestic product (GDP) as a proxy variable (Jambor and Torok, 2013). GDP_{it} is the GDP of the exporting country i in period t, and GDP_{jt} is the GDP of the exporting destination country j in period t. The larger an exporting country's economic scale is, the stronger its supply capacity of goods and services is, thus it is better to maintain the continuous improvement of export capacity. The larger the economic scale of the export destination country is, the more kinds and quantities of commodities it needs, thus promoting the increase in the quantity of commodities exported by the exporting country.

(2) Demographic factors. A country with a large population means a large market size (Lewer and Berg 2008; Kahouli and Maktouf 2015), which provides prerequisites for economies of scale as well as larger trade volume (Doan and Xing 2018). GDP_{it} is the population of exporting country i in period t, and GDP_{jt} is the population of exporting destination country j in period t.

(3) Geographic distance. Geographic distance represents transportation cost, and the longer the distance is, the higher the trade cost will be, leading to the reduction of trade volume of the exporting country (Chaney, 2018). $Dist_{ij}$ is the geographic distance between the capitals of trading country i and trading country j.

(4) Borders. If the two countries own a shared border, customs clearance time and corresponding costs are lower than those of other trading partners, creating better conditions for the occurrence of trade (Karemera et al. 1999; Metulini, Patuelli, and Griffith, 2018). $Border_{ij}$ is used to describe whether the exporting country i shares a boundary with the exporting destination country j, which is a dummy variable. When the value of this variable is 1, it indicates the same border in the exporting destination country and the exporting destination country; otherwise, the value of this variable is 0.

(5) Common language. Common language is a concrete embodiment of the similarity of traditional culture between two countries, which is beneficial to the business negotiation. Countries with a common language have lower communication costs and greater trade volumes (Melitz, 2008). $Lang_{ij}$ indicates whether there is a common language between the exporting country i and the exporting destination country j, and is a dummy variable. When the value of this variable is 1, it indicates the common official language in the exporting destination country and the exporting destination country; otherwise, the value of this variable is 0.

(6) v_{ijt} is the stochastic error term that is normally distributed in model regression; μ_{ijt} is the trade inefficiency item, representing the inefficiency influencing factors of the exporting country's trade.

4.2 Inefficiency Model

Based on the earlier analysis, we establish the trade inefficiency model to identify the main factors affecting trade inefficiency. Although there are many factors forming trade costs, most of them can be summarized into three aspects: policy, information, and institution (Jacks et al., 2010). This report focuses on the impact of policy barriers, digitalization differences, and institutional differences on trade efficiency, thus we establish the following model.

$$u_{ijt} = \alpha_0 + \alpha_1 TF_{it} + \alpha_2 TF_{jt} + \alpha_3 Inter_{ijt} + \alpha_4 ID_{ijt} + \varepsilon_{ijt} \tag{12}$$

(1) Policy Barriers. The political barriers in this model mainly consider tariff and non-tariff barriers (NTB), both of which will damage trade efficiency (Anderson and Van Wincoop, 2003), as indicated by TF (trade freedom) in the index of economic freedom published by the Heritage Foundation. TF reflects a country's restriction and hindrance to importing and exporting trade. How trade liberalization affects exports has been discussed—for example, by making it easier for producers to shift resources to the trading sector, thereby increasing the sensitivity of exports to changes in prices and incomes, and possibly boosting exports by promoting structural change and improving efficiency (Santos-Paulino and Thirlwall, 2004). Trade liberalization involves both export and import. How to advance trade liberalization in an orderly manner to balance its impact on domestic imports and exports is an important issue worthy of the attention of developing countries (Santos-Paulino and Thirlwall, 2004). The trade freedom index is a comprehensive measure which includes not only the trade weighted average tariff rate based on import volume, but also NTB such as quantity, price, regulatory, investment, tariff, and direct government intervention (Doan and Xing 2018). TF_{it} is the trade freedom index of exporter i in period t, and TF_{jt} is the trade freedom index of export destination country j in period t. The higher the trade freedom index, the lower the political barriers. The calculation method is as follows.

$$TF_{it} = \left(\left(\frac{Tariff_{max} - Tariff_i}{Tariff_{max} - Tariff_{min}}\right) * 100\right) - NTB_{it} \tag{13}$$

$$TF_{jt} = \left(\left(\frac{Tariff_{max} - Tariff_j}{Tariff_{max} - Tariff_{min}}\right) * 100\right) - NTB_{jt} \tag{14}$$

(2) Digitalization Difference. The wide application of the internet has changed the role of data and information in trade, making digital trade, online shopping or e-commerce the norm in today's world. The rapid development of the internet can solve the problem of information asymmetry between exporting countries and importing countries, eliminating the 'iceberg cost' in the process of trade between two countries. At the same time, the use of the internet also makes the information connectivity between countries more convenient, reduces the communication cost, and improves the level of trade between two countries. The digitalization difference caused between the two sides may hinder the release of the potential of bilateral trade. $Inter_{ijt}$ is the difference in the percentage of individuals using the internet between exporting country i and export target country j in period t.

