Hong Kong Research Institute of Humanities and Social Sciences

Journal of Economic Insights

Volume1, Issue1 ISSN 3078-5979 www.wisvora.com

Research on how trade facilitation affects export technology complexity geographically in B&R countries

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Article Info

Accepted:2024.10.19

Keywords:
Trade Facilitation;
Export Technological Complexity;
Spatial Effects;
The Belt and Road

JEL Classification:
M41; G32; J32

DOI: 10.70693/jei.v1i1.94

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Abstract

In the face of a harsh and complicated international environment, as well as the continuous rise in global trade protectionism, the B&R Initiative provides countries along its path with a vital spatial path and opportunities for collaboration. This research uses the geographic Durbin model and the spatial error model from both static and dynamic perspectives from 2008 to 2020 to evaluate the spatial impact of trade facilitation on the export technological complexity of the countries along the B&R Initiative. The results show that, although the effect of trailing one period is not as substantial, the degree of trade facilitation of the nations along the B&R Initiative positively influences the level of export technology complexity, providing a considerable spatial spillover effect. The impact of trade facilitation level on export technology complexity is significantly influenced by trade costs; the impact of trailing one period is not apparent; and the overall performance of the impact effect of different trade facilitation level sub-indicators and different regions is robust. Therefore, it is critical to maintain pressure for the implementation of the Belt and Road Initiative and to use regional spatial links and the multilateral trading system to coordinate trade agreements.

1. Introduction

The world is currently undergoing unprecedented change at an accelerating rate; trade protectionism and unilateralism are on the rise; the international business environment is deteriorating; and many nations are dealing with economic issues like trade restrictions, supply chain disruptions, and increased investment uncertainty. Proposing interregional cooperation initiatives has numerous significance in the current international environment, as it can facilitate cultural exchanges, promote regional integration, increase international collaboration, and promote economic development. With the goal of promoting the economic development of the nations along the route and achieving win-win outcomes, China has proposed the "Belt and Road" (henceforth referred to as "B&R"), an important initiative and platform for cooperation and exchange between China and other nations (Sun et al. 2020). Geographically speaking, the "Belt" consists of the three Silk Road economic belts: "China-Russia-Europe," "China-Central Asia-West Asia-Mediterranean-Europe," and "China-Southeast Asia-South Asia-Indian Ocean." On the other hand, the "Road" consists of the two 21st-century maritime Silk roads: "China-South China Sea - South Pacific" and "China-Southeast Asia-South Asia-Indian Ocean." The nations along the route have been pushing for high-level, in-depth trade interactions since the project was proposed in 2013. By 2023, trade between China and B&R countries is expected to reach US$2.69 trillion, or 46.6% of China's total foreign trade. In order to achieve shared development and prosperity, it is crucial for China to address the issue of overcapacity, assist in changing its industrial structure, and realign itself in the global division of labor. At the same time, the initiative will support the development of infrastructure, encourage trade market expansion, and fortify humanistic exchanges and interactions among the nations along the route.

In order to investigate the influence of the initiative on the export structure and technological level of participating countries, a study on the spatial impact of trade facilitation on export technology complexity in B&R nations has been conducted. In order to provide a simpler, faster, and more cost-effective trade environment, trade facilitation is specifically defined as the promotion of openness and liberalization of international trade and investment through the reduction and simplification of trade procedures, the lowering of trade costs, and the increase of trade efficiency (World Bank, 2006). Export technology complexity, as defined by Hausmann, Hwang, and Rodrik (2007), is the level of technical difficulty and complexity of goods and services that are exported. It is a measure of the added value and competitiveness of goods and services in the market. The intricacy of export technology and trade facilitation are complimentary and mutually beneficial. The B&R Initiative will promote trade facilitation, which will make it easier for the countries along the route to enter into the global value chain and increase the technological content and added value of their exports. Trade facilitation can lower trade barriers and promote cross-border trade activities, which will in turn increase the level of exports of B&R countries (Hu, Jiang and Sun, 2022). Thus, from a spatial point of view, this paper takes into account the industrial division of labor and trade connections among various regions, finds and exploits opportunities for cooperation and potential benefits within the region, and explores the particular routes that B&R countries can take to increase the complexity of export technology by raising the degree of trade facilitation. In order to improve the technological content and quality level of exports, coordinate and optimize the overall environment along the route, and create a win-win situation for the region, this is very important.

A survey of the body of research indicates that most studies have concentrated on the connection between trade facilitation and export trade; hence, direct investigation into how trade facilitation affects export technological complexity is lacking. This paper centers on the research methodological endeavors of scholars concerning panel data modeling. Using the trade gravity model, Wilson, Mann, and Otsuki (2003, 2005, 2007), Feenstra and Ma (2014), and Ramasamy, Yeung, and Utoktham (2017) investigated the influence of trade facilitation on export trade. Using the SYS-GMM model, Amjad and Inmaculada (2023) reexamine the benefits of trade facilitation for bilateral commerce. Hong (2021) studies the effect of trade facilitation on value-added trade networks using social network analysis, whereas Luo, Wang, and Cao (2021) utilize a product quality heterogeneity model to examine the relationship between trade facilitation and the export of manufactured items. In terms of spatial econometric models, Li et al. (2021) use PSAR, PSEM, and PSDM models to explore the spatial role of trade facilitation on bilateral trade costs, while Xu and Li (2021) use spatial Durbin model, spatial panel GMM, and geographically weighted regression to conclude that an increase in the level of trade facilitation will lead to an increase in the trade flows along the B&R. The literature that is most directly relevant to this research concerns the effect of trade facilitation on the complexity of export technologies. Liapis (2011) focuses on the dynamic relationship between trade facilitation and the export technology complexity of agricultural exports, while Yi (2010) contends that trade facilitation increases the technological content of export products by lowering trade costs. Xiao Zhi and Xie (2020) find that a higher degree of facilitation has a positive impact on the export technology complexity of manufacturing exports.

