The Direct and Indirect Effect of the Belt and Road Initiative on Exports to China*

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Abstract

This study investigates the direct effect of a country's participation in China's Belt and Road Initiative (BRI) on its exports to China, as well as its indirect effect on other countries' exports to China. Using an event study approach, staggered difference-in-differences methodology, and spatial econometric models, we find that participation in the BRI significantly increases member countries' exports to China, partly because of improvements in infrastructure. We also find evidence showing that countries without strong pre-existing political ties with China are more likely to experience greater export gains after joining the BRI. Furthermore, employing the Spatial Durbin Model, we find that the BRI has a significantly negative indirect effect on exports of countries with a manufacturing share similar to those of BRI members. This result likely reflects heightened competitive pressures, as the BRI increases exports from members to China. However, when using a spatial weight matrix constructed based on geographic distance, we find no significant indirect effect, suggesting that the positive effect of the BRI does not spill over to geographic neighbor countries through infrastructure development.

Keywords: Belt and Road Initiative, exports, staggered DID, spatial econometric models

JEL Codes: F13, F14, R12

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1 Introduction

The Belt and Road Initiative (BRI), launched by Chinese President Xi Jinping in 2013, is a global development strategy aimed at fostering infrastructure development in Asia, Europe, and Africa and economic integration and policy coordination between China and these regions. According to China's Ministry of Commerce, the total trade volume between China and BRI countries reached nearly USD 2.9 trillion in 2022. As a transformative policy, the BRI now encompasses over 140 countries and regions worldwide, profoundly altering global trade and investment dynamics (Nedopil, 2024).

A substantial body of literature has examined the political and economic implications of the BRI, and most studies emphasize international investment and trade as its core objectives (Huang, 2016; Yu et al., 2020). In the realm of international trade, the literature consistently highlights the direct positive effect of the BRI on trade flows among member countries. For example, Baniya, Rocha, and Ruta (2020) specifically focused on trade flows between BRI member countries and found that the BRI significantly increases the bilateral trade volume among these countries. Numerous studies have also explored trade between China and BRI member countries. Yu et al. (2020), using a Difference-in-Differences (DID) model, revealed that the BRI significantly enhances China's exports to member countries. Lu et al. (2024), also employing a DID approach, found that the BRI facilitates the optimization of China's product structure while boosting its imports from member countries.

One shortcoming of these existing studies on the BRI is that they do not examine the indirect effect of the BRI on trade of non-BRI countries. However, in the related literature on the impact of free trade agreements (FTAs) on international trade, existing studies have often considered both the direct effect on trade of FTA member countries and the indirect effect on trade of non-member countries.

Theoretically, Viner (1950) highlighted the concept of trade diversion, suggesting that FTAs lower trade costs among member countries, potentially reducing trade with non-member countries and diverting trade flows toward members. Empirically, Conconi et al. (2018) showed that the North American Free Trade Agreement (NAFTA) led to a decline in member countries' imports of intermediate goods from third-party countries. Conversely, some studies argued that FTAs may generate a positive indirect effect for non-member countries. For example, Yang and Martinez-Zarzoso (2014) found that the ASEAN-China Free Trade Agreement not only increased intra-member trade but also enhanced trade flows between member and non-member countries by reducing trade costs. Lee, Mulabdic, and Ruta (2023) similarly found that Regional Trade Agreements (RTAs) can increase non-member countries' exports to members, suggesting that non-member countries are not excluded from trade networks. While the BRI is not a traditional FTA, it may also generate an indirect effect on non-member countries. However, research on the indirect effect of the BRI remains scarce.

One commonly used approach to analyze the indirect effect is the application of spatial econometric models. These models have been extensively used in studies that examine the indirect effect of environmental policies, high-speed rail development, and other phenomena (Du et al., 2021; Jia, Shao, and Yang, 2021; Weng, Huang, and Greenwood-Nimmo, 2023). Some studies have applied spatial econometric models to analyze international investment. For example, Friedt and Toner-Rodgers (2022) used a spatial autocorrelation combined (SAC) model to examine the impact of natural disasters in India on foreign direct investment (FDI). They found that while natural disasters significantly reduce FDI in affected regions, they lead to a positive spillover effect in neighboring unaffected regions, as multinational corporations redirect investments.

To examine the indirect effect of the BRI on the trade of non-member countries, this study, following Delgado and Florax (2015) and Friedt and Toner-Rodgers (2022), integrates DID and spatial econometric models. More precisely, in addition to employing event study estimates and staggered DID methods to examine the direct impact of the BRI on member countries' exports to China, this study accounts for potential spatial autocorrelation based on geographic or economic distance stemming from the implementation of the BRI. To address this, we utilize the Spatial Durbin Model (SDM), which effectively controls for spatial autocorrelation. Moreover, the SDM enables us to quantify the indirect effect arising from spatial dependence, particularly the effect on non-member countries.

Using these approaches, this paper finds a positive direct effect of a country's participation in the BRI on its exports to China. We reveal that the BRI improves infrastructure and institutional quality in its member countries and strengthens political relationships between members and China. However, our mediation analysis indicates that the BRI's effect on exports to China may be explained by improvements in infrastructure, but not by other channels. Further, according to our heterogeneity analysis, the direct positive effect of the BRI is more pronounced among countries that had not established close political ties with China prior to the BRI and in particular product groups, such as chemical products, base metals, and textiles.

In addition, we find that countries' participation in the BRI negatively impacts exports to China from other countries with similar industrial structure to the BRI member countries, possibly because the BRI enhances its members' export competitiveness and potentially crowds out non-members' exports to China. Additionally, there is no evidence that the BRI generates a positive indirect effect for geographically proximate neighboring countries, suggesting the BRI has not effectively integrated non-members close to its members into China's trade network through infrastructure improvements.

This paper makes four key contributions. First, while most studies on the BRI's direct effect rely on DID models and treat 2013 as the starting year of the BRI (Yu et al., 2020; Lu et al., 2024), this approach may introduce bias because countries joined the BRI at different times. This study uses data from Nedopil (2023) on the specific years in which 147 countries signed the BRI Memorandum of Understanding (MOU). Based on the data, we adopt a staggered DID model of Callaway and Sant'Anna (2021) to estimate the causal effect, incorporating possible heterogeneous effects depending on the year of participating in the BRI. Second, this study not only examines the direct effect of the BRI on trade but also investigates its indirect effect on non-member countries. Recognizing the potential spatial autocorrelation of exports to China, we employ the SAC and SDM to account for spatial dependencies and estimate the BRI's indirect effect on other countries. Our finding that the BRI has a negative indirect effect on non-member countries with industrial structure similar to members is new in the literature. Third, we examine the potential mechanisms and find that improvements in infrastructure due to the BRI is likely to be a channel of the positive effect of the BRI on exports to China. This conclusion is supported by another finding that the BRI raises exports to countries other than China. Finally, our findings related to political relationships suggests that although the BRI is primarily aimed at strengthening economic relationships, it plays a vital role in fostering interlinkages of political and economic ties between BRI members and China. Accordingly, our study provides evidence to understand the BRI from a political economy perspective.

2 Conceptual Framework

2.1 Direct effects

Building on the prior works on the direct effect of the BRI on exports of member countries, this study focuses on its four core mechanisms.

First, the BRI enhances member countries' infrastructure, which increases their exports to China. Many studies have focused on the impact of infrastructure development on reducing trade costs and promoting trade (Francois and Manchin, 2013; Donaldson, 2018). At its core, the BRI involves large-scale infrastructure projects, including investments in ports, airports, highways, railways, and other logistics facilities (Nedopil, 2024). From both empirical and theoretical perspectives, Baniya, Rocha, and Ruta (2020) and De Soyres, Mulabdic, and Ruta (2020) demonstrated that infrastructure improvements under the BRI reduce trade costs for member countries. Similarly, Lu et al. (2024) identified enhanced bilateral trade logistics performance as a key mechanism behind the increase in China's imports from member countries.

Second, the increase in exports may also be attributed to the BRI's role in enhancing institutional quality and governance in member countries. Many studies have found that trade flows are positively affected by the institutional quality in the destination country measured by the level of anti-corruption, governance quality, political stability, and the rule of law (Álvarez et al., 2018; Anderson and Marcouiller, 2002). In addition, the quality of informal institution, measured by the trust level, enhances trade (Yu, Beugelsdijk, and De Haan, 2015). According to Huang (2016), two key components of the BRI are "policy dialogue" and "unimpeded trade". In other words, China seeks to engage in policy exchanges with other countries through the BRI and aims to eliminate institutional trade barriers to facilitate smoother trade flows. These efforts may help improve the institutional environment of member countries, reduce institutional disparities between China and its BRI partners, and ultimately lower trade costs.

Third, the BRI may increase exports from members to China through foreign direct investment (FDI). Sahoo and Dash (2022) suggested that FDI can enhance the export capacity of host countries through various mechanisms, including improvements in productivity and skills and increased access to global supply chains. Additionally, their study emphasized that FDI particularly influences trade between host and home countries because of intra-firm trade. Liu, Wang, and Wei (2001) arrived at a similar conclusion, demonstrating that inward FDI in China has notably boosted China's exports to the investor countries. Several studies have also found the causal impact of the BRI on FDI flows (Todo, Nishitateno, and Brown, 2025; Du and Zhang, 2018; Shao, 2020). Such Chinese FDI promoted by the BRI may also increase exports to China.

Finally, the BRI may promote exports to China by strengthening bilateral political relationships between China and member countries. Many studies revealed a negative effect of deteriorating political ties on damage international trade (Long, 2008; Du et al., 2017) and a positive effect of improving political ties (Nitsch, 2007). The BRI fosters closer bilateral political relations, because it encompasses multi-dimensional cooperation in areas such as infrastructure and financial investment, as argued by Lu, Gu, and Zeng (2021). These diverse forms of collaboration require frequent diplomatic communication and tighter policy coordination. This channel is different from the other three in that this particularly promotes exports to China while the others can influence exports to countries other than China.

2.2 Indirect effects

We also hypothesize that the BRI generates an indirect effect on exports of non-member countries through two mechanisms, one positive and the other negative.

First, the BRI may have a positive indirect effect on geographically proximate countries, increasing their exports to China. By improving member countries' infrastructure, the BRI often creates regional benefits for international trade. Notably, newly constructed railways or ports in a member country may increase neighboring countries' exports through the improved infrastructure of the BRI countries. This implies that neighboring countries may also be integrated into the international trade network with China through the BRI.

For example, the China-Europe Railway Express, which was developed under the BRI, operates as an international rail transport service for containers and other goods between China, Europe, and other BRI countries. The China-Europe Railway Express is connected to the existing European railway system in Poland, enabling goods from China to be exported to a wider range of European regions, including non-BRI member countries (China Railway Express, 2024a). Additionally, in recent years, the railway network of the China-Europe Railway Express has gradually extended to non-BRI member countries, such as the United Kingdom and the Netherlands (China Railway Express, 2024b). The land transport provided by the China-Europe Railway Express significantly reduces transportation time and costs, and not only BRI member countries but also non-member countries can benefit from the positive indirect trade effect brought about by the BRI.

Second, however, the BRI could also have a negative indirect effect on other countries with economic structures similar to those of member countries. Krugman's new trade theory highlighted the competitive effect among countries with similar resource endowments, particularly when competing in the same markets (Krugman, 1991). Countries with similar resource endowments often produce and export similar products. By enhancing member countries' competitiveness, the BRI enables them to export these goods at lower costs or higher efficiency, thereby "crowding out" non-member countries' exports to China. This competitive effect may reduce non-member countries' trade with China.

Specifically, Viner (1950) introduced the concept of trade diversion, suggesting that preferential tariffs resulting from trade agreements reduce trade costs between member countries, which may lead to a reduction in trade with non-member countries as trade is diverted to member countries. A substantial body of literature has focused on the trade diversion effect potentially caused by FTAs or RTAs (Magee, 2008; Dai, Yotov, and Zylkin, 2014; Anderson and

Yotov, 2016; Singh, 2021; Lambert and McKoy, 2009; Sun and Reed, 2010; Liu and Devadoss, 2013; Russ and Swenson, 2019). Notably, Clarete, Edmonds, and Wallack (2003) examined the major 11 preferential trade agreements in Asia and other regions, noting that most Asian regional agreements tend to be outward-oriented, meaning that member countries continue to trade with non-members. However, agreements such as the ANDEAN Pact, Mercado Común del Sur (MERCOSUR) and South Pacific Regional Trade and Economic Cooperation Agreement (SPARTECA) exhibit the trade diversion effect, where the increase in internal trade among member countries often comes at the expense of trade with non-members. Although the BRI is not a traditional FTAs, it also involves measures to eliminate trade barriers and reduce trade costs, which may cause China to shift its trade from non-member countries to BRI member countries, generating a negative indirect effect on non-members.