$$Inter_{ijt} = \left|Inter_{it} - Inter_{jt}\right| \tag{15}$$

(3) Institutional Distance. The theory of institutional economics states that the improvement of a country's institution helps to reduce transaction costs and promote the development of trade, while the narrowing of the distance also helps to improve the terms of trade. In bilateral trade, institutional

distance is an important factor affecting international trade. Institutional distance is defined as 'the degree to which the institutions of any two countries differ in formal or normative terms' (Gaur and Lu, 2007). It is generally accepted that institutional distance symbolizes the degree of identity and may hinder access to local knowledge and effective resource utilization (Xu and Shenkar, 2002; Shah et al., 2019). Using the method of Kaufmann and Kraay (2002), institutional factors affecting trade are divided into six aspects, including people's will and responsibility, political stability, government efficiency, executive ability, legal effect, and corruption control. Zheng et al. (2020) draws on the research ideas of Kogut and Singh (1988) to deal comprehensively with institutional distance, using the following formula.

$$ID_{ij} = \left[\sum_{a=1}^{6} \left(I_i^a - I_j^a\right)^2 \Big/ V_a\right] \Big/ 6 \qquad (16)$$

Where ID_{ij} is the comprehensive index of institutional difference between exporting country i and export target country j; I_i^a and I_j^a represent the a-dimension institutional factors of exporting country and exporting destination country respectively. V_a represents the variance of the index in the a-dimension of the sample country. Thus, the higher the composite index score, the greater the difference in exporting and importing countries.

4.3 Data Source

The sample used in this report is panel data covering 11 CAREC region countries (Afghanistan, Azerbaijan, China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan) from 2001 to 2020.

The export data in the main model comes from the UN Comtrade Database; specifically, we apply the annual bilateral trade data of each country using HS code. Since Tajikistan and Turkmenistan have serious data gaps, import data from the corresponding partner countries in the same database are used as substitutes. Both GDP and population data are from the World Bank WDI database, using GDP data in current dollar terms and total population data respectively. In addition, geographic distance, adjacent borders, and common language that reflect geographic characteristics are all from the CEPII database, in which geographic distance is selected as geographic distance weighted by population.

Among the influencing factors of the inefficiency model, the index of trade freedom representing political barriers comes from the Heritage Foundation. The index of per capita internet usage, which reflects the digital difference, comes from the World Bank WDI database. The measurement of institutional distance is based on six factors, and the original data comes from the World Bank WGI database.

5 Calculation and Analysis on Trade Efficiency and Its Influencing Factors

5.1 Test of the Main Model Factors

In this report, all calculations are based on STATA 16, and the construction of the subject model in the SFA model includes the economic scale, population size, geographic distance, border situation, and common language of both sides of trade. Descriptive statistics are shown in Table 1.

Table 1 Descriptive statistics of variables in the main model

Variable	Sample size	Mean	Standard deviation	Minimum value	Maximum value
Exports	1,526	6.11 e+08	2.01 e+09	30	1.83 e+10
GDP in the exporting country	2,180	7.06 e+11	2.50 e+12	1.08 e+09	1.47 e+13
Population in the exporting country	2,200	1.34 e+08	3.82 e+08	2,419,588	1.40 e+09
GDP in the importing country	2,180	7.06 e+11	2.50 e+12	1.08 e+09	1.47 e+13
Population in the importing country	2,200	1.48 e+08	3.81 e+08	2,419,588	1.40 e+09
Geographic distance	2,200	2,143.43	1,455.063	194.98	5,852.92
Border	2,200	0.327273	0.469324	0	1
Common language	2,200	0.018182	0.133639	0	1

Likelihood ratio (LR) is used to test whether a variable can be added to the model. Let L(H1) denote the likelihood function value of the unconstrained model, then the LR statistic is:

$$\mathrm{LR} = (-2) \times [lnL(H_0) - lnL(H_1)] \tag{17}$$

The basic model includes only GDP and geographic distance of both countries. Four likelihood ratio tests are established successively, i.e., the population of exporting country, the population of importing country, border and common language are introduced into the tests respectively. The test results are shown in table 2.

Table 2 Hypothesis testing results of variables

	Ho	Chi-squared statistic	P value	Results
Whether to introduce the population of the exporting country	H0: The parameter constraint is effective, and the constrained model is superior to the unconstrained model with population factor of exporting country	59.34	0.0000	Refuse
Whether to introduce the population of export destination	H0: The parameter constraint is effective, and the constrained model is superior to the unconstrained model with population factor of destination country	5.26	0.218	Refuse
Whether to introduce border	H0: The parameter constraint is effective, and the constrained model is superior to the unconstrained model with boundary factors	164.18	0.0000	Refuse
Whether to introduce common language	H0: The parameter constraint is effective, and the constrained model is superior to the unconstrained model with common language factor	0.02	0.8919	Accept