To summarize, research has focused primarily on how trade facilitation affects export trade in terms of volume, types, prices, and other aspects of export trade; however, little attention has been given to how trade facilitation affects export technology complexity from a spatial standpoint. By considering the effects of variables like geographic distance, the economic development of surrounding nations, and cultural differences on trade, spatial econometric models will offer a more thorough and methodical evaluation of the relationship between trade facilitation and export technology complexity. In order to construct the spatial Durbin model and spatial error model, this paper will begin by examining the direct impact and spatial effect of trade facilitation on the export technology complexity. Using the B&R countries as research samples from 2008 to 2020, it will then begin by examining the spatial autocorrelation degree, spatial benchmark regression, and spatial error model to determine how trade facilitation affects the technical complexity of exports. To investigate the spatial relationship between the two, consider the autocorrelation degree, spatial baseline regression, spatial dynamic effect, direct and indirect effect, sub-indicator and sub-region heterogeneity, and trade cost threshold effect.

There could be four innovations in this paper: First, the direct and indirect effects are considered to examine the significant role that spatial factors play in international trade, and the impact of trade facilitation on the export technology complexity of B&R countries is examined using a spatial perspective from both the static and dynamic perspectives; Second, the total import and export trade is used as an economic indicator, which enhances the connotation of the spatial weight matrix, and the relationship between the matrix and trade facilitation and the complexity of export technology is fully taken into consideration when building the matrix; Thirdly, the sample countries are divided into four regions: West Asia and North Africa, Central and Eastern Europe, South-East Asia and South Asia, Central Asia, Mongolia, and Russia; the level of trade facilitation is divided into five sub-indicators: the port environment, the customs environment, the institutional environment, the innovation capacity, the financial environment, and e-commerce; Establishing a threshold effect model is the fourth step in examining the non-linear effects of trade facilitation on export technology complexity from a trade costs perspective. Additionally, the impact mechanism of trade facilitation on export technology complexity is being further investigated.

2. Literature Review

2.1 Trade facilitation's direct effect on export technological complexity

The goal of this article is to examine how trade facilitation affects export technological complexity through four different lenses: lower trade costs, lower risk and uncertainty, higher company innovation capacity, and external knowledge spillovers.

First, trade costs should be decreased. Transport expenses, transaction costs, information costs, institutional costs, and other expenses are included in trade costs. First, assessing the port environment is a crucial component in building the trade facilitation index system. Secondly, the building of numerous infrastructure projects, including ports, railroads, and highways, can significantly lower the transportation expenses incurred by export-oriented businesses. Lastly, the swift growth of the financial and e-commerce sectors enhances the utilization of expenses associated with in-person meetings during traditional transaction processes. Lastly, the Internet serves to mitigate the information asymmetry issues on both sides of the trade. A good institutional environment, which includes the protection of intellectual property rights for trade activities, the maintenance of judicial independence, the reduction of the burden of government regulation, the improvement of government decision-making transparency, etc., can also help to lower the cost of system formulation, implementation, and maintenance. E-commerce businesses and modern logistics systems save transaction costs and information costs. In conclusion, increasing trade facilitation can lower trade costs overall, improve export products' standing in the global value chain, and raise the complexity of export technologies.

Second, lessening uncertainty and hazards. Export businesses must prevent endogenous risks like trade contracts and international settlements in order to manage the many risks and uncertainties associated with international trade. They also need to be aware of external risks like natural disasters, fluctuations in exchange rates, and changes in trade policies in other countries. Increases in trade facilitation have the following effects: at the macro level, they effectively reduce the likelihood that unstable elements will arise in export trade; at the micro level, they make it easier for businesses to engage in cross-border trade and reduce the instability in export trade caused by trade barriers, policy changes, and other factors. They also improve the flexibility of investment and trade flows and lessen the negative effects of exchange rate fluctuations and financial risks. It increases the competitiveness and stability of businesses by encouraging them to adjust to changes in both the internal and external contexts.

Thirdly, it's to improve businesses' ability to innovate. The learning effect allows export enterprises to make timely adjustments to meet the demands of the global market and realize independent innovation based on the current production method. On the other hand, after trade facilitation levels are raised, export enterprises master the innovation ability of acquiring new technologies and the research quality of scientific research institutions can be enhanced. This can support the reform of business transaction methods, such as the emergence of cross-border e-commerce, big data and accurate positioning of the target transaction, the optimization of the service trade mode deepening and other businesses, and provide a favorable environment for the enterprise's technological innovation and internationalization. Reaching a high degree of trade facilitation increases the depth of exports by strengthening businesses' ability to innovate, which helps them finish export projects with high levels of technological advancement and manufacturing quality.

Access to external knowledge spillovers is the fourth. From the standpoint of industries, nations that prioritize the advancement of trade facilitation have numerous chances to engage in the global division of labor. In the process of interacting with upstream design and development, midstream production and manufacturing, and downstream sales and services, the relevant industries benefit from the cross-border flow of technological knowledge; from the standpoint of enterprises, they face intense competition in the export market following the improvement of the trade environment, and they must combine external knowledge to expand their talent pools and technological resources. Thus, we put forth hypothesis H1.

H1: The complexity of export technologies is positively correlated with an increase in trade facilitation.

2.2 Trade facilitation's spatial impact on export technology complexity

Such spatial spillover effects are primarily reflected in the geographical proximity of the countries along the route, the imitative competition and cooperation between individuals in the countries along the route, and the spillover effects. This allows for a deeper exploration of the spatial role of trade facilitation on the export technology complexity in the B&R countries.

The first is the countries' close proximity to one another on the route. The first law of geography states that geographic proximity, which is typical in the environmental, geological, and economic domains, is the basic definition of spatial correlation and spatial agglomeration. This paper's research object is the B&R countries, which span six continents, including Asia, Europe, and Africa. It covers numerous countries and significant city nodes, such as the China-South Asia-West Asia Economic Belt, the China-Mongolia-Russia Economic Belt, the New Asia-Europe Land Bridge Economic Belt, and other routes. It is precisely the border and proximity of these natural endowments that establish the natural primitive conditions for the spatial spillover of the export technology complexity from the level of trade facilitation of the participating countries.