In addition, the BRI may enhance the production capacity of member countries. For example, Liu et al. (2024) highlighted that the BRI has established numerous Overseas Industrial Parks (OIPs) in member countries, which ultimately boosted their production capacities. The improvements in production efficiency resulting from the BRI also affect the competitiveness of member countries in the trade market, leading to further trade diversion.

In summary, we predict that the BRI is more likely to increase exports from non-BRI countries with geographic proximity to BRI countries through infrastructure development, while it may decrease exports from those with industrial proximity through the loss of relative competitiveness. We will test these two hypotheses in the empirical section.

3 Empirical Methodology

3.1 Event study estimates

Based on the conceptual framework in the previous section, we propose the following event study estimates to analyze the direct effect of the BRI on member countries' exports to China:

$$\log(Export_{it}) = \sum_{l} \beta_l D_{it}^{l} + \mu_i + \lambda_t + \epsilon_{it} \tag{1}$$

where $\log(Export_{it})$ represents the logarithm of export values of country i to China in year t. D_{it}^{l} equals one if country i participates in the BRI in year $t-l$ and the current year is t, where $l \in \{\dots, -3, -2, 0, 1, 2, 3, \dots\}$, and zero otherwise. For example, $D_{it}^{1} = 1$ if country i participated in the BRI 1 year ago, whereas $D_{it}^{-2} = 1$ if country i will participate 2 years later. Therefore, β_l indicates the effect of the participation in the BRI l years after the participation (or $-l$ years before the participation when $l < 0$). To avoid multicollinearity, we excluded the period $l = -1$ and treated it as the reference period for the analysis. Variable μ_i represents country-level fixed effects, controlling for time-invariant and country-specific factors such as culture and geography, whereas λ_t represents year-level fixed effects, controlling for common trends across all countries, such as global recessions. Finally, ϵ_{it} is the error term.

3.2 Staggered DID estimates

Many recent studies have highlighted the potential biases that arise when treatment effects are heterogeneous (De Chaisemartin and D'Haultfœuille, 2020; Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021; Sun and Abraham, 2021; Borusyak, Jaravel, and Spiess, 2024). Simple DID estimates typically compare the differences between treatment and control groups before and after policy implementation. However, when the adoption periods of treatments are staggered, simple DID may incorrectly treat the early-treated group as the control group when compared to the later-treated group. As a result, when treatment effects are heterogeneous across adoption periods, simple DID provide biased estimates.

To mitigate biases arising from heterogeneous treatment effects, this study employs the staggered DID approach proposed by Callaway and Sant'Anna (2021). Compared to the traditional simple DID method, this estimator identifies "good 2x2 comparisons," meaning that it only compares the treated group with the never-treated group or the treated group with the not-yet-treated group. After estimating treatment effects for each group and time period, this method applies inverse probability weights (IPW) to account for treatment probabilities and calculates the aggregated treatment effect as a weighted average of group-time specific effects.

3.3 Spatial DID estimates

In addition to addressing heterogeneous treatment effects, the stable unit treatment value assumption (SUTVA) emphasizes another key condition for identifying causal effects that the treatment has no indirect effect on the control group. In our case, the SUTVA assumes that a country's participation in the BRI should not influence the outcomes of non-participant countries, including its geographical neighbors and countries with similar industry structure. Delgado and Florax (2015) noted that violations of SUTVA can render traditional DID models invalid for causal inference. They proposed a spatial DID model that accounts for spatial autocorrelation and thus can alleviate biases due to the violation of the SUTVA. Furthermore, from the policy perspective, another key advantage of the spatial DID model is its ability to identify not only the direct effect of a policy but also the indirect effect on neighboring regions through spatial relationships. Therefore, this study employs the spatial DID approach to analyze both direct and indirect effects.

Following the methodologies of LeSage and Pace (2009) and Friedt and Toner-Rodgers (2022), we use a spatial autocorrelation combined (SAC) model. Specifically, we hypothesize that a country's exports may be influenced by the exports of its "neighbors" in terms of the distance between observations. The distance can be defined by geographic distance and economic distance including similarities of the industry and trade structure. The SAC model accounts for spatial correlation in both the dependent variable and the disturbance process. Building on Equation (1), we incorporate a spatial weight matrix w to measure distances between countries. Details on the construction of spatial matrix are provided later. Estimation is conducted using the following equation:

$$\log(Export_{it}) = \rho \sum_{j \neq i} w_{ij} \cdot \log(Export_{jt}) + \sum_{l} \beta_l D_{it}^{l} + \mu_i + \lambda_t + \epsilon_{it}, \tag{2}$$

where

$$\epsilon_{it} = \lambda \sum_{j} w_{ij}\epsilon_{jt} + u_{it}, \tag{3}$$

and w_{ij} is country-pair ij's element of a weight matrix w, or the distance between countries i and j. The term $\rho \sum_{j\neq i} w_{ij} \cdot \log(Export_{jt})$ represents the spatial lag of the dependent variable, where ρ is the spatial lag coefficient, capturing how the exports of neighboring countries influence the exports of the focal country i. The error term ϵ_{it} includes $\lambda \sum_{j\neq i} w_{ij}\epsilon_{jt}$, which represents the spatial correlation of the error term.

In addition, we also employ the Spatial Durbin Model (SDM). Compared to the SAC model, the SDM model accounts for the spatial correlation of independent variables, meaning that the BRI participation status of neighboring countries may also influence the BRI country's exports to China. The estimation is conducted using the following equation:

$$\begin{aligned} \log(Export_{it}) = \rho \sum_{j\neq i} w_{ij} \cdot \log(Export_{jt}) \\ + \sum_{l} \beta_l D^l_{it} + \sum_{l} \theta_l \sum_{j\neq i} w_{ij} \cdot D^l_{jt} + \mu_i + \lambda_t + \epsilon_{it}, \end{aligned} \tag{4}$$

where $\sum_l \theta_l \sum_{j\neq i} w_{ij} \cdot D^l_{jt}$ represents the spatial lag of the independent variable, capturing how the treatment status of neighboring countries influences the focal country's exports.

We primarily use two types of weight matrices for the analysis. The first is the commonly used geographic distance matrix, which measures the geographical proximity between countries. Using longitude and latitude data for the capitals of each country obtained from Natural Earth (2024), we construct an inverse distance matrix based on the geographic distance.

To better investigate the potential impact of similarity in the industrial structure on exports, we also employ the economic distance matrix. Using United Nations (2024) for 2006, the initial year of our sample period, we calculate the share of manufacturing output in GDP for each country. Following the methodology of Jeanty (2010), we construct the economic distance matrix as specified in the following equation:

$$w_{ij} = \frac{1}{|SHARE^s_i - SHARE^s_j| + 1}, \tag{5}$$

where $SHARE^s_i$ is the share of sector s in GDP of country i. Equation (5) implies that country pairs with similar industrial structures are assigned higher weights, while those with more divergent structures are assigned lower weights.

In addition, LeSage and Pace (2009) pointed out that due to spatial dependence, traditional methods cannot be used to interpret the coefficients, as the dependence expands the information set, which not only includes the information from the unit itself but also the information from neighboring regions. To address this issue, we follow the approach of LeSage and Pace (2009) and Weng, Huang, and Greenwood-Nimmo (2023) to demonstrate how the coefficients of the SDM model should be interpreted and rewrite Equation (4) as:

$$\boldsymbol{EXPORT}_t = (\boldsymbol{I}_N - \rho \boldsymbol{W})^{-1} (\boldsymbol{D}_t\boldsymbol{\beta} + \boldsymbol{W}\boldsymbol{D}_t\boldsymbol{\theta}) + \boldsymbol{R}_t, \tag{6}$$

where $\boldsymbol{EXPORT}_t$ represents the matrix of the dependent variable for exports to China, $(\boldsymbol{I}_N - \rho \boldsymbol{W})^{-1}$ represents the inverse matrix of the spatial lag effect, which expands as $(\mathbf{I}_N - \rho\mathbf{W})^{-1} = \mathbf{I} + \rho\mathbf{W} + \rho^2\mathbf{W}^2 + \rho^3\mathbf{W}^3 + \ldots$, and $\boldsymbol{D}_t$ represents the implementation status of the BRI, and $\boldsymbol{R}_t$ represents the remaining terms.

Next, we take partial derivatives of the expected value of exports to China with respect to the implementation status of the BRI in relative period l at a given time t to obtain:

$$\begin{aligned}\left[\frac{\partial E(\boldsymbol{EXPORT})}{\partial D_1^l} \cdots \frac{\partial E(\boldsymbol{EXPORT})}{\partial D_N^l}\right]_t &= (\boldsymbol{I}_N - \rho\boldsymbol{W})^{-1}\begin{bmatrix} \beta_l & \theta_l w_{12} & \cdots & \theta_l w_{1N} \\ \theta_l w_{21} & \beta_l & \cdots & \theta_l w_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \theta_l w_{N1} & \theta_l w_{N2} & \cdots & \beta_l \end{bmatrix} \\ &= (\mathbf{I}_N - \rho\mathbf{W})^{-1}(\beta_l \mathbf{I}_N + \theta_l \mathbf{W})\end{aligned} \tag{7}$$

In the matrix on the right-hand side of Equation (7), the diagonal elements represent the impact of changes in the implementation status of the BRI in relative period l on a country's own exports to China. By contrast, the off-diagonal elements represent the impact of changes in the implementation status of the BRI in period l in other countries j on country i's exports to China. Equation 7 highlights that the direct and indirect effects depend on the product of $(\mathbf{I}_N - \rho\mathbf{W})^{-1}$, which represents spatial transmission relationships, and matrix $(\beta_l \mathbf{I}_N + \theta_l \mathbf{W})$, which represents pure effects. Accordingly, the total direct effect including transmission effects from others is not simply β_l but the average of the diagonal elements of Equation (7). Similarly, the total indirect effect is the average of the row sums of the off-diagonal elements of the Equation (7).

4 Data

This study utilizes data from UN Comtrade (United Nations Statistics Division, 2024), covering the bilateral export value (in USD) from each country to China over 18 years, from 2006 to 2023. The dataset includes an unbalanced panel with 3,747 observations from 214 countries and a balanced panel with 3,366 observations from 187 countries over the same period. Our primary analysis is based on the balanced panel data, while results using the unbalanced panel data presented in the Appendix Figure A1 are similar to our benchmark results. For export values, we apply a logarithmic transformation.

For the treatment indicator of BRI participation, we rely on data from the Green Finance and Development Center (Nedopil, 2023) and define BRI member countries as those that have signed a BRI memorandum of understanding (MOU) with China. We obtained the signing dates for 147 countries, and the distribution of these signing dates is shown in Figure 1. It is worth noting that in this study, we treat the year prior to the MOU signing as the starting year of treatment. This assumption reflects the long-term nature of the BRI, as for some countries, the signing of the MOU may merely formalize policy cooperation activities that had already begun, avoiding the possible anticipation effect and ensuring the pre-treatment parallel trend.

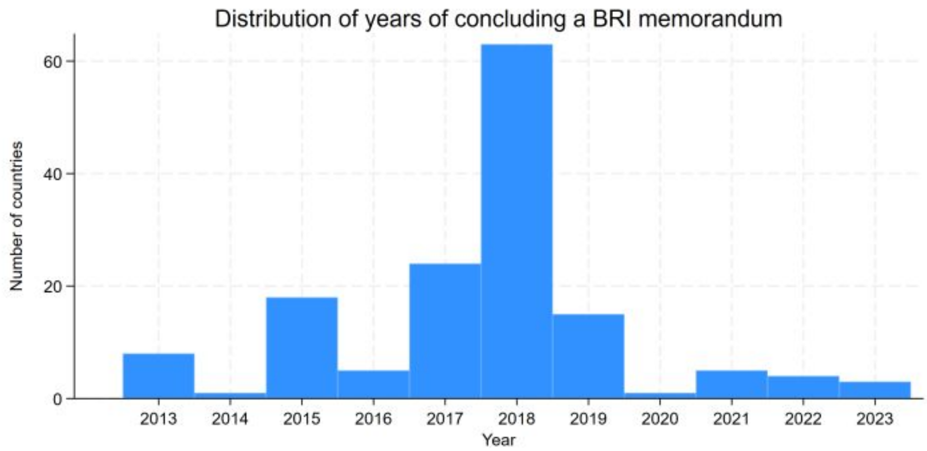


Figure 1. Distribution of Years of Concluding a BRI memorandum

Source: Nedopil (2023)

Table 1 presents the descriptive statistics of the variables used in this study. The first three variables are the core variables of the analysis, while the remaining variables are used for mechanism tests and heterogeneity analyses.