The test results show that the main body model should introduce the GDP, geographic distance, population, and borders, but should not introduce the common language. In the sample, only Kazakhstan and the Kyrgyz Republic share a common language, and the remaining 98% of the sample countries do not have a common language, so it will not be introduced. The revised model specification is as follows.

$$ln\ T_{ijt} = \beta_0 + \beta_1\ ln\ GDP_{it} + \beta_2 lnGDP_{jt} + \beta_3\ ln\ Pop_{it} + \beta_4 lnPop_{jt} + \beta_5\ ln\ Dist_{ij} + \beta_6 lnBorder_{ij} + v_{ijt} - \mu_{ijt} \quad (18)$$

5.2 Results of the Main Model Regression

To test the robustness of the main model, control variables were gradually added to conduct regression respectively based on the economic scale and geographic distance of the exporting and destination countries, and the estimated results of gravity model (1-3), non-time-varying SFA model (4-6) and time-varying SFA model (7-9) were listed respectively, as shown in Table 3.

Table 3 Regression results of the main model

	The gravity model			Time-invariant SFA model			Time-varying SFA model		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Lngdpi	0.614*** (0.05)	0.639*** (0.051)	0.741*** (0.049)	0.569*** (0.047)	0.759*** (0.064)	0.698*** (0.061)	0.650*** (0.049)	0.753*** (0.060)	0.684*** (0.061)
Lngdpj	0.616*** (0.029)	0.497*** (0.059)	0.438*** (0.056)	0.497*** (0.037)	0.239*** (0.070)	0.316*** (0.066)	0.592*** (0.039)	0.398*** (0.078)	0.483*** (0.082)
Lndist	1.619*** (0.082)	1.616*** (0.082)	0.914*** (0.094)	0.905*** (0.195)	1.424*** (0.197)	1.084*** (0.208)	1.591*** (0.252)	1.693*** (0.215)	1.426*** (0.220)
Lnpopi	0.486*** (0.063)	0.463*** (0.063)	0.101 (0.066)	0.147* (0.071)	0.136* (0.066)	0.058 (0.071)	0.249*** (0.069)	0.208** (0.068)	0.145* (0.072)
Lnpopj		0.161* (0.07)	0.013 (0.068)		0.489*** (0.104)	0.274* (0.110)		0.321** (0.109)	0.115 (0.122)
Border			2.105*** (0.160)			0.968*** (0.285)			0.878** (0.29)
_cons	9.324*** (0.959)	9.389*** (0.958)	7.898*** (0.915)	2.019 (1.504)	5.014*** (1.368)	3.445* (1.701)	3.146 (1.871)	5.155*** (1.521)	3.314 (1.798)
lnsigma2				2.848*** (0.401)	2.966*** (0.503)	2.920*** (0.526)	2.801*** (0.418)	3.006*** (0.497)	2.838*** (0.453)
Lgtgamma				2.586*** (0.433)	2.709*** (0.537)	2.665*** (0.564)	2.548*** (0.450)	2.765*** (0.528)	2.591*** (0.488)
mu				0.386 (2.099)	1.608 (3.388)	1.624 (3.504)	0.691 (2.172)	1.266 (3.326)	0.331 (2.589)
η							0.012*** (0.002)	0.010*** (0.002)	0.010*** (0.002)
Sigma2				17.25	19.417	18.543	16.463	20.207	17.075
γ				0.93	0.938	0.935	0.927	0.941	0.93
Sigma_ mu 2				16.042	18.205	17.336	15.269	19.009	15.884
Sigma_v2				1.208	1.212	1.207	1.195	1.197	1.191
N	1,510	1,510	1,510	1,510	1,510	1,510	1,510	1,510	1,510
Ll	3,412.57	3,409.94	3,327.85	2,482.27	2,475.69	2,467.9935	2,466.5	2,464.95	2,458.4601

Note: ***, **, and * mean significant at 1%, 5%, and 10% levels respectively, standard error in brackets.

The estimation results are used to evaluate the proportion of the non-efficiency part of the random error term. If $\gamma = 0$, it means that there is no error caused by the non-efficiency term; if $\gamma = 1$, it means that all the random error terms come from the non-efficiency term. If the γ statistic is significant, it is reasonable to use the SFA method. The estimation results show that the fluctuation of μ is 93%~95% in both time-varying and time-invariant SFA models, and it is significant at the level of 1%. The total fluctuation is caused mainly by the fluctuation of inefficient factors, and the SFA model is more suitable.

Models 4-6 are time-invariant random frontier gravity model, while models 7-9 are time-varying random frontier gravity model and η is the time-varying coefficient, which is significantly negative at 1% level. During the 20 years from 2001 to 2020, inefficiency factors in the CAREC region increased with time, while trade efficiency gradually decreased with time. Trade cooperation in the CAREC region has not progressed significantly.