The second is enterprises in B&R countries imitating, competing, and working together. Enhancing trade facilitation in the nations along the route can lower trade costs, increase transaction efficiency, widen import and export channels, draw in foreign capital and enterprises to conduct trade activities on the domestic market, establish local factories or collaborate with nearby businesses, and create a positive feedback loop that will encourage the nation to keep improving its business environment and draw in neighboring nations to replicate and model their successful trading practices. Longer product life cycles across the region will result from this in a setting of collaboration and competition, extending profitability and raising revenues as well as enhancing the competitiveness of local products in global value chains.

The spillover impact comes in third. The improvement of trade facilitation in one country will, on the one hand, generate positive externalities in the process of economic cooperation, trade exchanges, and cultural exchanges among neighboring countries, forming a benign spillover effect on other space-related countries, including knowledge, technology, human capital, and other aspects of radiation. However, the rise of transnational firms has facilitated the exchange of technology and expertise across the nations along their path, resulting in the formation of regional development alliances in numerous nations. Participation in deep-level, high-quality export activities and coordinated regional growth are facilitated by this stability spillover effect. In light of this, we put forth hypothesis H2.

H2: Increasing trade facilitation levels has a positive spatial spillover effect on export technological complexity.

3. Research design

3.1 Variable measurement and data sources

3.1.1 Explanatory variable: trade facilitation

With reference to Sakyi et al. (2017) and Wilson, Mann, and Otsuki (2003, 2005, 2007) for the trade facilitation level (FAC) system construction and measurement method, this paper aims to use principal component analysis to calculate the trade facilitation level of 42 B&R countries from 2008 to 2020. Following the proposal of the B&R initiative, the nations along the route have increased the extent of market openness, enhanced their ability for multichannel innovation, swiftly developed new industries like banking and finance, and built financial hubs and free trade zones. In this paper, two dimensions of innovation capacity (R), financial environment, and e-commerce (F) are added to the traditional three indicators of port environment (P), customs environment (C), and institutional environment (I). This results in a total of five first-level indicators and nineteen second-level indicators to construct the trade facilitation level indicator system (Table 1). The secondary indicators are calibrated during the measurement process so that the indicator values range from 0 to 1. According to the test results, the principal component analysis approach is appropriate for gauging the degree of trade facilitation of bordering nations, as each year's KMO value is larger than 0.8 and the SMC value is greater than 0.6.

Table 1 Construction of the indicator system for the level of trade facilitation

First-level indicators	Second-level indicators	Scoring range	Data sources	Causality
Port environment (P)	Quality of road facilities (P1)	1-7	GCR	+
	Quality of railway facilities (P2)	1-7	GCR	+
	Quality of port facilities (P3)	1-7	GCR	+
	Quality of aviation facilities (P4)	1-7	GCR	+
Customs environment (C)	Prevalence of trade barriers (C1)	1-7	GCR	+
	Customs procedural burden (C2)	1-7	GCR	+
	Impact of rules on FDI (C3)	1-7	GCR	+

	Trade tariffs (C4)	1-100	GCR	-
Institutional environment (I)	Intellectual Property Protection (I1)	1-7	GCR	+
	Judicial independence (I2)	1-7	GCR	+
	Burden of government regulation (I3)	1-7	GCR	+
	Transparency in government decision-making (I4)	1-7	GCR	+
	Integrity of Government (I5)	1-100	CPI	+
Innovation capacity (R)	Availability of the latest technology (R1)	1-7	GCR	+
	Innovative capacity (R2)	1-7	GCR	+
	Quality of scientific research institutions (R3)	1-7	GCR	+
Financial environment and e-commerce (F)	Financial capital availability (F1)	1-7	GCR	+
	Financial services robustness (F2)	1-7	GCR	+
	Internet usage (F3)	1-100	GCR	+

Note: The Global Competitiveness Report is referred to as GCR, and the Global Corruption Perceptions Index Report is referred to as CPI.

3.1.2 Explanatory variable: export technology complexity

In the UN Comtrade database, the export technological complexity of the nations along the B&R is measured using the SITC Rev.3 set of 3-quantile items, in accordance with the research methodology of Hausmann, Hwang, and Rodrik (2003,2007). First, the industry-level export technology complexity is computed.

$$PRODY_d^t = \sum_{i=1}^{n} \frac{(x_{id}/\sum_d x_{id})}{\sum_i (x_{id}/\sum_d x_{id})} y_i \tag{1}$$

Second, the export technology complexity is determined at the national level using a weighted average.

$$EXPY_i = \sum_d \frac{x_{id}}{\sum_d x_{id}} * \sum_{i=1}^{n} \frac{(x_{id}/\sum_d x_{id})}{\sum_i (x_{id}/\sum_d x_{id})} y_i \tag{2}$$

Where t is the year, and i is the country, n is the number of countries, and d is the industry sector,

y_i is i country's GDP per capita.

3.1.3 Threshold variable: trade costs

By utilizing Novy and Gravity's (2013) research technique, the cost of trade between China and B&R countries may be calculated.

$$COST_{ij} = [\frac{(s \bullet GDP_i - Exp_i)(s \bullet GDP_j - Exp_j)}{x_{ij}x_{ji}}]^{\frac{1}{2(\sigma-1)}} - 1 \quad (3)$$

Among them, x_{ij}, x_{ji} are country i's exports to j and country j's exports to i, and GDP_i、GDP_j is the GDP of country i and j, .Exp_i、Exp_j is the total exports of country i and j, and s is the share of traded goods, which takes the value 0.8, σ is the elasticity of substitution, which takes the value of 8 (Anderson and Wincoop, 2003).

3.1.4 Control variables

The population growth rate (POP), the consumer price index (CPI), government financing (GOV), and whether or not it is a member of the WTO (WTO) and EN or ASEAN (EN&ASEAN) are the control variables used for this article. The spatial effect of RECs on export technological complexity is examined using the following control variables: membership in the EU or ASEAN, and membership in the World Trade Organization (WTO), where membership takes the value of 1 and vice versa. Countries that are close in location, share similar cultures, and have similar economic goals might strengthen their cooperation by joining RECs. However, because of the exclusivity feature, these countries are forced to erect trade barriers with the outside world, which heightens intergroup rivalry. Given how the two interact, it is unclear which way the impact on export technological complexity is projected to go. When the predicted sign is positive, a greater population growth rate (POP) indicates that a nation has a rich endowment of labor resources, which boosts the level of domestic output and hence supports exports. An increase in the consumer price index (CPI) signals improved economic conditions and more purchasing power, which in turn drives up trade demand and raises export technology complexity. Government financing (GOV) expenditures will be a part of the flow of capital into the export industry to support the sector, but they may also result in an increase in the money supply at home, which would lead to inflation and an appreciation of exchange rates—the opposite of the role that trade activities play—and make it impossible to predict the expected path. Thus far, the titles, definitions, origins, and causal relationships of the primary variables in this study are displayed here.