Table 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Export value	3,366	8.055e+09	2.398e+10	10	2.132e+11
-in log	3,366	19.382	3.673	2.303	26.086
Dummy for participation in BRI	3,366	0.353	0.478	0	1
Mechanism variables					
Rail lines	1,112	10,198.435	23,666.863	230.1	194,431
-in log	1,112	8.171	1.335	5.439	12.178
Number of broadband subscriptions	2,959	3,027,893.8	9,462,045.8	0	127,100,000
-in log	2,950	12.082	2.988	3.258	18.661
Sister cities	3,366	0.507	1.366	0	15
Diplomatic relations	3,240	2.181	1.709	0	6
Index of rule of law	3,091	-0.088	0.999	-2.591	2.125
Index of corruption	3,091	-0.085	1.003	-1.849	2.459
Heterogeneity tests					
Dummy for diplomatic relations	3,240	0.489	0.499	0	1
Dummy for sister cities	3,366	0.717	0.451	0	1
Dummy for FTA	3,366	0.128	0.335	0	1

Source: Nedopil (2023), United Nations Statistics Division (2024), World Bank (2024a), Chinese People's Association for Friendship with Foreign Countries (2024), Ministry of Commerce of the People's Republic of China (2024), and Ministry of Foreign Affairs of the People's Republic of China (2024)

As we argued in Section 2.1, one possible mechanism of the effect of the BRI on exports of member countries is improvements in infrastructure. To measure the level of infrastructure, we use rail lines in kilometers and the number of broadband subscriptions, taken from the World Bank's World Development Indicators (World Bank, 2024a).

Another potential mechanism is improvements in the institutional quality, which is measured by the index of rule of law that represents the effectiveness of a country's legal system, the enforceability of contracts, and other dimensions and the index of corruption based on factors such as administrative corruption and electoral corruption, taken from World Bank (2024b). Note that a higher value of the corruption index indicates a lower level of corruption. The two indices are normalized so that the mean is zero and the variance is one.

Moreover, strengthening political relationships with China may also increase exports to China. Then, we employ two measures to evaluate political ties with China: the annual change in the number of cities within a country or region that have established friendly city relationships with Chinese provinces taken from Chinese People's Association for Friendship with Foreign Countries (2024); and a categorical variable from zero to six that indicates the levels of diplomatic relationships with China using the data from Ministry of Foreign Affairs of the People's Republic of China (2024) and following the definition of Xiang (2023). The definition of each level of diplomatic relationships is explained in detail in the Appendix A.

For the heterogeneity analysis later, we divide our sample into two according to various factors, such as the level of economic and political relationships. To measure the strength of economic ties with China, we use the dummy variable for FTAs that indicates whether a country had signed a FTA or RTA with China prior to the signing of the MOU, based on the data of Ministry of Commerce of the People's Republic of China (2024). Similarly, we construct two dummy variables for political ties. A dummy variable is one if a country had established a general partnership or a higher-level relationship with China (the categorical variable is positive) prior to the signing of the MOU. The other dummy is one if a country had established at least one sister city relationship with China before the MOU was signed.

5 Results of the Direct Effect

In this section, we present the results of the direct effect of the BRI on member countries' exports to China, including estimates from the event study, staggered DID, and spatial models. In addition, we show results from mechanism and heterogeneity analyses. In the next section, we will present the results of the indirect effect of the BRI.

5.1 Event study and staggered DID models

We start with the results from the simple event study model represented by Equation (1) presented in Figure 2. Here, we display the estimated coefficients for the seven years before and after the BRI, as observations outside this range are sparse and lead to larger standard errors and wider confidence intervals.

The results show that for the seven years prior to the participation in the BRI, the estimated coefficients are very close to zero and statistically insignificant at the 5-percent level. This indicates no pre-existing differences between the treatment and control groups before the BRI, and we also do not observe any upward trends before the treatment. Therefore, the assumption of the parallel trend in the pre-treatment period that is crucial to the causal inference using DID is satisfied.

In addition, Figure 2 indicates an upward trend in exports to China two years after the

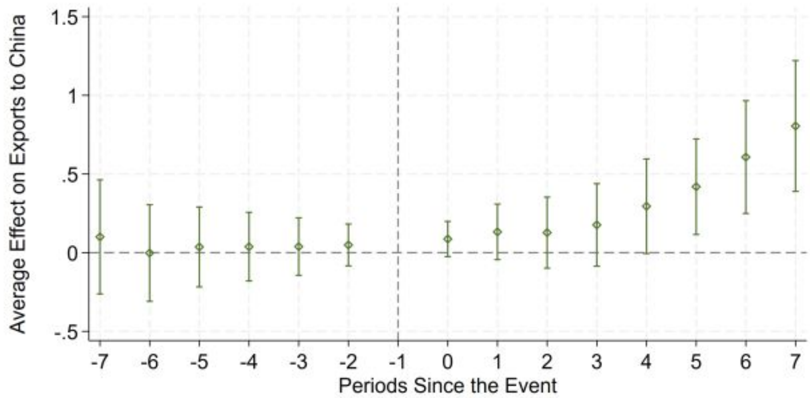


Figure 2. Effect of the BRI on Exports to China: Event Study Estimates

Note: This figure shows the average treatment effect of the BRI on exports to China, using event study estimation with country fixed effects and year fixed effects. The bars represent 95% confidence intervals, and standard errors are clustered at the country level. Additionally, the year before the policy implementation is set as the reference year.

treatment. From the fourth post-treatment year onward, the estimated coefficients become statistically significant. This implies that, compared to non-BRI countries, BRI member countries increased their exports to China four years after their participation in the BRI. The positive effect grows from around 40% in the fifth period to around 80% in the seventh period, showing a substantial effect in size.

Further, we extend the simple event study model to a staggered DID model and present the results in Figure 3. The findings are consistent with those from the event study analysis, i.e., the pre-treatment parallel trend and a positive and significant effect a few years after the BRI participation. Note that the estimate for $l \geq 0$ is the weighted average of the difference between the outcome variable in periods -1 (the reference period) and l, as in the standard DID, whereas the estimate for $l \leq -1$ indicates the corresponding difference between periods $l - 1$ and l, following Callaway and Sant'Anna (2021). The similarities between the results from the simple event study and staggered DID models imply that the size of the effect of participation in the BRI on exports to China is relatively homogeneous across participation years.

5.2 Spatial DID estimates

In this subsection, we present the direct effect of the BRI, estimated using the SAC model represented by Equation (2), which accounts for spatial autocorrelation in both exports and the error term. Two types of spatial weight matrices are employed: the inverse geographic distance matrix and the economic distance matrix constructed using the share of manufacturing output in GDP (Equation (5)). Additionally, we use the SDM model specified in Equation (4) to control for spatial autocorrelation in both exports and the BRI participation status.

The results are shown in Figure 4. Panel (a) presents the estimation results based on the geographic distance matrix, while panel (b) shows the results based on the manufacturing share matrix. In both figures, the blue line represents the SAC model, and the red line represents the SDM model. All four estimation methods yield results consistent with the previous models.

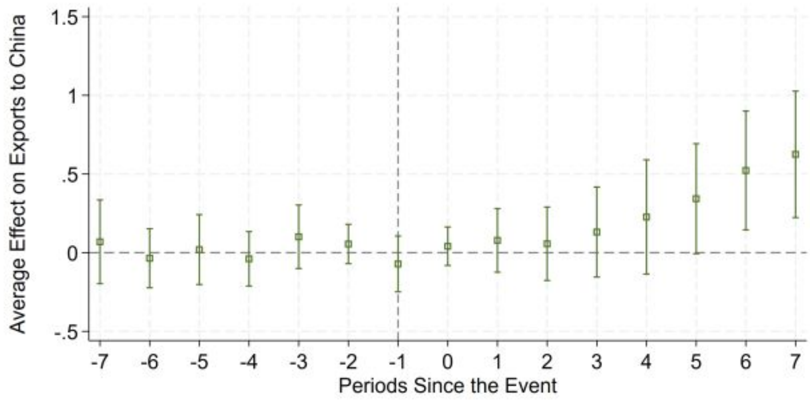


Figure 3. Effect of the BRI on Exports to China: Staggered DID Estimates

Note: This figure shows the average treatment effect of the BRI on exports to China, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

Starting from the fourth year after participating in the BRI, member countries significantly increase their exports to China.

It is worth noting that because spatial autocorrelation is considered, the estimated direct effect here include not only the "pure policy effect" of the BRI itself but also "feedback effects" from other countries. For example, after a country joins the BRI, it may exert a negative indirect effect on structurally similar countries, reducing their exports to China. This reduction in exports from similar countries can, in turn, reinforce the focal country's exports to China, further amplifying the direct effect. Consequently, the estimated coefficients here are slightly larger than those from the event study and staggered DID models shown in Figures 2 and 3.

6 Mechanisms of the direct effect

Given the positive direct effect of the BRI on exports to China, we now explore the channels through which the direct effect is generated. In particular, we focus on improvements in infrastructure, institutional quality, and political relationships with China as potential channels, as we argued in Section 2.1. Specifically, we first estimate the following equation to test whether the BRI has an impact on each of the mechanism variables.

$$Mechanism_{it} = \sum_{l} \beta_l D_{it}^{l} + \mu_i + \lambda_t + \epsilon_{it} \tag{8}$$

We reply on the staggered DID model to estimate Equation (8) because the direct effect estimated from spatial DID models include feedback effects. These are not entirely equivalent to the "pure direct effect" of the treatment group, which could lead to confusion and make the mechanism analysis results difficult to interpret. We then incorporate each of these mechanism variables into the original regression equation and estimate the following equation using the

(a) Using Geographic Distance

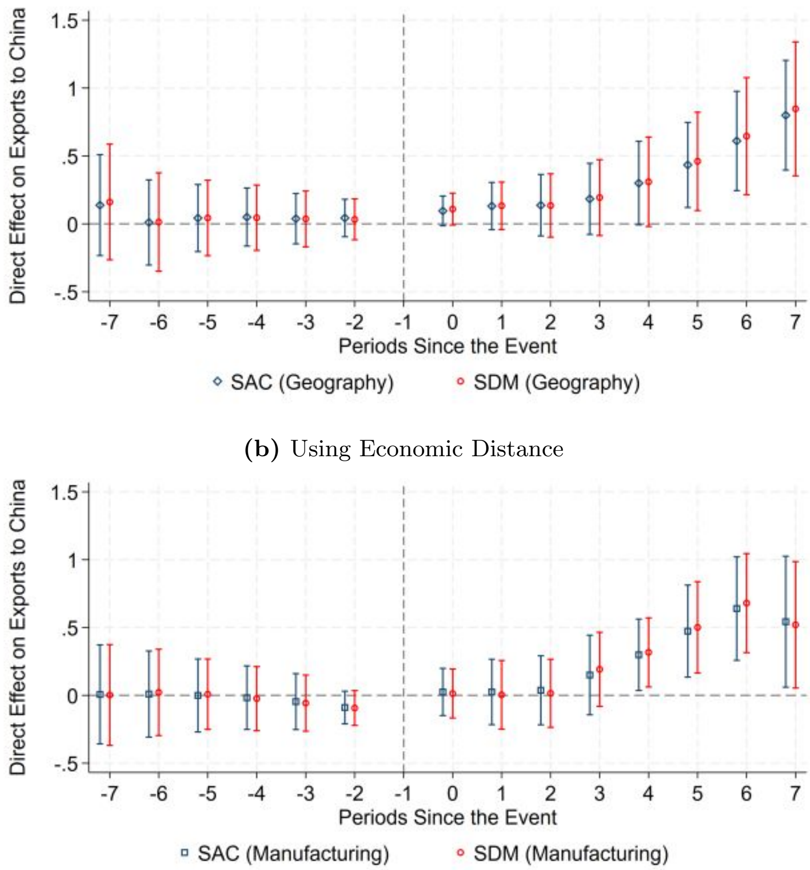


Figure 4. Effect of the BRI on Exports to China: Spatial DID Estimates

Note: This figure shows the direct effect of the BRI on exports to China, using spatial DID estimation with country fixed effects and year fixed effects. Panel (a) presents the estimation results based on the geographic weight matrix. Panel (b) shows the estimation results based on the manufacturing structure weight matrix. The blue (red) dots and lines indicate the results of SAC estimation (SDM estimation). The bars represent 95% confidence intervals, and standard errors are clustered at the country level. Additionally, the year before the policy implementation is set as the reference year.

staggered DID:

$$\log(Export_{it}) = \sum_{l} \beta_l D_{it}^l + Mechanism_{it} + \mu_i + \lambda_t + \epsilon_{it} \tag{9}$$

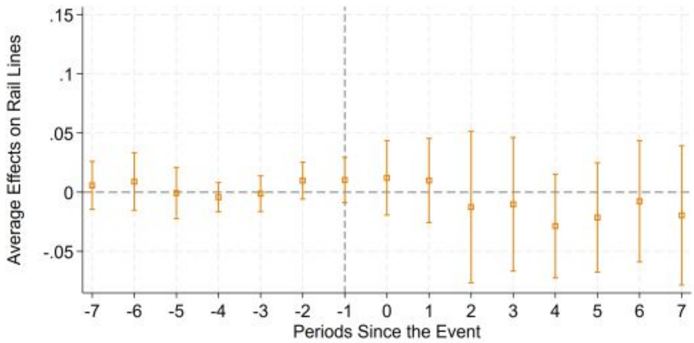
If β_l estimated from Equation (9) becomes smaller than its original estimate from Equation (1), we conclude that part of the direct effect of the BRI comes through the BRI effect on the added mechanism variable and thus that the mechanism variable is a channel of the positive direct effect, based on the standard mediation analysis (Celli, 2022), .