By adopting different estimation methods and gradually adding control variables to carry out regression respectively, the estimation results of control variables are stable. The calculation results show that the GDP of both exporting country and destination country has a positive and significant impact on export trade at the level of 1%, and the expansion of national economic scale has an important impact on bilateral trade. The driving effect of the export country's GDP on export trade efficiency is significantly higher than that of the export destination country's GDP, indicating that it is crucial to improve a country's economic development level and maintain an effective supply of commodities for expanding export scale.

The transportation cost represented by geographic distance has a negative impact on export trade efficiency, and is significant at 1% level. Transport costs are an important impediment to trade. The influencing coefficient of geographic distance is significantly higher than other control variables, indicating that CAREC regional trade is still limited by transportation infrastructure construction.

The population of exporting country and destination country has a positive impact on export trade efficiency. The increase of population of exporting country increases commodity market demand, while the increase of population of destination country improves market supply capacity. Demographic variables gradually weakened and their coefficients reduced with the addition of other variables. It shows that while the increase of population in exporting countries increases the market demand, part of the commodities for foreign trade began to meet the demands of the domestic market (Endoh, 1999), the increase of export destination stimulates countries to improve the self-sufficiency of commodities (Brada and Mendez, 1985).

Border between countries has a significant positive impact on export trade efficiency, since CAREC countries are mostly landlocked countries with relatively insufficient trade facilitation measures, complicated trade clearance procedures increase time costs, and trade between neighboring countries saves customs clearance times.

5.3 Trade Efficiency Analysis

Our samples include the bilateral data from 11 countries in the CAREC region, the time-varying coefficient in time-varying stochastic frontier is negative in the gravity model, and is significant at 1% level, meaning CAREC export trade efficiency of most countries in the region from 2001-2020 gradually reduce, while in the meantime, regional trade cooperation did not keep pace with the expansion of the trade ideal boundary.

In the specific calculation, it is found that although the time-varying SFA model is suitable for most countries, the trade efficiency of Afghanistan, Kazakhstan, Mongolia and Turkmenistan has no obvious time-varying characteristics, so it is impossible to obtain the results of trade efficiency by using this method. To fully display the trade efficiency of all CAREC region countries, the change of trade efficiency is ignored and the analysis is based on the calculation results of non-time varying SFA model, as shown in Table 4.

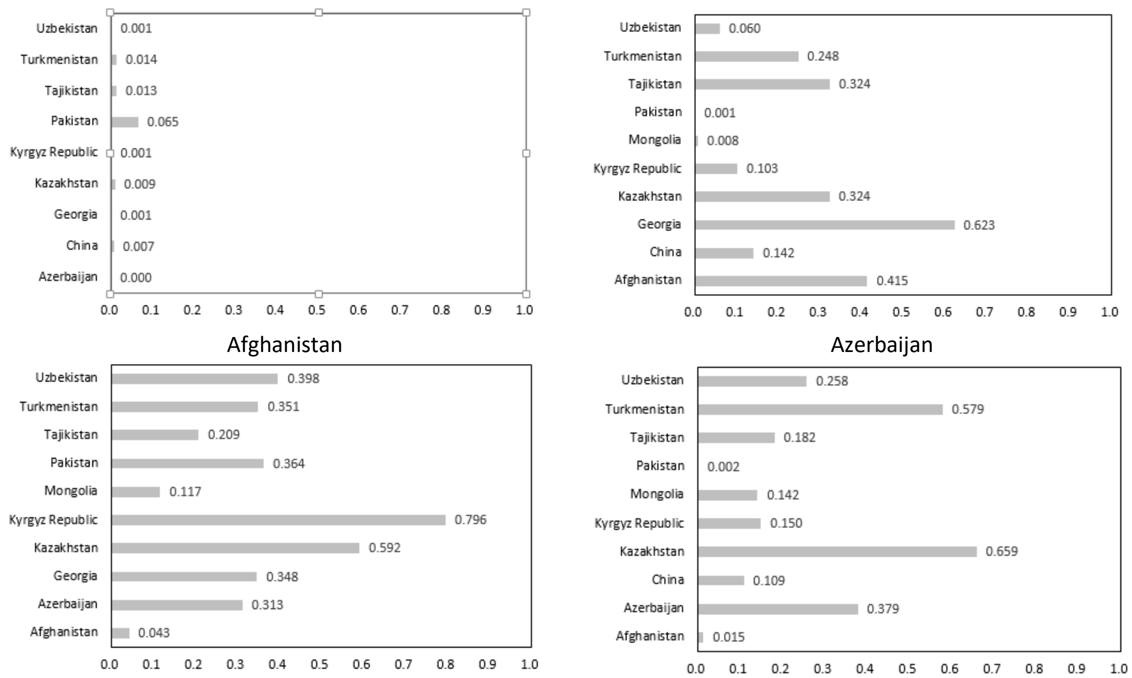
Table 4 Trade efficiency of CAREC countries