Table 2 Variable names, variable meanings, data sources and causality

Variable names	Variable meanings	Data sources
EXPY	Export technology complexity	UN Comtrade database
FAC	Trade facilitation	GCR, CPI
COST	Trade cost	GCR, "Global Integrity Index"
WTO	WTO member or not	WTO Official Website
EN&ASEAN	EN&ASEAN member or not	EN, ASEAN official website
POP	Population growth rate	WB database
CPI	Consumer price index	WB database
GOV	The proportion of general government expenditure in GDP	IMF

3.2 Spatial weight matrix setting

This paper establishes the spatial weight matrix based on three principles: first, the principle of proximity, which constructs the spatial proximity weight matrix (W1) based on the existence of Rook neighborhoods between the 42 B&R countries. When a neighborhood borders a country along a line, it takes the value of 1, and vice versa, it takes the value of 0. The second is the economic distance principle, which chooses the GDP and total import and export commerce of the nations along the line. To create the spatial trade weight matrix (W2) and spatial output value weight matrix (W3), the total import and export trade as well as the gross domestic product of the countries along the route are chosen. Then, using the Euclidean distance calculation criterion, the inverse of the absolute value of the difference between the two economic indicators is made. The third principle pertains to geographic location, wherein the spatial distance weight matrix (W4) is constructed based on the proximity of the capitals of B&R countries. The inverse of the physical distance between the capitals of the two countries is taken into account. W1 and W4 data were sourced from the CEPII database, while W2 and W3 data were taken from the WB database.

3.3 Modelling

3.3.1 Spatial modelling

Spatial auto-regression (SAR), spatial error (SEM), and spatial Durbin (SDM) models are frequently utilized in spatial panel econometric models (Lesage and Pace, 2009). Along with the research theme, the export technology complexity of the countries along the route in SAR is influenced by the neighboring countries' export technology complexity under the influence of the spatial transmission mechanism; in SEM, the neighboring countries' error terms spatially affect the export technology complexity of the countries along the route because of differences in sample country locations and interactions; and in SDM, the export technology complexity of B&R countries is influenced by both the home country's and the neighboring countries' trade facilitation levels. The Spatial Durbin Model (SDM) can be chosen for additional study in this paper by combining the findings of the WALD test and the LR test in Table 3.

Table 3 Results of WALD test and LR test

	WALD test		LR test	
	W1	W2	W1	W2
Comparing SDM and SAR	P=0.008	P=0.028	P=0.000	P=0.000
Comparing SDM and SEM	P=0.020	P=0.092	P=0.000	P=0.000

3.3.1.1 The spatial Durbin model

Create the static spatial Durbin model (SDM) as indicated by formula (4). Since the spatial impact of trade facilitation level on export technology complexity may occur gradually, choose the trade facilitation level's lagged period to create the dynamic spatial Durbin model, as indicated by formula (5).

$$lnEXPY_{it} = \alpha_0 + \rho W_j lnEXPY_{it} + \beta_1 lnFAC_{it} + \beta_2 W_j lnFAC_{it} + \varphi X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (4)$$

$$lnEXPY_{it} = \alpha_0 + \rho W_j lnEXPY_{it} + \beta_1 lnFAC_{it-1} + \beta_2 W_j lnFAC_{it-1} + \varphi X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (5)$$

Where $EXPY_{it}$ is the level of the export technology complexity, andFAC_{it} is the trade facilitation level, W_j is the spatial weight matrix, including the spatial proximity weight matrix W1 and spatial trade weight matrixW2, X_{it} is the control variable, and α_0 is the constant term, β_1、φ are the regression coefficients of trade facilitation on the export technology complexity, ρ、β_2 is the spatial autocorrelation coefficient between the export technology complexity and trade facilitation, and μ_i is the individual fixed effect, γ_t is the time fixed effect, ε_{it} is the general disturbance term.

3.3.1.2 Spatial error modelling

The spatial error model (SEM) is constructed as shown in formula (6)-(7), where η_{it} is also the model disturbance term, and the spatial error term of the export technology complexity and trade facilitation level is examined to improve the estimation efficiency.

$$lnEXPY_{it} = \alpha_0 + \beta lnFAC_{it} + \varphi X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (6)$$

$$\varepsilon_{it} = \lambda W_j \varepsilon_{it} + \eta_{it} \quad (7)$$

3.3.2 Threshold effect modelling

The impact of trade facilitation on export technological complexity may be non-linear, influenced by the threshold variable trade cost. The threshold effect model formula (8) is designed to investigate this non-linear relationship.

$$lnEXPY_{it} = \beta_0 + \beta_1 lnFAC_{it} * I(lnCost \leq \lambda_1) + \beta_2 lnFAC_{it} * I(\lambda_1 < lnCost \leq \lambda_2) + \beta_n lnFAC_{it} * I(\lambda_{n-1} < lnCost \leq \lambda_n) + \beta_{n+1} lnFAC_{it} * I(lnCost > \lambda_n) + \alpha X_{it} + \varepsilon_{it} \quad (8)$$

Where Cost is the threshold variable trade cost, λ_n is the value of the threshold confidence interval to be satisfied for trade costs, n is the number of thresholds, I is the indicative function, which takes the value of 1 when the condition is met and 0 otherwise, and the rest of the variables have the same meaning as above.