6.1 Infrastructure

First, we examine the infrastructure channel as a potential mechanism. We use rail lines as an indicator of transportation infrastructure, and the number of broadband subscriptions as an indicator of digital infrastructure for the mechanism analysis.

Figure 5 presents the impact of the BRI on infrastructure. The results in Panel (a) show no significant effect of the BRI on a country's rail lines, while those in Panel (b) suggest that the BRI significantly improved digital infrastructure in member countries. However, the finding for broadband subscriptions should be treated with caution due to a violation of the parallel trends assumption prior to the policy implementation.

(a) Effect on Rail Lines



(b) Effect on Broadband Subscriptions

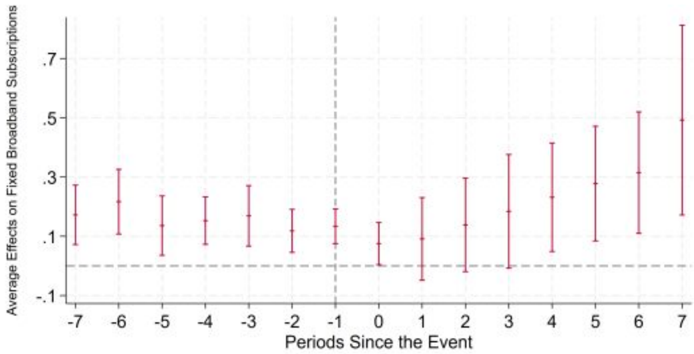
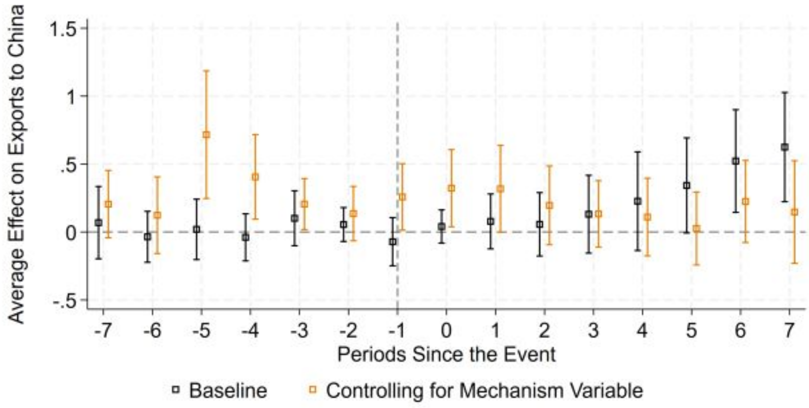


Figure 5. Effect of the BRI on Infrastructure

Note: These figures show the average treatment effect of the BRI on rail lines(a) and broadband subscriptions(b), using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

Next, based on Equation (9), we incorporate each of the two mechanism variables into the regression and present the coefficients β_l in Figure 6. In the figure, the black line represents the estimated effect of the BRI on exports to China without controlling for any mechanism variables, whereas the colored lines are that with controls. We find that after including rail lines (Panel a) and broadband subscriptions (Panel b), the coefficients in periods 6 and 7 become smaller and statistically insignificant. This result suggests that the positive effect of the BRI on exports to China previously found is absorbed by the effect of infrastructure on exports, indicating that improvements in infrastructure by the BRI could be one of the channels through which the BRI promotes exports. Although this result provides some support for infrastructure as a potential mechanism through which the BRI affects exports, it should be interpreted with caution given the previously mentioned pre-existing differences in infrastructure development.

(a) Controlling for Rail Lines



(b) Controlling for Broadband Subscriptions

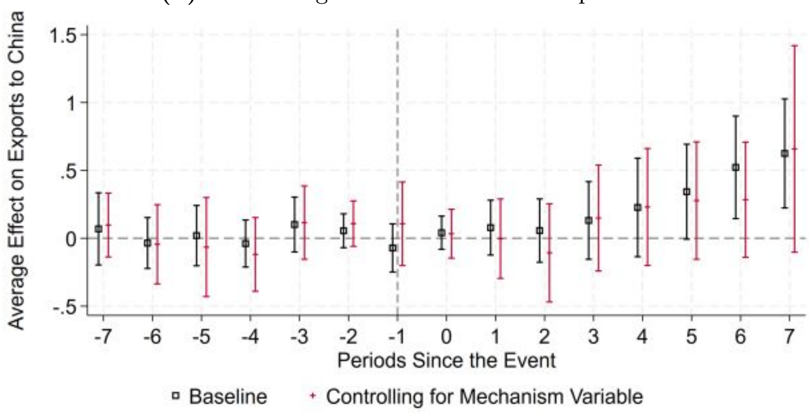


Figure 6. Effect of the BRI on Exports After Controlling for Infrastructure Variables

Note: These figures illustrate the estimated effect of the BRI on exports to China after including each infrastructure-related mechanism variable—rail lines (a) and broadband subscriptions (b)—in the regression. The estimation uses the staggered DID approach proposed by Callaway and Sant'Anna, with country and year fixed effects included. The bars indicate 95% confidence intervals, and standard errors are clustered at the country level.

6.2 Institutional quality

In addition, we use the rule of law index and corruption index to measure a country's governance quality, allowing us to examine whether the BRI promotes exports to China by improving the institutional quality of member countries.

As shown in Figure 7, the BRI significantly improves the rule of law index in member countries. This may reflect the BRI's role in fostering cooperation between member countries and China in legal systems and policy frameworks. For example, the BRI encourages member countries to enhance trade- and investment-related legal frameworks. Next, we examine whether the two institutional quality indicators are mechanism of the effect of the BRI on exports to China using the same procedure above and present the results in Figure 8. We find that the estimated coefficients of the BRI remain statistically significant, and their magnitudes are even larger than those in the baseline regression.

In addition to the index of the rule of law, we utilize the (inverse) index of corruption to measure the institutional quality and find results similar to those using the index of the rule of

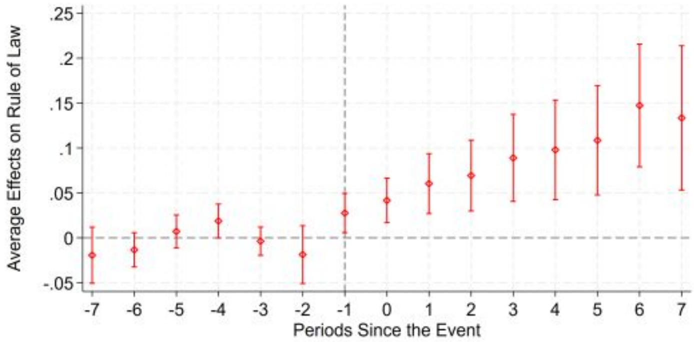


Figure 7. Effect of the BRI on the Rule of Law

Note: These figures show the average treatment effect of the BRI on the index of rule of law, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

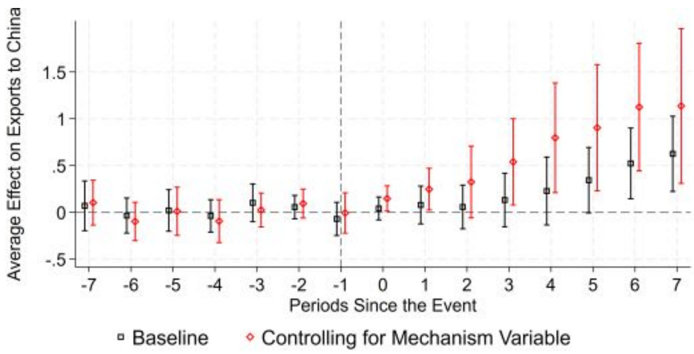


Figure 8. Effect of the BRI on Exports After Controlling for the Rule of Law Index

Note: This figure shows the estimated effect of the BRI on exports to China after controlling for the index of rule of law in the regression model. The estimation uses the staggered DID method proposed by Callaway and Sant'Anna, including country and year fixed effects. The bars represent 95% confidence intervals, with standard errors clustered at the country level.

law (Appendix Figures A2 and A3). Although participation in the BRI has a positive effect on the corruption level, the inclusion of the corruption index does not lead to lower coefficients of the BRI.

These results suggest that although the BRI does improve the institutional quality of member countries, such improvements do not appear to significantly contribute to the promotion of exports to China in this context. One possible explanation is that institutional quality may not be a decisive factor in trade with China. Benáček et al. (2014), for example, found that for some countries, FDI is more influenced by productivity and infrastructure than by institutional quality or political stability. This reasoning may also apply to bilateral trade under the BRI framework, where China often prioritizes economic complementarity and cooperation potential over the institutional quality of its partner countries.

6.3 Effect of the BRI on exports to countries other than China

The previous subsections found that improvements in infrastructure may be a possible mechanism of the effect of the BRI on exports to China. To further explore the possibility, we examine the effect of a country's participation in the BRI on its exports to countries other than China. If the improvement in infrastructure due to the BRI promote exports to China, it is most likely to increase exports to other countries as well.

The results using the staggered DID of Callaway and Sant'Anna (2021) that correspond to the results in Figure 3 and those using two types of the Spatial Durbin Model that correspond to Panel (b) of Figure 4 are presented in Figure 9. It is shown that the effect of a country's participation in the BRI on exports to countries other than China is positive, significant in many periods after the participation, and increasing over time. This finding suggests that the BRI not only enhances the bilateral trade capacity of member countries with China but also expands their overall export capacity to global markets. This improvement in export capacity may be associated with infrastructure development or other member country-level improvements facilitated by the BRI.

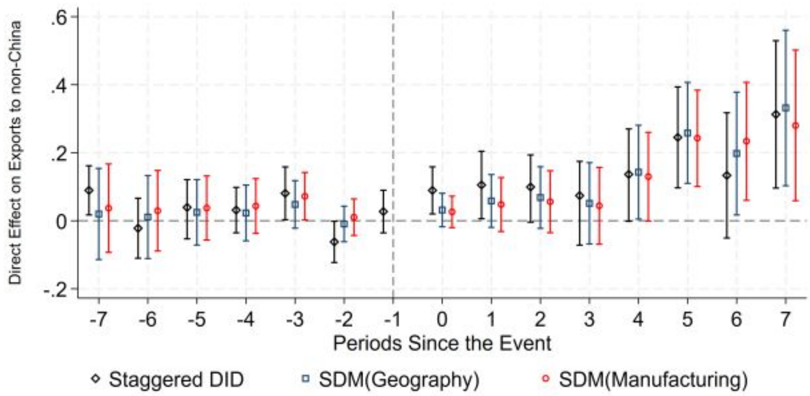


Figure 9. Effect of the BRI on Exports to non-China Countries

Note: This figure shows the direct effect of the BRI on exports to non-China countries, using both staggered DID and spatial DID estimation with country fixed effects and year fixed effects. The black dots and lines indicate the results of staggered DID estimation. The blue (red) dots and lines indicate the results of SDM estimation using the geographic distance matrix (manufacturing economic distance matrix). The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

6.4 Political relationships

Lastly, we investigate whether enhanced political relationships with China constitute a potential channel through which the BRI facilitates export growth. Political ties are measured by the level of diplomatic relationships and the increase in the number of sister cities with China.

As shown in Figure 10, the BRI significantly elevates the level of diplomatic relations, suggesting that the BRI strengthens cooperation at both the local government level and the official state-to-state level. Further, we incorporate the variable for the diplomatic relationships with China into the regression and present the results in Figure 11. After controlling for the potential mechanism variable, the coefficients of the BRI on exports remain largely unchanged. When we utilize the number of sister cities as an alternative measure of the diplomatic relationships, we find similar results as shown in Appendix Figures A4 and A5. These results suggest that, while the BRI significantly enhances political ties between member countries and China, such ties do not appear to serve as direct mediating channels in promoting exports.