	AFG	AZE	CHN	KAZ	KGZ	GEO	MNG	PAK	TJK	TKM	UZB
AFG	*	0	0.007	0.001	0.001	0.009	.	0.065	0.013	0.014	0.001
AZE	0.415	*	0.142	0.623	0.103	0.324	0.008	0.001	0.324	0.248	0.06
CHN	0.043	0.313	*	0.348	0.796	0.592	0.117	0.364	0.209	0.351	0.398
KAZ	0.015	0.379	0.109	*	0.15	0.659	0.142	0.002	0.182	0.579	0.258
KGZ	0.263	0.136	0.078	0.131	*	0.164	0.245	0.001	0.316	0.21	0.244
GEO	0.696	0.853	0.79	0.436	0.133	*	0.597	0.003	0.846	0.17	0.313
MNG	.	0.002	0.747	0	0.017	0.052	*	0	0.001	0.008	0.01
PAK	0.276	0.036	0.159	0.026	0.005	0.014	0.002	*	0.003	0.006	0.004
TJK	0.267	0.009	0.074	0.004	0.054	.	.	.	*	.	0.118
TKM	0.485	0.47	0.741	0.882	0.065	.	.	.	.	*	0.312
UZB	0.458	0.254	0.681	0.332	0.453	0.48	0.032	0.035	0.116	0.093	*

In 110 groups of bilateral trade efficiency results, there are 10 groups with no estimation results because of incomplete export data. So we have a total of 100 sets of trade efficiency results. Among them, there are 56 countries with their trade efficiency lower than 0.2, suggesting that the current level of actual trade is far from ideal, trade resistance is high, and regional trade integration can play a larger role.

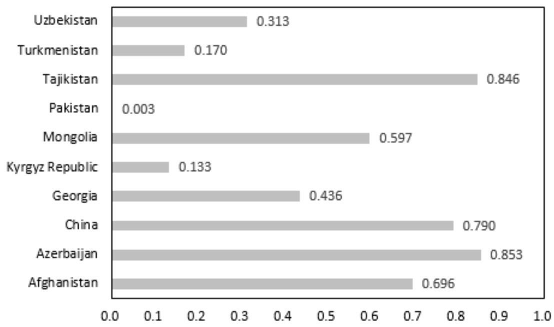
To compare the export trade efficiency of each country in the CAREC region to other countries, the results are made into the following bar charts in Figure 1.

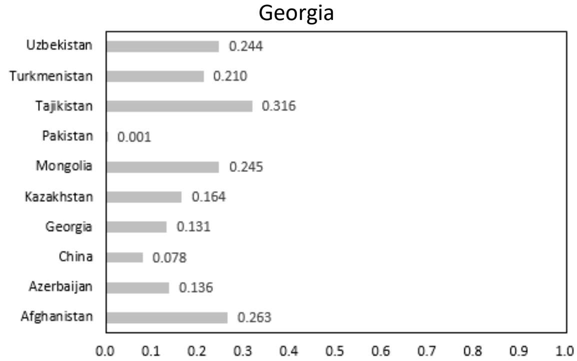
Figure 1 Trade efficiency of CAREC countries