4. Empirical analysis

4.1 Spatial global autocorrelation

The spatial dependency of the two is investigated from the perspective of global spatial autocorrelation, motivated by the necessity to look into the effects of trade facilitation level on the export technological complexity of B&R countries from a spatial perspective from 2008 to 2020. First, the Moran index of B&R countries is computed in order to analyze the spatial distribution of export technological complexity and trade facilitation. The spatial trade weight matrix (W2) has the highest degree of significant global autocorrelation among the four spatial weight matrices created in this paper. It is followed by the spatial proximity weight matrix (W1), while the spatial output value weight matrix (W3) and the spatial distance weight matrix (W4) have small and weak degrees of significance for autocorrelation (Table 4).While W2 focuses on the mapping of the whole scale of import and export trade between nations in the spatial structure, W1 symbolizes the degree of spatial dependency on the geographic relationship of whether or not the countries along the route have common boundaries. In conclusion, W1 and W2 are chosen to be the spatial weight matrices used in the analysis.

The findings indicate that trade facilitation and export technology complexity in B&R nations exhibit considerable positive spatial autocorrelation from 2008 to 2020, with the exception of trade facilitation in 2014, which fails the significance test in W2. The two are consistently clearly geographically grouped when viewed through the lens of spatial pattern, and in both W1 and W2, the export technology complexity has a higher degree of autocorrelation than trade facilitation. The observed disparity in the vertical trade facilitation gap between each location and the innate natural endowments and acquired economic development environment could be the cause of this, as seen by the comparatively weak geographical association. There is a trend from "high - high" or "low - low" concentration state to "high - low" concentration state, and the degree of spatial concentration of trade facilitation level steadily diminishes with time. Following the 2008 global financial crisis, the degree of spatial autocorrelation continued to weaken. However, since the B&R Initiative was proposed in 2013, the positive effects of the improved business environment and the encouragement of foreign trade policies have strengthened the spatial dependence of the export technology complexity once again. The export technology complexity's spatial autocorrelation first declined and then rebounded, with overall fluctuations but maintaining a steady growth trend. In summary, the degree of trade facilitation and export technology complexity of B&R countries are influenced by spatial factors such as import and export trade and geographic proximity. This paper will use spatial econometric modeling to investigate the relationship between trade facilitation and export technology complexity from a spatial perspective.

Table 4 Test of global autocorrelation for export technology complexity and trade facilitation

Variables	lnFAC				lnEXPY			
Matrix	W1		W2		W1		W2	
Moran Index	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
2008	0.180	0.091	0.153	0.024	0.432	0.001	0.431	0.001
2009	0.197	0.087	0.133	0.035	0.299	0.014	0.329	0.080
2010	0.193	0.085	0.096	0.090	0.283	0.021	0.291	0.018
2011	0.138	0.092	0.175	0.013	0.234	0.031	0.267	0.044
2012	0.147	0.093	0.170	0.045	0.189	0.087	0.252	0.074
2013	0.137	0.094	0.118	0.078	0.198	0.080	0.239	0.045
2014	0.096	0.093	0.151	0.030	0.212	0.064	0.244	0.041

2015	0.080	0.091	0.082	0.180	0.208	0.069	0.228	0.054
2016	0.012	0.073	0.077	0.099	0.203	0.076	0.222	0.061
2017	0.042	0.090	0.114	0.073	0.191	0.093	0.209	0.076
2018	0.048	0.085	0.103	0.082	0.300	0.011	0.344	0.005
2019	0.061	0.090	0.112	0.080	0.274	0.019	0.325	0.008
2020	0.034	0.083	0.138	0.092	0.261	0.027	0.305	0.013

4.2 Spatial benchmark regression results

This study examines the spatial relationship between trade facilitation level and export technological complexity in B&R countries using the POLS, SEM, and SDM models, as indicated in Table 5. Overall, the degree of trade facilitation in B&R countries has a strong positive impact on the export technological complexity, which is supported by the POLS model without taking spatial considerations into account and the SEM and SDM models with spatial weight matrices W1 and W2. This supports hypothesis H1.

First, a country along the route experiencing greater trade facilitation will see an increase in the export technology complexity of its own exports; additionally, through spatial spillovers, this will positively affect the export technology complexity of other countries. This is indicated by the significantly positive spatial autocorrelation coefficients in matrices W1 and W2. This is consistent with hypothesis H2, and the key causes are the geographical closeness of the nations along the route, the imitation of rivalry and cooperation among individuals in the countries along the route, and the spillover effect. In the meantime, comparing the regression results of W1 and W2, it is evident that the spatial proximity weight matrix W1 has a slightly better spillover effect than the spatial trade weight matrix W2, suggesting that, of the two elements of the correlation between whether it is related to import and export trade or not, the clustering effect of the export technology complexity is more closely related to the former. The import and export trade is primarily an economic relationship that depends on geography to continue developing, whereas the proximity of the countries along the route is a natural and long-term connection. As a result, the former has a stronger effect on the export technology complexity of other countries along the route. Second, the spatial error terms are significant in matrices W1 and W2, suggesting that the export technology complexity is influenced by numerous other unobservable error terms, which could be closely related to the region's factor structure, political risk, social customs, cultural traditions, and so forth, in addition to variables like population size, trade facilitation level, and government financing.

When we look at the control variables, we can see that, first, the indicators of regional economic integration related to the WTO, EN, and ASEAN show more negative impacts. This means that trade barriers are being deepened externally by the organization, and trade protectionism is on the rise. These factors are not helpful for improving the technological content and quality of exports in the context of the global economy. Second, the population size (POP) has a significant negative impact on the complexity of export technologies in all models. The population growth rate does not imply that the population structure is adjusted or that human capital is accumulated; rather, the countries along the route face general issues such as rusty labor skills, a shortage of high-quality talent, and rising labor costs. Contrarily, population expansion will result in increasing rivalry for workers, environmental damage, and strain on scarce resources, all of which will impede exporting nations' ability to become more competitive. Thirdly, the size and composition of the domestic consumer market in B&R countries will not change significantly in the near future, and there is little correlation between the improvement of export commerce and the consumer price index (CPI) and the complexity of export technology. Fourth, the rise in the percentage of general government spending (GOV) limits the amount of resources allotted to exports during the resource allocation process, which in turn restrains the advancement of export technological complexity.