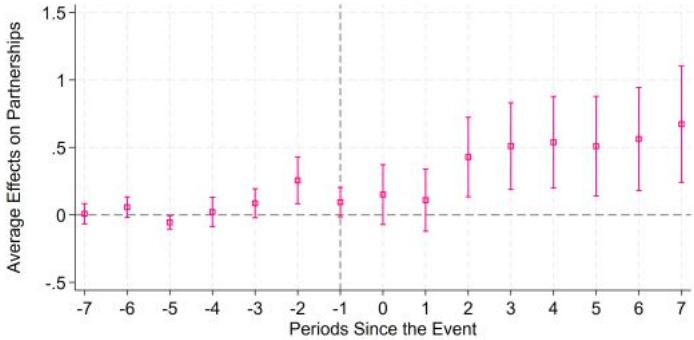


Figure 10. Effect of the BRI on the Diplomatic Relationships

Note: These figures show the average treatment effect of the BRI on the categorical variable from 0 to 6 that measures diplomatic relationships with China, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

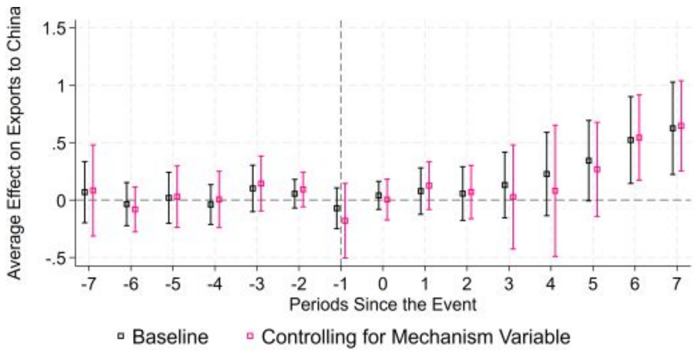


Figure 11. Effect of the BRI on Exports After Controlling for Diplomatic Relationships

Note: These figures show the estimated effect of the BRI on exports to China after controlling for two political connection variables—sister-city relationships (a) and diplomatic relations (b). The estimation is based on the staggered DID method proposed by Callaway and Sant'Anna, with country and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

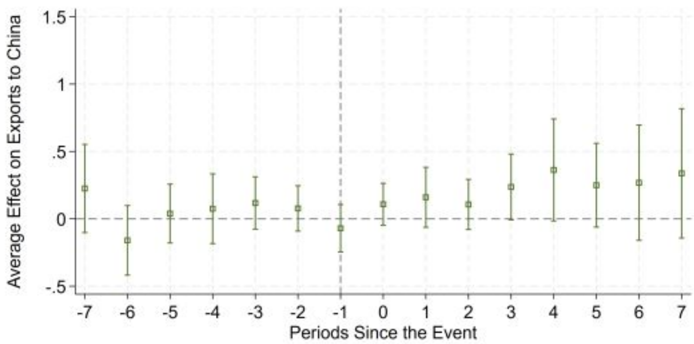
7 Heterogeneity of the direct effect

We further examine the heterogeneity of the direct effect of the BRI from three perspectives: the level of political ties with China; the level of economic ties with China; and different product categories.

7.1 Political relationships

First, we divide the sample into two sub-samples according to a measure of political ties, or the level of diplomatic relationships. Specifically, we classify countries by whether a country had established a "general partnership" (see Appendix A for the definition) or higher-level diplomatic relationship with China prior to signing an MOU. The list of countries for each group are presented in Appendix Table A2. Panels (a) and (b) of Figure 12 present the results for countries with higher and lower diplomatic relationships with China prior to the BRI, respectively. Participation in the BRI does not significantly increase exports to China from countries with strong political ties with China but significantly increases exports from countries with prior weak political ties with China.

(a) Countries with Stronger Diplomatic Relationships with China



(b) Countries with Weaker Diplomatic Relationships with China

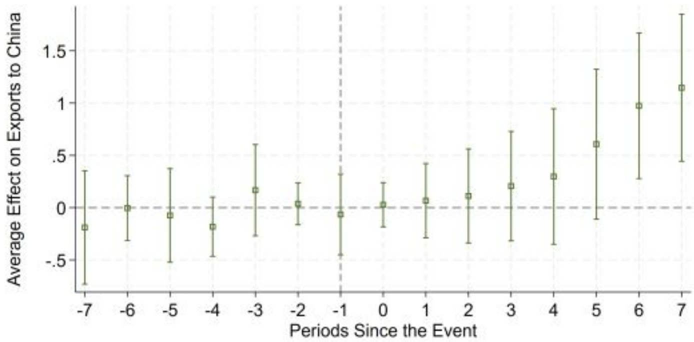


Figure 12. Heterogeneity of the Direct Effect by Diplomatic Relationship with China

Note: These figures show the average treatment effect of the BRI on exports to China, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. Panel (a) shows the results for countries that had established a general partnership or higher-level diplomatic relationship with China before signing an MOU. Panel (b) presents the results for countries without such a diplomatic relationship. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

Alternatively, we employ the number of sister cities between the focal country and China to measure the level of political ties with China and divide countries into two depending on whether a country has any sister-city relationship with China or not. The list of countries for each sub-sample is presented in Appendix Table A1, whereas the results are illustrated by Appendix Figure A6. Using this alternative criteria, we find the effect of the BRI is significantly positive for countries with any sister-city relationship with China while it is not significant otherwise.

These results suggest that the BRI particularly promotes exports to China from countries that were only weakly linked with China politically before the BRI. This is probably because exports from these countries were suppressed due to the lack of political ties with China but boosted once they participated in the BRI and strengthened their political ties (Figure 10). By contrast, countries that already had close political relationships with China, the marginal effect of the BRI on political connectivity and thus on exports may be limited. This is similar to the convergence effect where poor countries tend to increase their GDP faster than richer countries.

7.2 Economic relationships

Next, we examine the heterogeneity in the effect of the BRI based on countries' pre-existing economic relationships with China. These ties are measured by whether a country has an FTA or RTA with China prior to the MOU. The list of countries in each group is presented in Appendix Table A3. We apply the same staggered DID estimation to each group for this heterogeneity analysis.

The results presented in Figure 13 show that the BRI promotes exports to China from both groups of countries. Although the positive effect of the BRI on exports from countries that had signed FTAs or RTAs with China is observed at an earlier stage (starting from the fourth period after implementation) and larger than the effect on exports from countries without any FTA or RTA with China, the difference between countries with and without prior FTA relationships is not substantial.

Therefore, although we find that for countries without prior political ties to China, the BRI acts as a platform to boost their exports to China more than for those with political ties, whether countries had prior FTA relationships with China do not influence the BRI effect. The result on FTAs may be attributed to the fact that existing FTAs help reduce transaction barriers, enlarge the effect of the BRI later, and offset the convergence effect.

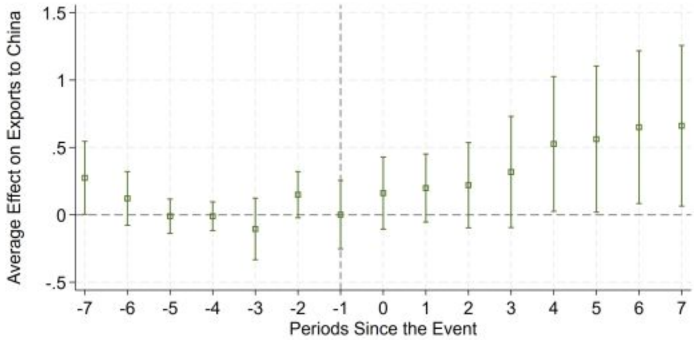
7.3 Product categories

Finally, We also examine the direct effect of the BRI on exports to China across different product categories. We aggregate all 97 product categories at the HS 2-digit level into 21, following World Customs Organization (2024). The list of categories and descriptive statistics of exports in each category are presented in Appendix Table A4.

We present results for selected three product categories, chemical products, base metal products, and textiles, for which the effect is clearly significant, in Figure 14, while results for other categories in Appendix Figures A7-A9.

A possible explanation to the positive effect on exports of the three categories, particularly, base metal products and textiles, is the comparative advantages of BRI member countries. Many BRI member countries are rich in natural resources, and their participation in the BRI has enabled them to export raw materials to China, fostering industrial complementarity. In addition, some BRI countries benefit from relatively low labor costs. As labor costs in China have risen, the country has gradually shifted parts of its low-end manufacturing, such as the textile industry, to other countries. This helps explain the observed increase in textile exports to China following BRI participation.

(a) Countries with FTA/RTA



(b) Countries without FTA/RTA

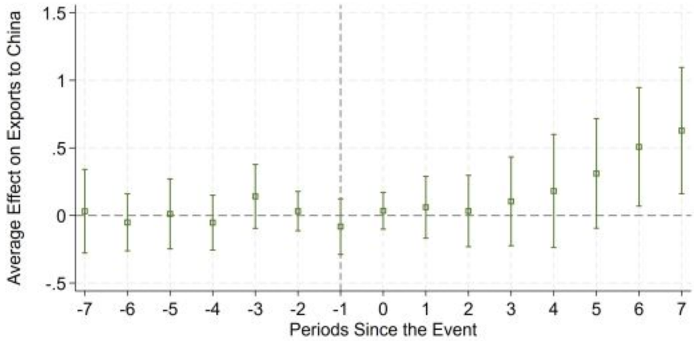


Figure 13. Heterogeneity of the Direct Effect by FTA/RTA with China

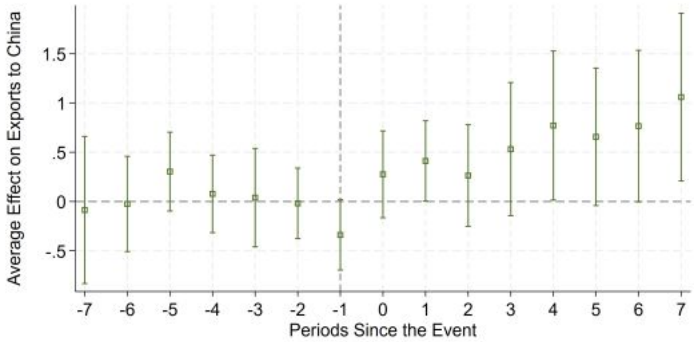
Note: These figures show the average treatment effect of the BRI on exports to China, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. Panel (a) presents the results for countries that had signed FTA/RTA with China prior to the MOU, while Panel (b) shows the results for countries that had not signed any such agreements. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

Another possible factor of the positive effects on exports of the three is China's strong demand for these products. China's high economic growth has boosted demand for industrial materials including base metals, leading China to be the world's largest importer of raw metals (Perger, 2022). In addition, Hong et al. (2019) pointed out that as China's economic policy has shifted from investment-driven to consumption-driven growth, consumer preferences have moved toward more diverse and sophisticated goods, such as high-end personal care products including chemical products. In addition, key strategic industries supported by the Chinese government, such as aerospace, electric vehicles, and battery manufacturing, heavily rely on chemical inputs.

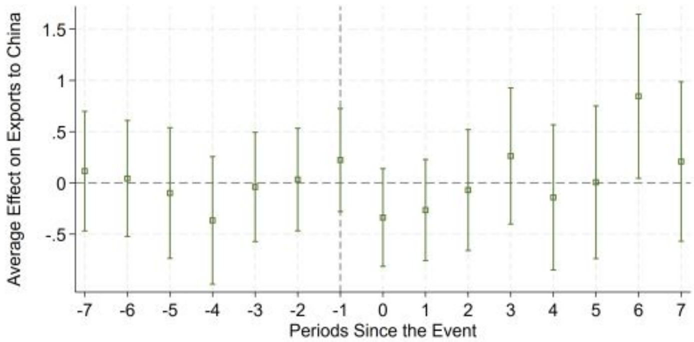
In other product groups, although we observe a statistically significant effect in certain periods for groups such as animal and animal products, plastics and rubber, construction and glass products, transportation equipment, precision instruments, and miscellaneous manufactures (Figure A7), the coefficients tend to fluctuate around zero. These effects may not be directly attributable to the BRI and should therefore be interpreted with caution.

For the remaining 12 product groups, we do not find any significant effect (Figure A8 and Figure A9). This lack of significance may be due to the relatively small scale of some products, such as precious metals and jewelry or art and antiques, which limits the scope for BRI to have a measurable impact. Another possible explanation is that the benefits of infrastructure improvements are more immediately realized in bulk commodities, such as metals and chemicals, that are heavily dependent on transport conditions. In contrast, sectors involving high value-added or processed products may require longer-term cooperation, and the effects on exports may not yet be observable in the short run.