China

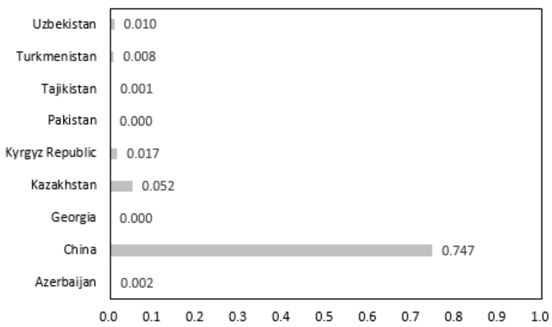
Georgia

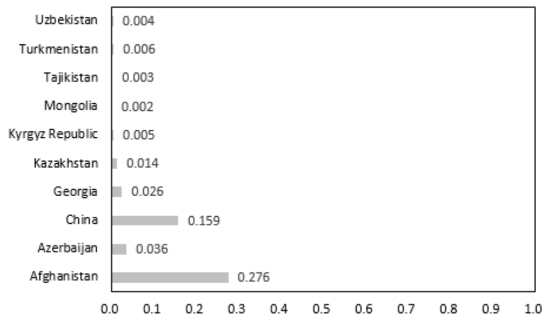




Kazakhstan

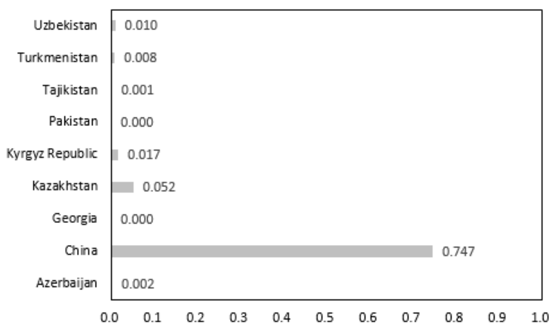
The Kyrgyz Republic

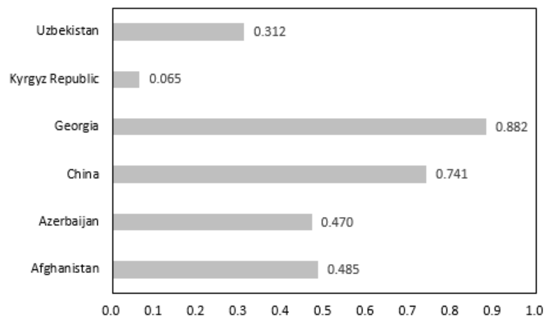




Mongolia

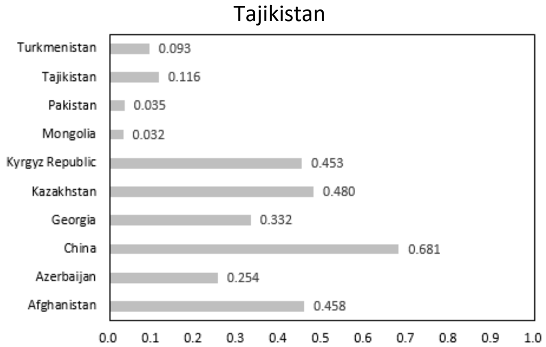
Pakistan





Tajikistan

Turkmenistan



Uzbekistan

The results show that Afghanistan and Tajikistan, because of their low economic level in the world, are generally inefficient in export trade to all countries in the region and have not formed close trade relations. The trade efficiency of the Kyrgyz Republic and Pakistan to other countries in CAREC region is also at a low level. The trade efficiency of the Kyrgyz Republic is lower than 0.35. Even for Kazakhstan, which is also a member of Eurasian Economic Union (EAEU), the trade efficiency is only 0.164. Pakistan's main export commodities are textiles, and Afghanistan is one of the important exporters of Pakistan, with the highest trade efficiency of 0.276 in the region, followed by China with 0.159. The main export commodities are agricultural products, and the trade efficiency of other countries is lower than 0.1.

The outstanding characteristic of Mongolia and Uzbekistan is that their export efficiency to China is higher than that of other countries in the region. Mongolia's trade volume with CAREC countries is far away from the ideal value, and the trade efficiency with most countries is lower than 0.1, but the export trade efficiency to China is very high, reaching 0.747. Mongolia's export trade volume to China accounts for more than 60% of the total. China and Mongolia will implement the tariff reduction arrangement under the Asia-Pacific Trade Agreement (APTA) on 1 January 2021. Goods from China and Mongolia will enjoy lower tariffs, which can be expected to further improve trade efficiency. Meanwhile, China and Mongolia launched a feasibility study on a free trade agreement in 2017, and have held several seminars on it, which is expected to further deepen bilateral economic and trade cooperation. Uzbekistan's trade efficiency is highest with China at 0.681. As a country with a comparatively large population, Uzbekistan attaches great importance to foreign trade, and its trade efficiency is above 0.3 with the Kyrgyz Republic, Kazakhstan, Georgia, and Afghanistan, but there is still a big gap between the ideal value of trade, indicating great trade potential.

Kazakhstan relies on rich natural resources and promotes rapid economic growth through export trade. It is a CAREC country with a comparatively better economic and business environment. Kazakhstan attaches great importance to foreign trade, and its trade efficiency with CAREC countries is high. The current trade volume with Azerbaijan, Tajikistan, and China exceeds or approaches 80% of the ideal value, and the trade efficiency with Mongolia and Afghanistan is 0.6-0.7.

Turkmenistan's main exporter is China, followed by Uzbekistan and Russian [②]. Turkmenistan has the highest trade efficiency of 0.882 with Georgia, followed by 0.741 with China, and 0.3-0.5 with Azerbaijan, Afghanistan, and Uzbekistan.

The trade efficiency of Azerbaijan with CAREC countries is low and the trade potential is large, because the main export destination countries of Azerbaijan are not CAREC countries. In 2020, the export to Italy and Turkey accounted for 30.4% and 18.9% of the export share respectively[③]. In CAREC countries, Azerbaijan and Georgia were the most efficient, reaching 62.3% of optimal trade level.

The main export destination countries of Georgia are not CAREC countries also. The first and second largest exporting countries of Georgia are Turkey and Russia, and China is the third[④]. In 2020, the export share to China increased. But overall, the trade efficiency with China is still at a very low level, only 0.109, indicating great trade potential. Georgia's export trade efficiency to Kazakhstan and Turkmenistan is high, which is 0.659 and 0.579 respectively.

[②] Calculate according to UN Comtrade database. Turkmenistan does not have export data in this database, using other countries import data instead.

[③] Calculate according to UN Comtrade database

[④] The rankings come from Ministry of Commerce of the People's Republic.

http://tradeinservices.mofcom.gov.cn/article/tongji/guoji/201911/94763.html

China is an important trading partner. CAREC regional countries trade efficiently with many countries. This is especially true with China's western border of the Kyrgyz Republic and Kazakhstan, where export trade efficiency reaches 0.796 and 0.592 respectively, while with Uzbekistan, Turkmenistan, Pakistan, Georgia and Azerbaijan, export trade efficiency is around 0.3.