Table 5 Benchmark regression results

Variables	lnEXPY				
	POLS	SEM		SDM	
		W1	W2	W1	W2
ρ				0.055***	0.051**
				(0.01)	(0.01)
λ		0.539***	0.555***		
		(0.00)	(0.00)		
lnFAC	0.013**	0.014***	0.011**	0.012**	0.014**
	(0.02)	(0.01)	(0.04)	(0.03)	(0.02)
WTO	-0.042	-0.050	-0.048	-0.029	-0.032
	(0.53)	(0.53)	(0.55)	(0.78)	(0.76)

EN&ASEAN	-0.013	-0.010	-0.008	0.015	0.022
	(0.74)	(0.84)	(0.87)	(0.86)	(0.80)
POP	-0.010***	-0.007***	-0.007***	-0.008***	-0.008***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CPI	0.001***	0.000***	0.000**	0.000**	0.000**
	(0.00)	(0.00)	(0.01)	(0.02)	(0.01)
GOV	-0.037***	-0.020***	-0.018**	-0.029***	-0.029***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
cons	10.214***	10.258***	10.262***	10.028***	10.032***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
sigma2_e		0.003***	0.003***	0.003***	0.003***
		(0.00)	(0.00)	(0.00)	(0.00)
Log L		787.061	774.338	773.532	719.752
N	546	546	546	546	546

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels. Values in parentheses correspond to standard errors. Unless specified otherwise, the same applies below.

4.3 Spatial dynamic regression results

In order to mitigate the endogeneity issue brought on by the time-invariant omitted variables, it may be helpful to treat the trade facilitation level as a one-period lag when analyzing the spatial dynamics of the two, given that there may be a time lag in the transmission mechanism of the level affecting export technology complexity in B&R countries. The findings in Table 6 demonstrate that, first, when employing the spatial trade weight matrix W2, the trade facilitation level has a positive lagged influence on export technological complexity in both SEM and SDM models. Following the introduction of the B&R initiative, the policy environments of the countries along the route have been continuously optimized. In 2022, Chinese enterprises signed 5,514 new contracts for foreign projects with B&R countries, creating new opportunities and driving forces. The inherent development conditions of the previous period from the time dimension will have a positive impact on the current level of trade facilitation. Second, the spatial spillover effect of W1 and W2 in the various models varies numerically in size. Additionally, the spatial trade weight matrix's lag one period of the trade facilitation level results in a bigger spatial lag effect on the augmentation of export technological complexity. In order to complete the construction of the economic indicator, which considers not only geographic proximity but also trade scale, trade density, and other economic links, W2 is based on the construction of the total import and export trade of the countries along the route. The spatial transmission mechanism of trade facilitation lags one period for the neighboring countries, but becomes more effective as globalization advances and trade links become more dependent on economic factors rather than geographic distance.

Table 6 Dynamic regression result

Variables	lnEXPY				
	POLS	SEM		SDM	
		W1	W2	W1	W2
ρ				0.050**	0.429***
				(0.01)	(0.00)
λ		0.557***	0.729***		
		(0.00)	(0.00)		
lnFAC	0.015**	0.010	0.017***	0.014**	0.016***
	(0.04)	(0.11)	(0.00)	(0.03)	(0.00)
L.lnFAC	-0.005	0.004	0.010*	-0.000	0.001*
	(0.47)	(0.49)	(0.98)	(0.95)	(0.83)
sigma2_e		0.003***	0.002***	0.003***	0.002***
		(0.00)	(0.00)	(0.00)	(0.00)
Log L		733.268	776.947	727.303	823.778
control variable	Yes	Yes	Yes	Yes	Yes
N	546	546	546	546	546

4.4 Direct effect and indirect effect

The direct effect is the direct impact of the trade facilitation level of B&R countries on the export technology complexity of their own exports, while the indirect effect is the feedback accumulation of the spatial spillover effect on the neighboring countries, and the total effect represents the total effect on export technology complexity of all the countries along the route, and further introduces the decomposition effect to comprehensively analyze the spatial impact of the trade facilitation level on the export technology complexity. The decomposition impact is further integrated in order to do a comprehensive analysis of the geographical influence of trade facilitation level on export technological complexity. First, as can be seen from Table 7's regression results, W2 has a significantly negative indirect effect on export technological complexity, but W1's level of trade facilitation has a significantly favorable direct effect. This implies that trade facilitation levels along the route may have a negative geographical spillover effect on neighboring nations, even while it is certainly encouraged for countries to increase the complexity of their export technology. Along the line where nations have the first-mover advantage of integrating into the central link of the global value chain, trade facilitation is situated at a high level of development. As a result, trade facilitation is progressively closing the trade deficit with surrounding nations, which has a negative externality on export technological complexity and is harmful to the expansion of adjacent nations' export quantities and export quality.

Table 7 Direct effect, indirect effect and total effect

Variables	lnEXPY					
	Direct effect		Indirect effect		Total effect	
	W1	W2	W1	W2	W1	W2
lnFAC	0.014**	0.014***	-0.004	-0.048***	0.010	0.035*
	(0.02)	(0.01)	(0.68)	(0.00)	(0.36)	(0.05)
control variable	Yes	Yes	Yes	Yes	Yes	Yes
N	546	546	546	546	546	546

4.5 Heterogeneity analysis

4.5.1 Heterogeneity of trade facilitation sub-indicators

To gain an understanding of the main points, challenges, and pain points of trade links, it is important to investigate the spatial effects of different trade facilitation sub-indicators on the export technology complexity in B&R countries. For instance, port and coastal environments can expedite the clearance of goods through customs and reduce logistical costs; improving institutional environments can help reduce administrative costs and legal risks for businesses; and innovation capacity and financial e-commerce can encourage technological innovation and business market expansion. Table 8's model results demonstrate that raising each trade facilitation sub-indicator in the participating countries will both positively spatially spillover to other countries and significantly increase the export technology complexity of those countries' own exports. The port environment and innovation capability have the greatest promotion effects among them, while the regression coefficients for the institutional, financial, e-commerce, and customs environments are similar. When the causes of this are examined, it becomes clear that while the port environment, institutional environment, and other factors also have a significant impact on the export competitiveness of the nation, their main contribution is to the creation of a favorable business environment and trading platform that support technological innovation and the internationalization process. Meanwhile, the innovation capacity is the main driver of the export technology complexity, which in turn determines the nation's technological level and competitiveness in the market. The nation's export industries and businesses are propelled by innovation capacity to consistently launch new goods, procedures, and services, optimize management and production techniques, cut expenses and boost productivity, and raise product value addition and market share.