(a) Chemicals



(b) Base Metals and Articles of Base Metal



(c) Textiles

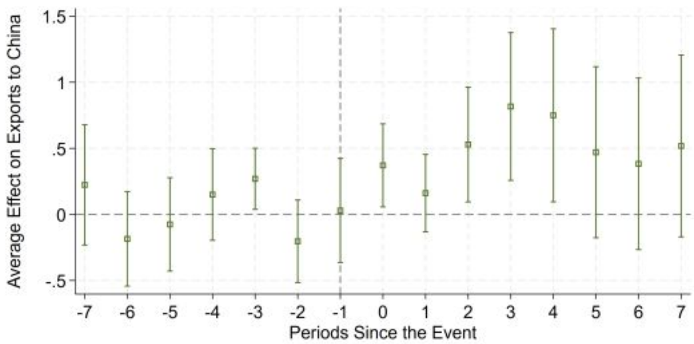


Figure 14. Heterogeneity of the Direct Effect Across Product Categories (1)

Note: This figure presents the estimated direct effects of the BRI on exports to China across three product categories—chemicals, base metals, and textiles—using staggered DID estimation (Callaway and Sant'Anna method). All regressions include country and year fixed effects. The bars represent 95% confidence intervals, with standard errors clustered at the country level.

8 Results of the Indirect Effect

This section explores the indirect effect of a country's participation in the BRI on exports from other countries to China. For this purpose, we rely on the SDM in Equation (4) that has an advantage over the SAC model in Equation (2), because the SDM incorporates feedback effects from other countries by including exports from others in the set of independent variables and calculates the total indirect effect by Equation (7).

8.1 Indirect effect based on geographic distance

We begin by constructing an inverse distance matrix based on the geographic distances between national capitals to analyze the role of geographic proximity in the BRI's indirect effect. The results shown in Figure 15 indicate no evidence that the BRI generates a significant indirect effect on exports to China from countries geographically close to BRI member countries. This indicates that while BRI member countries increase their exports to China, the BRI does not enhance the export capacity of geographic neighbor countries.

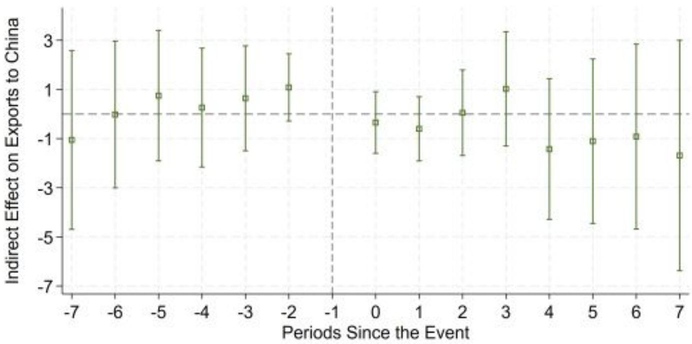


Figure 15. Indirect Effect of the BRI on Geographic Neighbor Countries

Note: This figure shows the effect of the BRI on exports to China for countries geographically close to member countries, using the SDM with country and year fixed effects. The bars represent 95% confidence intervals, and standard errors are clustered at the country level. The year before the policy implementation is set as the reference year.

In Section 2.2, we proposed that the BRI might have a positive indirect effect on geographically proximate countries through infrastructure development in BRI countries. However, we did not find evidence supporting this hypothesis. The lack of any significant indirect effect may stem from the BRI's focus on bilateral cooperation between member countries and China, rather than regional coordination. The BRI primarily emphasizes bilateral collaboration, particularly in infrastructure investment and policy alignment. Most BRI projects are designed to enhance direct connectivity between member countries and China, rather than fostering multilateral coordination across the broader region. This approach limits the participation of neighboring countries in the trade networks built through the BRI, preventing them from reaping its benefits.

8.2 Indirect effect based on economic distance

Next, we construct an economic distance matrix using the share of manufacturing in GDP, as presented by Equation (5). Countries with comparable manufacturing shares typically have similar capital-labor ratios and technological levels, resulting in the production and export of similar industrial goods and their competitive relationships in exports to China (Section 2.2).

The results in Figure 16 show a significant negative effect, indicating that while the BRI promotes member countries' exports to China, it simultaneously lowers exports of non-member countries with a manufacturing share similar to member countries.

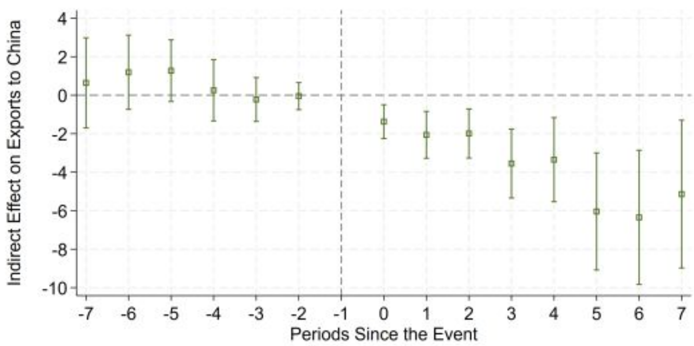


Figure 16. Indirect Effect of the BRI on Economically Similar Countries

Note: This figure shows the effect of the BRI on exports to China for countries with the industry structure similar to member countries, using the SDM estimation with country and year fixed effects. The bars represent 95% confidence intervals, and standard errors are clustered at the country level. The year before the policy implementation is set as the reference year.

This negative effect likely arises because member countries participating in the BRI reduce trade costs and improve trade efficiency, thereby enhancing their export competitiveness. Their export products may directly compete with those of non-member countries, leading to a loss of market share for the latter. Additionally, the BRI fosters supply chain integration between China and member countries. As a result, China may increasingly prefer to import manufactured goods from member countries, reducing demand for similar goods from non-member countries and further exacerbating their export losses.

The magnitude of the indirect effect is quite large, because it depends on the product of two matrices shown in Equation (7). The large effect may result from an overestimated ρ (-1.38), whereas its reasonable range is between -1 and 1 (LeSage and Pace, 2009). One possible reason for this overestimation is the inclusion of an extended event-study window (14 periods before and 11 after policy implementation). Because ρ is estimated via Maximum Likelihood Estimation (MLE), an excessive number of independent variables and their lags may lead to overestimation as the model seeks to fit the data more closely. This inflated ρ accumulates and amplifies the indirect effect through the spatial transmission matrix.

Therefore, as an alternative specification, we shorten the event-study window to 14 periods (7 years before and after BRI) and 10 periods (5 years before and after). Under these specifications, the estimated ρ values are -0.98 and -0.86, both within a reasonable range. The results of the shortened window are presented in the Appendix Figure A11, where we find a similar negative indirect effect, and the estimated coefficients around -2. This suggests that the significantly negative impact of the BRI on exports to China from economic neighbor countries to BRI members is robust to these alternative specifications, although the size of the impact varies.

We also find indirect evidence in the analysis of the effect of the BRI on exports from non-members to non-China countries. Using the matrix based on the share of manufacturing in GDP, we analyze the indirect effect of the BRI on exports to non-China countries. The results shown in Appendix Figure A12 indicate that the BRI increases exports to non-China from countries with manufacturing structures similar to those of member countries. This positive indirect effect arises possibly because those similar countries lose the market share in China and thus are encouraged to redirect their exports to other markets.

9 Conclusion

This study explores the direct and indirect effect of the Belt and Road Initiative (BRI) on exports to China. Using a combination of event study, staggered DID, and spatial econometric models, we provide the following robust evidence of the BRI's impact and delve into the mechanisms behind these effects.

First, we find that participation in the BRI significantly increases member countries' exports to China and to other countries. Mechanism analysis finds weak evidence showing that improvements in infrastructure are the primary driver of this direct effect. In the heterogeneity analysis, we observe that the BRI serves as a platform to foster new cooperative relationships, particularly benefiting countries that had not established strong political ties with China prior to joining. At the product level, we find that the BRI has a particularly positive impact on exports of chemicals, basic metals, and textiles.

Second, the analysis of the indirect effect using spatial econometric models reveals that the BRI does not generate a significant indirect effect on exports to China from geographically neighbors to BRI members. This lack of impact reflects the bilateral nature of the BRI's design, which prioritizes direct connectivity between member countries and China rather than fostering broader regional integration. In contrast, countries with a manufacturing share similar to BRI members lower exports to China, as enhanced export competitiveness of BRI members leads to a crowding-out effect.

Overall, our findings highlight the multifaceted impacts of the BRI on global trade. While the BRI successfully enhances member countries' export capacity to China, the effects are uneven across regions and sectors. The results emphasize the need for more comprehensive regional cooperation to extend the benefits of the BRI beyond bilateral relationships. Additionally, policymakers should consider strategies to address the competitive pressures faced by non-member countries and promote more inclusive trade networks under the BRI framework. In conclusion, this study contributes to the growing literature on the BRI and provides new insights into the spatial and economic dynamics of global trade.

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A Appendix

Definition of diplomatic relationships

We construct a categorical variable from zero to six that indicates the levels of diplomatic relationships with China using the data from Ministry of Foreign Affairs of the People's Republic of China (2024) and following the definition of Xiang (2023). We categorize diplomatic partnerships into seven hierarchical types as follows: no diplomatic relations (0); diplomatic relations only (1); general partnerships (2); partnerships starting with "comprehensive" or "all-round" (3); general strategic partnerships (4); strategic partnerships starting with "comprehensive," "global," or "all-round" (5); and strategic partnerships beginning with "all-weather" or "permanent" (6).

In the definition of the categories, "partnerships" refer to general cooperation in areas such as trade and culture. And "strategic partnerships" involve more sensitive domains such as security, defense and international coordination. Terms like "comprehensive" or "all-round" suggest broader collaboration, while "all-weather" or "permanent" strategic partnerships represent the highest and most stable level of bilateral relations.

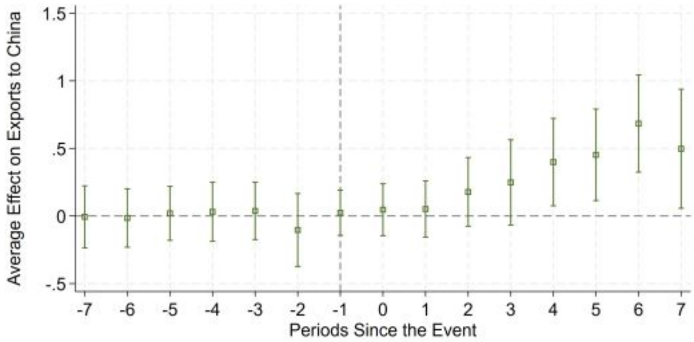


Figure A1. Staggered DID Estimates of Exports to China (Unbalanced)

Note: This figure shows the average treatment effect of the BRI on exports to China, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The analysis is based on an unbalanced panel. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

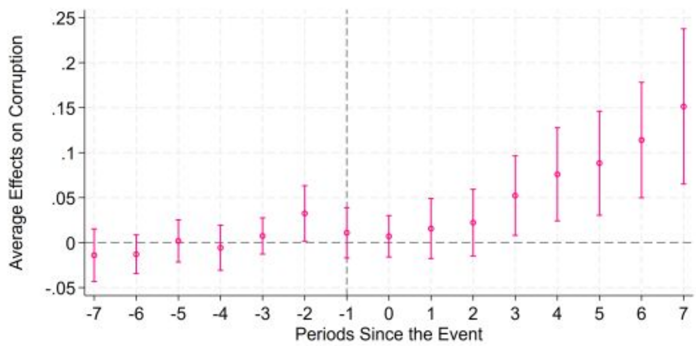


Figure A2. Effect of the BRI on Corruption Index

Note: This figure shows the average treatment effect of the BRI on the (inverse) index of corruption, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

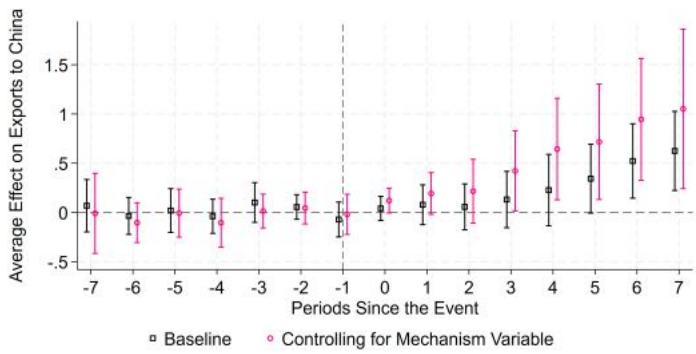


Figure A3. Effect of the BRI on Exports After Controlling for the Corruption Index

Note: This figure shows the estimated effect of the BRI on exports to China after controlling for the corruption index in the regression model. The estimation uses the staggered DID method proposed by Callaway and Sant'Anna, including country and year fixed effects. The bars represent 95% confidence intervals, with standard errors clustered at the country level.