5.4 Estimation of Inefficiency Model

The one step method is adopted to focus on the impact of policy barriers, digital differences, and institutional distance on trade efficiency. Descriptive statistics are shown in Table 5.

Table 5 Descriptive statistics of variables of inefficiency factors

Variable	Sample size	Mea n	Standard deviation	Minimum value	Maximum value
Political barriers of exporting country	2,040	72.86	10.51	22.00	89.40
Political barriers in export destination countries	2,040	71.77	11.02	22.00	89.40
Digitalization difference	1,766	14.64	16.05	0.00	68.74
Institutional distance	1,980	2.17	2.11	0.03	15.50

The regression results of the SFA model show that trade inefficiency factors have an important impact on export trade efficiency. Among the factors of trade inefficiency, influencing factors such as trade barrier, digitalization difference, and institutional distance are further examined. Model 10-12 adds one factor respectively, model 13-15 adds two factors at a time, and model 16 adds three factors simultaneously. The regression results of the one step time varying SFA model are shown in Table 6.

Table 6 Estimation results of stochastic frontier gravity model

	Model 10	**Model 11**	**Model 12**	**Model 13**	**Model 14**	**Model 15**	**Model 16**
Lngdpi	0.570*** (0.069)	0.723*** (0.085)	0.667*** (0.065)	0.542*** (0.097)	0.542*** (0.071)	0.697*** (0.084)	0.510*** (0.094)
Lngdpj	0.403*** (0.095)	0.619*** (0.097)	0.460*** (0.082)	0.660*** (0.115)	0.384*** (0.094)	0.612*** (0.094)	0.624*** (0.110)
Lndist	1.369*** (0.237)	1.898*** (0.268)	1.340*** (0.221)	1.999*** (0.272)	1.313*** (0.231)	1.823*** (0.263)	1.913*** (0.265)
Lnpopi	0.263*** (0.077)	0.253 (0.130)	0.190* (0.086)	0.500*** (0.139)	0.333*** (0.090)	0.312* (0.126)	0.559*** (0.134)
Lnpopj	0.201 (0.14)	0.062 (0.128)	0.161 (0.122)	0.047 (0.153)	0.245 (0.138)	0.088 (0.125)	0.102 (0.147)
Border	0.968** (0.318)	0.661 (0.364)	0.780** (0.294)	0.686 (0.406)	0.856** (0.317)	0.596 (0.357)	0.63 (0.397)
Tfi	0.017*** (0.005)			0.012* (0.005)	0.019 **** (0.005)		0.015** (0.005)
Tfj	0.006 (0.004)			0.004 (0.004)	0.005 (0.004)		0.004 (0.005)
interij		0.008* (0.003)		0.010** (0.004)		0.007* (0.003)	0.009* (0.003)
Id			0.022 (0.014)		0.026 (0.015)	0.022 (0.015)	0.025 (0.016)
_cons	4.032* (1.901)	4.763* (2.173)	4.393* (1.779)	5.500* (2.279)	5.199 (1.886)	5.863** (2.112)	6.556** (2.223)
lnsigma2	2.625*** (0.401)	2.982*** (0.499)	2.881*** (0.467)	2.612*** (0.469)	2.664*** (0.413)	2.986*** (0.502)	2.604*** (0.472)

	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
Lgtgamma	2.383*** (0.44)	2.822*** (0.528)	2.744*** (0.498)	2.407*** (0.512)	2.546*** (0.447)	2.971*** (0.528)	2.565*** (0.509)
Mu	0.684 (1.86)	0.903 (3.253)	0.528 (2.757)	0.174 (2.321)	0.552 (1.959)	0.912 (3.262)	0.201 (2.298)
Eta	0.010*** (0.002)	0.013*** (0.003)	0.010*** (0.002)	0.011** (0.004)	0.011*** (0.003)	0.013*** (0.003)	0.011** (0.003)
N	1,362	1,199	1,396	1,067	1,248	1,144	1,012
Ll	2,212.2385	1,936.2573	2,218.8333	1,720.8518	1,973.6376	1,782.5683	1,566.9265

Note: ***, **, and * mean significant at 1%, 5%, and 10% levels respectively, standard error in brackets.

Compared with the main model, economic size and geographic distance are still significant at 1% level. Again, in the CAREC region, the larger the economic scale, the stronger the economic spillover effect. The common economic development of the CAREC region will benefit the export trade of all CAREC countries. Transportation cost represented by geographic distance is an important constraint to trade development in the CAREC region. The integration of transportation infrastructure in the region will effectively reduce transportation cost and promote the development of export trade in various countries.

The political barriers in exporting countries significantly impede the efficiency of export trade in the CAREC region. The higher the trade freedom index, the lower the political barriers. Although the trade freedom index published by the Heritage Foundation includes tariff and non-tariff components, the part concerning tariffs focuses mainly on the weighted import tariffs of a country, but the composition of non-tariff trade barriers involves both import and export trade instruments. Typical examples of export trade instruments include export subsidies, voluntary export restrictions, and sanitary and phytosanitary standards (SPS) related to export.[5] In the process of the trade cooperation of CAREC countries, each member country should pay full attention to the impact of its own trade liberalization measures on its export trade, especially the part of NTB related to export.