Table 8 Spatial regression results for heterogeneity in trade facilitation sub-indicators

Variables	lnEXPY									
	Panel A: Port Environment		Panel B: Customs environment		Panel C: Institutional Environment		Panel D: Innovative capacity		Panel E: Financial environment and e-commerce	
	W1	W2	W1	W2	W1	W2	W1	W2	W1	W2
ρ	0.193***	0.271***	0.125***	0.152***	0.120***	0.128***	0.274***	0.340***	0.119***	0.258***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnFAC	0.013**	0.021***	0.020***	0.024***	0.001	0.001	0.030***	0.032***	0.020***	0.021***
	(0.02)	(0.00)	(0.00)	(0.00)	(0.17)	(0.81)	(0.00)	(0.00)	(0.00)	(0.00)
control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yea
N	546	546	546	546	546	546	546	546	546	546

4.5.2 Regional heterogeneity

We further divide the research sample into four regions, namely, West Asia and North Africa, Central and Eastern Europe, Southeast Asia and South Asia, Central Asia, Mongolia, and Russia, to analyze their spatial effects. This is because the countries along the routes are vast in size and span, the differences in geographic location are closely related to the abundance of natural factor endowments, and there is spatial heterogeneity among countries in different regions in the fields of technology and economy.

First, as can be seen from Table 9's regression results, all regions along the B&R exhibit robust overall substantial positive spatial spillover effects on export technology complexity. Of these, the impact on West Asia and North Africa, Central Asia, Mongolia, and Russia are the least, and the largest is on Southeast Asia, South Asia, and Central and Eastern Europe. The opening of the China-ASEAN Free Trade Area in Southeast Asia and South Asia, the proposed China-ASEAN "one-axis-two-wings" new pattern, and the construction of the China-Vietnam "two corridors and one circle" economic belt have shifted the focus of connectivity to the areas of finance and e-commerce; in contrast, the financial environment, infrastructure, and customs efficiency of West Asia and North Africa, the Central Asia-Mongolian-Russian region are in better shape. These developments have raised the level of trade facilitation in the Central and Eastern European region. Second, in West Asia, North Africa, and Central and Eastern Europe, the promotion effect of trade facilitation on the export technology complexity is not readily apparent. The region's economies are primarily reliant on resource exports, such as natural gas and oil, and consumer demand is skewed toward low-tech goods like food and textiles, which hinders economic diversification and technological advancement. On the other hand, the region's institutional environment is relatively weak in terms of contract enforcement, legal frameworks, and government administrative effectiveness, so trade facilitation's contribution to export technology complexity is probably minimal.

Table 9 Spatial regression results for regional heterogeneity

Variables	lnEXPY							
	West Asia and North Africa		Central and Eastern Europe		Southeast Asia and South Asia		Central Asia, Mongolia and Russia	
	W1	W2	W1	W2	W1	W2	W1	W2
ρ	0.189***	0.458***	0.205***	0.521***	0.102***	0.556***	0.325***	0.033
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.83)
lnFAC	0.024	0.020	0.001	0.001	0.037***	0.034***	0.127**	0.076
	(0.12)	(0.17)	(0.84)	(0.79)	(0.01)	(0.00)	(0.03)	(0.13)
sigma2_e	0.003***	0.003***	0.002***	0.001***	0.002***	0.002***	0.003***	0.002***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Log L	220.862	235.480	238.767	337.188	202.951	224.375	59.372	66.731

control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	169	169	195	195	143	143	39	39

5. Further analysis: Threshold estimation effects on trade costs

Trade cost is chosen as the threshold variable in order to thoroughly examine the mechanism by which trade facilitation affects export technology complexity in B&R countries. Bootstrap is then configured to repeat the sampling 300 times. The test results in Table 10 demonstrate that the single and double thresholds pass the test at the 10% statistical level, while the triple threshold is not significant at this level. These results suggest that trade cost has a double threshold effect on trade facilitation's ability to affect export technology complexity; the threshold values are 0.582 and 3.652, respectively.

Table 10 Threshold effect test results

Number of thresholds	F-value	P-value	1% threshold	5% threshold	10% threshold	Number of BS	threshold value
single threshold	25.32	0.017	28.077	21.619	18.840	300	0.580
double threshold	14.06	0.097	21.626	16.415	13.946	300	3.652
triple threshold	8.94	0.387	26.075	17.783	15.615	300	1.897

Table 11 shows that the impact of trade facilitation level on export technology complexity in B&R nations is significantly influenced by trade cost thresholds, suggesting that the relationship between trade facilitation and export technology complexity currently has a non-linear form. The regression coefficient of export technology complexity is 0.008 in the first stage, when the trade cost does not exceed 0.582. This suggests that when trade costs are low, the countries along the route's improved trade facilitation level has a positive effect on the export technology complexity, and more industries and enterprises have the chance to participate in international trade at this time, which encourages technology transfer and innovation. During the second stage, the estimated coefficient -0.014 passes the test at the 1% statistical significance level when the trade level is between 0.582 and 3.652. This indicates that instead of impeding the development of export technology complexity, the increase in trade costs is countered by an increase in trade facilitation in the countries along the route. Increased trade costs put businesses under more pressure to compete in the market, which can easily result in brain drain, affect industrial structure adjustment and optimization, and limit technological innovation and power transfer. On the other hand, increased trade costs put more financial pressure on the government, inadequate policy support, and may even exacerbate geopolitical risks, making the process of trade exchanges more uncertain and risky. When trade costs surpass 3.652 in the third stage, the export technology complexity coefficient value is -0.018. This indicates that, in contrast to the second stage, the degree of inhibition has increased, but the increase in trade facilitation level still results in a negative inhibition of export technology complexity. This is comparable to the second stage in that it involves an increase in trade costs. The main causes of this inhibition, along with the high level of market rivalry and restricted technological innovation capability, are brain drain, increased risk of uncertainty, and other factors.