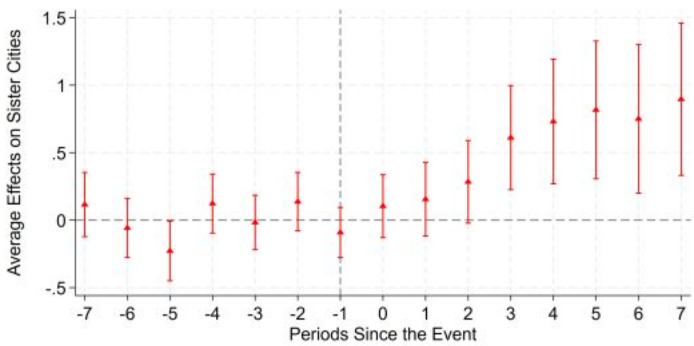


Figure A4. Effect of the BRI on the Number of Sister Cities

Note: These figures show the average treatment effect of the BRI on the number of the sister cities, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

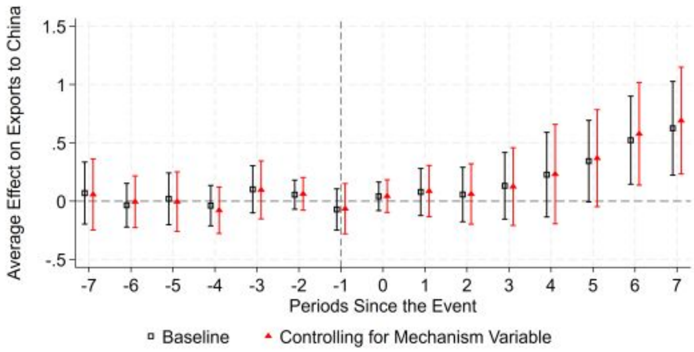
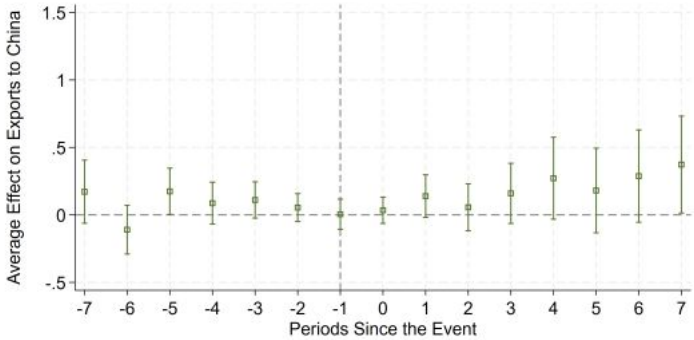


Figure A5. Effect of the BRI on Exports After Controlling for the Number of Sister Cities

Note: These figures show the estimated effect of the BRI on exports to China after controlling for the number of sister cities. The estimation is based on the staggered DID method proposed by Callaway and Sant'Anna, with country and year fixed effects included. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

(a) Countries with Sister-City Relationships



(b) Countries without Sister-City Relationships

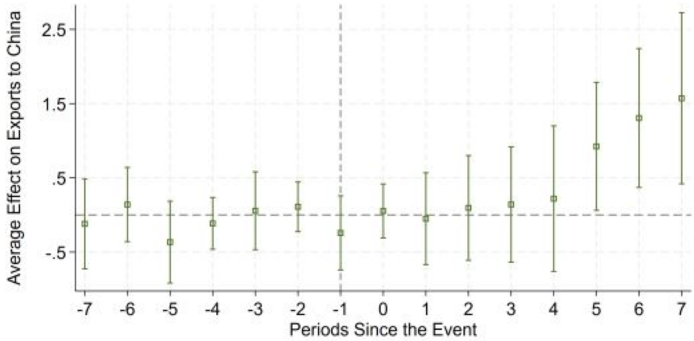
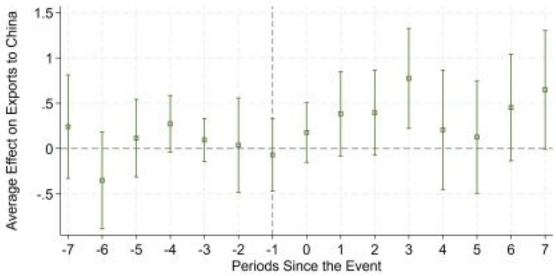


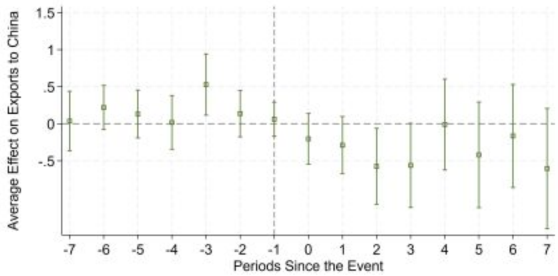
Figure A6. Heterogeneity of the Direct Effect by Sister-City Relationship with China

Note: These figures show the average treatment effect of the BRI on exports to China, using the staggered DID estimation proposed by Callaway and Sant'Anna, with country fixed effects and year fixed effects included. Panel (a) shows the subsample results for countries in a sister-city relationship with China, while Panel (b) shows the subsample results for countries not in a sister-city relationship with China. The bars represent 95% confidence intervals, and standard errors are clustered at the country level.

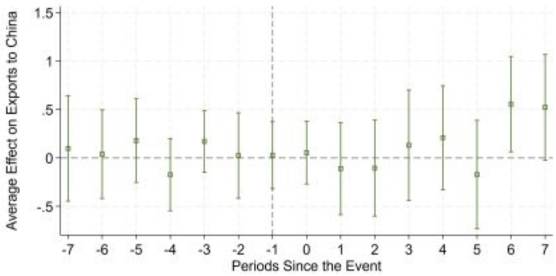
(a) Animal Products



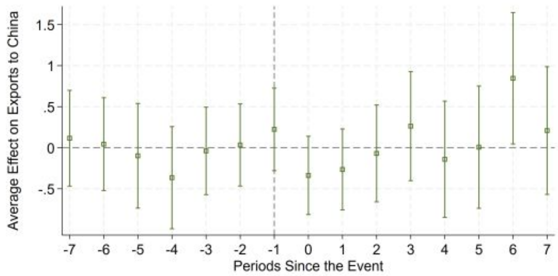
(b) Plastics and Rubber



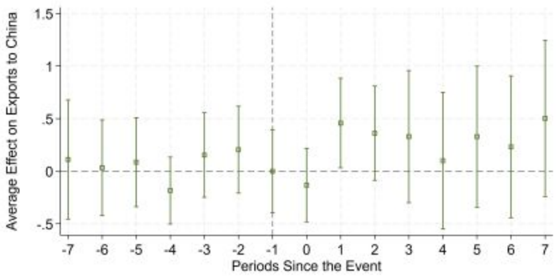
(c) Construction and Glass Products



(d) Transport Equipment



(e) Precision Instruments



(f) Miscellaneous Manufactures

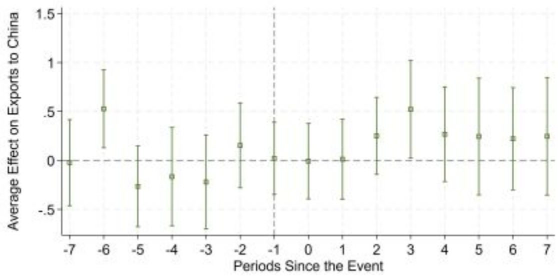
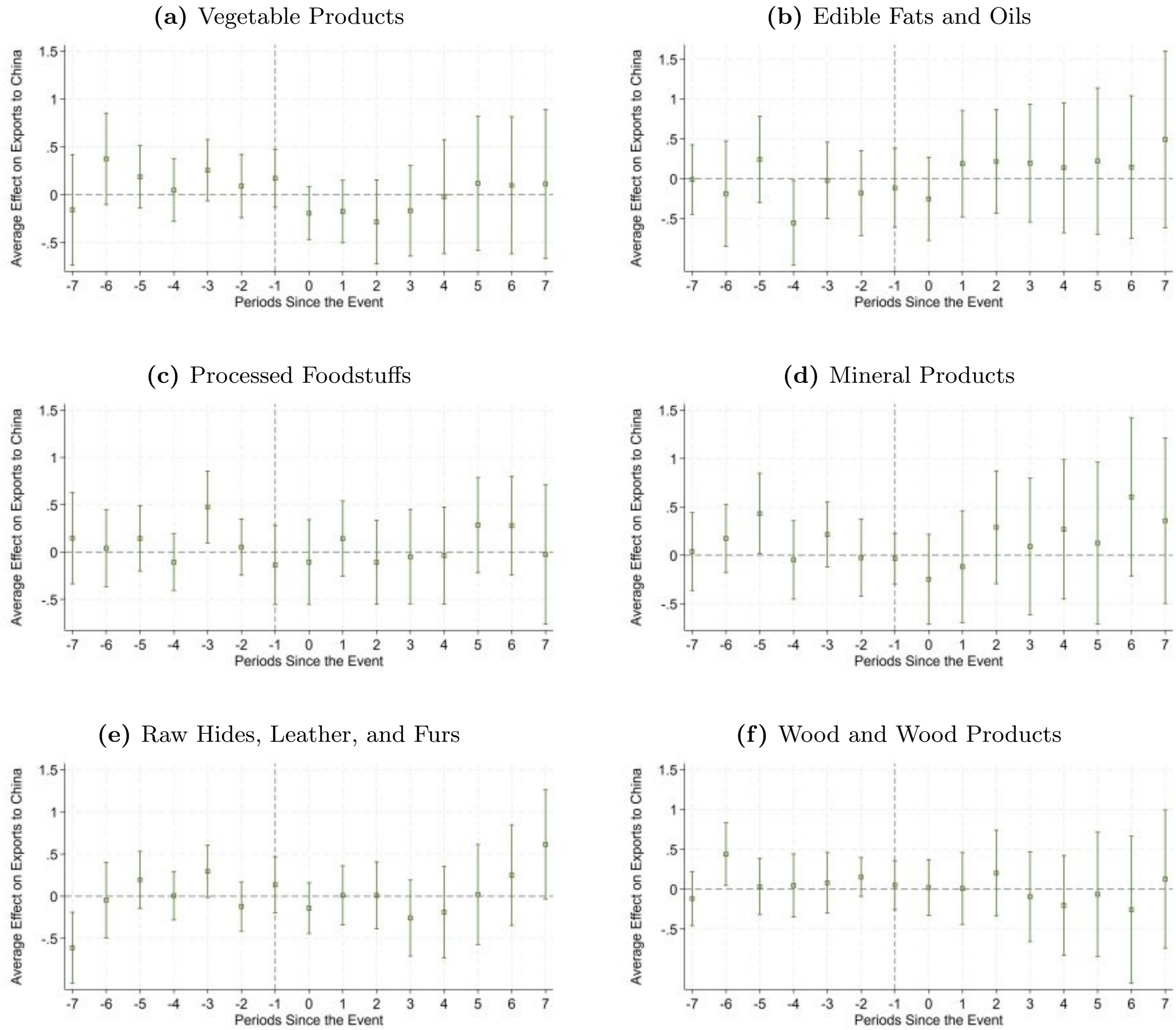


Figure A7. Heterogeneity of the Direct Effect Across Product Categories (2)

Note: These figures present the estimated direct effect of the BRI on exports to China across six product categories, based on staggered DID estimation (Callaway and Sant'Anna method). All regressions include country and year fixed effects. The bars represent 95% confidence intervals, with standard errors clustered at the country level.



(a) Vegetable Products

(b) Edible Fats and Oils

(c) Processed Foodstuffs

(d) Mineral Products

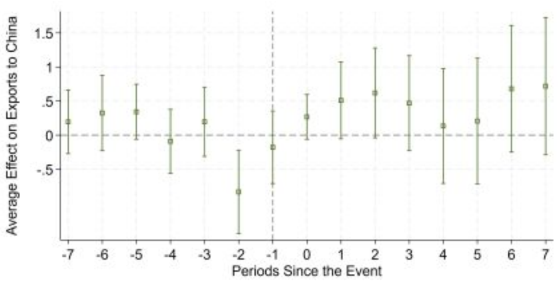
(e) Raw Hides, Leather, and Furs

(f) Wood and Wood Products

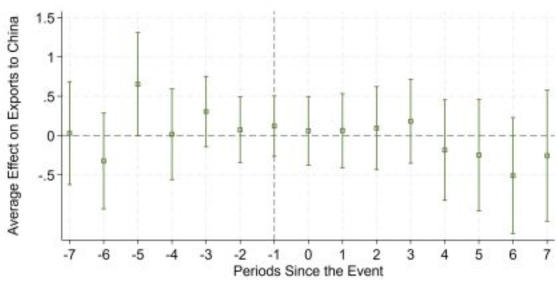
Figure A8. Heterogeneity of the Direct Effect Across Product Categories (3a)

Note: These figures show the estimated direct effect of the BRI on exports to China across selected product categories, based on staggered DID estimation (Callaway and Sant'Anna method). All regressions include country and year fixed effects.