In export trade, owing to the different level of economic development between the two sides, the development level of information technology is more obviously different, which is manifested as digitalization difference. The level of digital difference has a negative impact on export trade efficiency, and it is significant at the level of 10% in the gradual regression with political barriers, institutional distance, and other factors. Digital differences will hinder bilateral trade efficiency. At the same time, the introduction of digitalization differences reduces the significance level of bordering factors, indicating that with the digital development brought by the internet, trade convenience can be improved and the inherent influence of geographic factors on trade volume can be reduced.

Institutional distance has a negative effect on export trade efficiency, which is consistent with the expectation but not significant. Institutional differences cause ambiguous and non-standard information, increasing the management cost and risk of trade (Pinto et al., 2017); however, in the CAREC region, institutional distance is not a key trade efficiency factor. This could be because many CAREC countries are developing countries, without obvious institutional disparity and with relatively strong cultural compatibility, thus coping strategies are relatively easy to adopt.

[5] https://www.heritage.org/index/trade-freedom

6 Conclusions and Suggestions

We use the SFA model based on the sample of 11 CAREC countries, mainly focusing on their trade efficiency and potential. We consider not only economic scale, population size, and influencing factors such as geographic distance and border condition, but also political barriers, digitization differences, and the influence of institutional distance on export trade efficiency. Our main conclusions are as follows.

(1) CAREC regional trade efficiency is generally in decline; its regional trade falls behind the expansion speed of ideal boundary. Most CAREC countries became independent after the collapse of the Soviet Union and focused initially on national stability and reconstruction. Since the 21st century, some countries have strong willingness to foreign trade development, but owing to the limit of trade costs, intra-regional trade development did not keep pace with the expansion of the trade ideal boundary. From 2000 to 2020, the CAREC regional trade inefficiency factor resistance increased rather than decreased, the trade efficiency between most countries has gradually declined over time.

(2) Trade efficiency in the CAREC region is generally low; however, trade integration has a huge role to play. Countries in the CAREC region with trade efficiency below 0.2 account for 56%. This low efficiency clearly indicates that the current actual trade status deviates from the ideal trade level. CAREC regional trade integration development is expected to tap its potential. Actively promoting trade integration is one of CAREC's priorities. Other donors and multilateral agencies can support the CAREC initiatives for regional trade cooperation, which point towards a promising future.

(3) Transportation cost represented by geographic distance is the main constraint in the CAREC region. The impact of transportation cost is significantly higher than that of other control variables, indicating that regional trade is still limited by its backward transportation infrastructure. The transport network inherited from the Soviet Union in Central Asia cannot meet the development requirements of globalization. The countries in the region are encountering various problems in the economic restart; there are not enough funds to maintain the infrastructure, let alone construct a new transport network. At present, major powers, multilateral institutions, and non-governmental organizations are actively involved in building infrastructure in the region. Further efforts to promote regional connectivity in Central Asia remain an important focus in driving trade development in the region.

(4) The export country's trade barrier is an important factor hindering trade efficiency, and the expansion of export must reduce government control. The trade freedom index represents a country's restrictions and obstacles to import and export trade, which comprehensively reflects the political barriers to trade. Political barriers of exporting countries have a significant effect on the efficiency of export trade in the CAREC region; this is mainly reflected in export subsidies, voluntary export restrictions, SPS, and other NTB related to export. Therefore, to release trade potential, countries can start by optimizing their own trade policies, reducing government regulation, and gradually change to using market forces to achieve an effective allocation of resources.

(5) The digitalization difference between CAREC countries has a negative impact on their trade efficiency. Especially under the impact of the COVID-19 pandemic, the gap in digitalization may be further widened, which may become a new factor hindering the development of trade. While affecting the global economy, COVID-19 has indirectly promoted the spread of digital life and accelerated the application of digitalization in various fields, including international trade. However, the above characteristics are mainly reflected in countries with digital infrastructure and rich talent reserve for digital development. With weak digital infrastructure and insufficient digital development talent, countries are more likely to slow down the application of digital new technologies owing to the decrease of technology investment funds during the epidemic. In the process of regional economic

cooperation in Central Asia, more attention should be paid to the difference of informatization and its influence on regional trade.

(6) Institutional distance is not a key factor of trade inefficiency, and trade development in the CAREC region is less negatively affected by identity. Institutional distance reflects the institutional differences between the two countries, and exporters may be inclined to choose countries with similar systems as the export destination countries. Empirical studies show that institutional distance within the CAREC region has a negative impact on export trade efficiency, but it is not significant. Institutional distance is not a key factor of trade inefficiency, so trade development in the CAREC region should be more focused on trade itself, rather than on institutional disputes.

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