Table 11 Estimates of threshold regression results

Variables	Threshold estimate coefficient value
lnFAC ($lnCost\ \leq 0.582$)	0.008^{**}
lnFAC ($0.582 < lnCost\ \leq 3.652$)	-0.014^{***}
lnFAC ($Cost\ \geq 3.652$)	-0.018
control variable	Yes

6. Conclusions and Suggestions

6.1 Conclusions

The spatial Durbin model and the spatial error model are used in this paper to analyze the relationship between trade facilitation and export technology complexity from both a static and dynamic perspective. Additionally, the spatial heterogeneity by indicator and region is further examined. The spatial panel data of B&R countries from 2008 to 2020 is used. The primary findings of this study are as follows: First, the spatial dependence test results demonstrate that the export technology complexity and trade facilitation level of B&R countries exhibit clear spatial positive autocorrelation, with the latter fluctuating but overall maintaining a steady growth while the former gradually declining. Second, the spatial benchmark regression results demonstrate a significant positive spatial spillover effect of the trade facilitation level on export technology complexity, which is positively correlated with the spatial error term and marginally superior to the spatial trade matrix in the spatial proximity matrix. This suggests that as the trade facilitation level increases, the export technology complexity of the home country will also be positively impacted by the trade facilitation level growth in other countries along the route. Thirdly, in contrast to the spatial proximity matrix, the lagged one period of the trade facilitation level produces a larger spatial lagged effect in the spatial trade matrix on enhancing export technology complexity. These dynamic regression results indicate that the lagged effect of trade facilitation in the spatial regression model affecting export technology complexity is not obvious. The findings of the heterogeneity analysis indicate that: in terms of sub-indicators, the improvement of the trade facilitation sub-indicators of the countries along the route will significantly promote the enhancement of the technical complexity of the country's exports and also have spatial positive spillover effects on other countries. Fourth, the regression results of direct and indirect effects show that: the direct effect of trade facilitation level affecting export technology complexity is significantly positive; and the indirect and total effects are only evident in the spatial trade weight matrix. The port environment has the strongest promotion effect on innovation ability, while the regression coefficients for the institutional, financial, customs, and e-commerce environments are comparable. The degree of trade facilitation along the routes has a positive spillover effect on export technology complexity, with a slightly better degree for Central and Eastern Europe, Southeast Asia, and South Asia than for West Asia, North Africa, Central Asia, Mongolia, and Russia when it comes to subregions. Sixth, there is a notable trade cost threshold effect in B&R countries that is positive at low trade costs and inhibitory at high trade costs, depending on the degree of trade facilitation.

6.2 Suggestions

One the one hand, it's critical to fully utilize the benefits of regional spatial links and keep raising the bar for regional trade facilitation in B&R nations. The development of trade facilitation along the route varies among the countries due to differences in natural resources, factor endowment, culture, and history; the region of Central and Eastern Europe has fared better than the regions of West Asia and North Africa, Central Asia, Mongolia, and Russia. In addition to playing up to the spatial transmission mechanism of Central and Eastern Europe, Southeast Asia and South Asia, West Asia and North Africa, Central Asia and Mongolia and Russia, etc., the countries along the route should avail themselves of geo-connectivity in order to forge amicable economic and trade relations. The first goal is to increase the degree to which countries with high and low levels of trade facilitation are clustered together, and to foster the development of infrastructure and connectivity between the regions. Examples of this infrastructure include roads, ports, railways, and other forms of transportation, as well as the Internet, e-commerce, and other applications of information technology. The second goal is to increase trade and investment cooperation among regions, broaden the scope and field of investment, encourage cross-border capital and technology flows, and facilitate the deep integration of industrial and value chains.

However, in order to maximize the benefits of the multilateral trading system and to facilitate commerce between and within regions, the B&R strategy has been actively pushed into action. The study discovered that export technology complexity is negatively impacted by factors related to regional economic integration, such as whether or not to join the WTO and whether or not to be a member of EN&ASEAN. As a result, the first step is to improve interregional policy coordination and cooperation between the participating countries, develop and implement open and inclusive trade policies, and lower trade and non-tariff barriers. Examples of these include encouraging the participating countries to sign bilateral investment agreements and free trade agreements, creating trade and investment promotion agencies, and lowering trade barriers in emerging markets. The second step is to improve trade and investment regulation and supervision, protect intellectual property rights, enforce anti-monopoly supervision, establish and enhance the investment approval system, and encourage fairness and transparency in trade and investment.

Note

1. 42 B&R nations altogether from four regions are chosen for this paper: Central Asia, Mongolia and Russia, including Russia (RUS), Kazakhstan (KAZ) and Kyrgyzstan (KGZ), and Southeast Asia, including India (IND), Pakistan (PAK), Sri Lanka (LKA), Vietnam (VNM), Cambodia (KHM), Thailand (THA), Malaysia (MYS), Singapore (SGP), Indonesia (IDN), Brunei (BRN), and the Philippines (PHL), and 11 countries in West Asia and North Africa, including Turkey (TUR), the United Arab Emirates (ARE), Saudi Arabia (SAU), Qatar (QAT), Bahrain (BHR), Kuwait (KWT), Lebanon (LBN), Jordan (JOR), Israel (ISR), Armenia (ARM), Georgia (GEO), Azerbaijan (AZE), and Egypt (EGY), and 13 countries in Central and Eastern Europe, including Poland (POL), Czech Republic (CZE), Slovakia (SVK), Hungary (HUN), Slovenia (SVN), Croatia (HRV), Romania (ROU), Bulgaria (BGR), Bosnia and Herzegovina (BIH), Albania (ALB), Estonia (EST), Lithuania (LTU), Latvia (LVA), Ukraine (UKR), and Moldova (MDA). Source: China’s Belt and Road Network, https://www.yidaiyilu.gov.cn/.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Major project of the Key Research Base of Humanities and Social Sciences of the Ministry of Education of China: [Grant Number 22JJD790035].

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