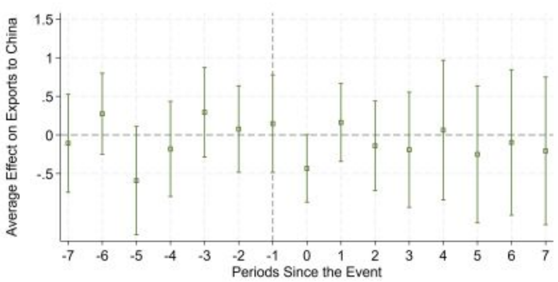
(a) Paper and Printed Materials



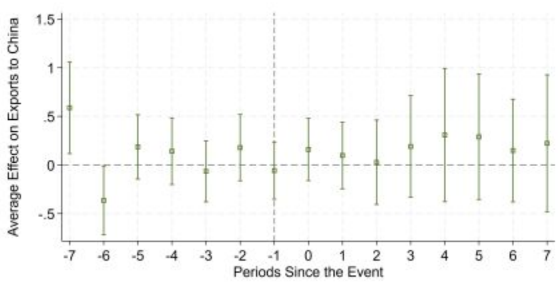
(b) Footwear and Headgear



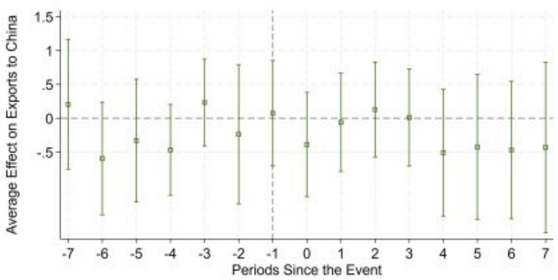
(c) Precious Metals and Jewelry



(d) Machinery and Electrical Equipment



(e) Art and Antiques



(f) Arms and Ammunition

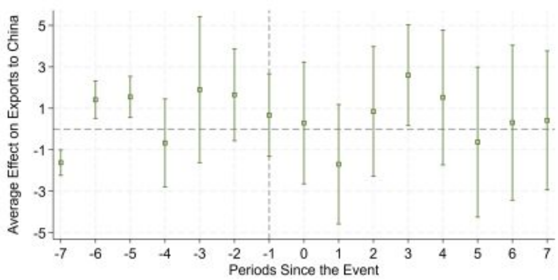


Figure A9. Heterogeneity of the Direct Effect Across Product Categories (3b)

Note: This figure continues the presentation of the estimated direct effect of the BRI across additional product categories. The same estimation strategy is applied, with country and year fixed effects included.

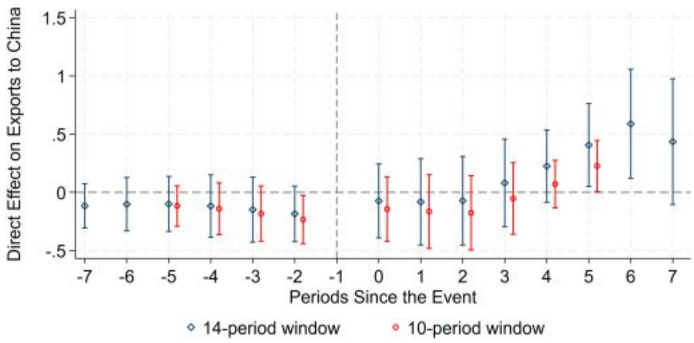


Figure A10. Direct Effect Results Based on the Manufacturing (Shorter Window Period)

Note: This figure shows the effect of the BRI on exports to China for countries with manufacturing structures similar to member countries, using spatial DID estimation (SDM) with country fixed effects and year fixed effects. The bars represent 95% confidence intervals, and standard errors are clustered at the country level. Additionally, the year before the policy implementation is set as the reference year.

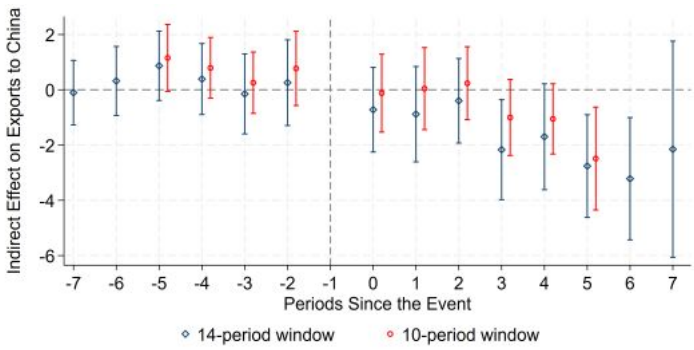


Figure A11. Indirect Effect Results Based on the Manufacturing (Shorter Window Period)

Note: This figure shows the effect of the BRI on exports to China for countries with manufacturing structures similar to member countries, using spatial DID estimation (SDM) with country fixed effects and year fixed effects. The bars represent 95% confidence intervals, and standard errors are clustered at the country level. Additionally, the year before the policy implementation is set as the reference year.

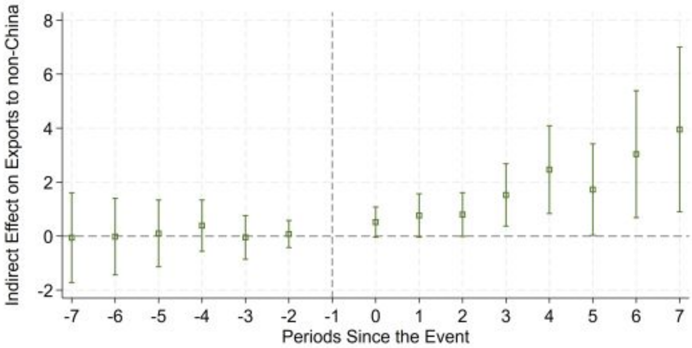


Figure A12. Indirect Effect of the BRI on Exports to non-CHN Countries

Note: This figure shows the effect of the BRI on exports to non-China destinations for countries with manufacturing structures similar to member countries, using spatial DID estimation (SDM) with country fixed effects and year fixed effects. The bars represent 95% confidence intervals, and standard errors are clustered at the country level. Additionally, the year before the policy implementation is set as the reference year.

Table A1. Country Groups by Pre-BRI Sister-City Relationships

Group	Countries
With Sister-City Relationships	Afghanistan, Albania, Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Benin, Bolivia (Plurinational State of), Bosnia Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Chad, Chile, Colombia, Congo, Costa Rica, Croatia, Cuba, Cyprus, Czechia, Côte d'Ivoire, Dem. People's Rep. of Korea, Dem. Rep. of the Congo, Denmark, Ecuador, Egypt, Ethiopia, FS Micronesia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Grenada, Guyana, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Lao People's Dem. Rep., Latvia, Lithuania, Madagascar, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nigeria, North Macedonia, Norway, Pakistan, Panama, Papua New Guinea, Peru, Philippines, Poland, Portugal, Qatar, Rep. of Korea, Romania, Russian Federation, Samoa, Serbia, Seychelles, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, State of Palestine, Sudan, Suriname, Sweden, Switzerland, Syria, Tajikistan, Thailand, Togo, Tonga, Tunisia, Turkmenistan, Türkiye, USA, Uganda, Ukraine, United Arab Emirates, United Kingdom, United Rep. of Tanzania, Uruguay, Uzbekistan, Vanuatu, Venezuela, Viet Nam, Yemen, Zambia, Zimbabwe
Without Sister-City Relationships	Andorra, Angola, Antigua and Barbuda, Bahamas, Bahrain, Barbados, Belize, Br. Virgin Isds, Central African Rep., Hong Kong SAR, Macao SAR, Cook Isds, Djibouti, Dominica, Dominican Rep., El Salvador, Equatorial Guinea, Eritrea, Estonia, Eswatini, Faeroe Isds, French Polynesia, Greenland, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Iraq, Kiribati, Kuwait, Lebanon, Lesotho, Liberia, Libya, Luxembourg, Malawi, Maldives, Marshall Isds, New Caledonia, Nicaragua, Niger, Oman, Paraguay, Rep. of Moldova, Rwanda, Saint Lucia, Saudi Arabia, Senegal, Solomon Isds, Somalia, Timor-Leste, Trinidad and Tobago

Table A2. Country Groups by Pre-BRI Diplomatic Relationships

Group	Countries
High Diplomatic Ties	Afghanistan, Algeria, Angola, Argentina, Australia, Austria, Bangladesh, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Cambodia, Canada, Chile, Colombia, Congo, Cook Isds, Croatia, Dem. Rep. of the Congo, Denmark, Djibouti, Ecuador, Egypt, Equatorial Guinea, FS Micronesia, Fiji, Finland, France, Germany, Greece, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Jordan, Kazakhstan, Lao People's Dem. Rep., Malaysia, Maldives, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Nepal, Netherlands, New Zealand, Niger, Nigeria, Pakistan, Papua New Guinea, Peru, Philippines, Poland, Portugal, Qatar, Rep. of Korea, Romania, Russian Federation, Samoa, Saudi Arabia, Senegal, Serbia, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, State of Palestine, Switzerland, Tajikistan, Thailand, Timor-Leste, Tonga, Trinidad and Tobago, Turkmenistan, Türkiye, Ukraine, United Arab Emirates, United Kingdom, Uruguay, Uzbekistan, Vanuatu, Venezuela, Viet Nam
Low Diplomatic Ties	Albania, Andorra, Antigua and Barbuda, Armenia, Azerbaijan, Bahamas, Bahrain, Barbados, Belarus, Belgium, Belize, Benin, Bolivia (Plurinational State of), Bosnia Herzegovina, Botswana, Burundi, Cameroon, Central African Rep., Chad, Costa Rica, Cuba, Cyprus, Czechia, Côte d'Ivoire, Dem. People's Rep. of Korea, Dominica, Dominican Rep., El Salvador, Eritrea, Estonia, Eswatini, Ethiopia, Gabon, Gambia, Georgia, Ghana, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iceland, Iraq, Japan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Mali, Malta, Marshall Isds, Mauritania, Mauritius, Namibia, Nicaragua, North Macedonia, Norway, Oman, Panama, Paraguay, Rep. of Moldova, Rwanda, Saint Lucia, Seychelles, Slovakia, Slovenia, Solomon Isds, Somalia, Sudan, Suriname, Sweden, Syria, Togo, Tunisia, USA, Uganda, United Rep. of Tanzania, Yemen, Zambia, Zimbabwe

Table A3. Country Groups by Pre-BRI FTA/RTA Status

Group	**Countries**
With FTA/RTA Signed Before BRI	Australia, Brunei Darussalam, Cambodia, Chile, Hong Kong SAR, Macao SAR, Costa Rica, Iceland, India, Indonesia, Japan, Lao People's Dem. Rep., Malaysia, Mauritius, Myanmar, New Zealand, Pakistan, Peru, Philippines, Rep. of Korea, Singapore, Switzerland, Thailand, Viet Nam
Without FTA/RTA Before BRI	Afghanistan, Albania, Algeria, Andorra, Angola, Antigua and Barbuda, Argentina, Armenia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bolivia (Plurinational State of), Bosnia Herzegovina, Botswana, Br. Virgin Isds, Brazil, Bulgaria, Burkina Faso, Burundi, Cameroon, Canada, Central African Rep., Chad, Colombia, Congo, Cook Isds, Croatia, Cuba, Cyprus, Czechia, Côte d'Ivoire, Dem. People's Rep. of Korea, Dem. Rep. of the Congo, Denmark, Djibouti, Dominica, Dominican Rep., Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Eswatini, Ethiopia, FS Micronesia, Faeroe Isds, Fiji, Finland, France, French Polynesia, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Greenland, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hungary, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Jordan, Kazakhstan, Kenya, Kiribati, Kuwait, Kyrgyzstan, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Madagascar, Malawi, Maldives, Mali, Malta, Marshall Isds, Mauritania, Mexico, Mongolia, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Caledonia, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman, Panama, Papua New Guinea, Paraguay, Poland, Portugal, Qatar, Rep. of Moldova, Romania, Russian Federation, Rwanda, Saint Lucia, Samoa, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Slovakia, Slovenia, Solomon Isds, Somalia, South Africa, Spain, Sri Lanka, State of Palestine, Sudan, Suriname, Sweden, Syria, Tajikistan, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkmenistan, Türkiye, USA, Uganda, Ukraine, United Arab Emirates, United Kingdom, United Rep. of Tanzania, Uruguay, Uzbekistan, Vanuatu, Venezuela, Yemen, Zambia, Zimbabwe

Table A4. Descriptive Statistics of Trade by Product Categories

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Animal_products	2,187	15.102	3.722	0	23.043
Vegetable_products	2,443	14.802	4.048	0	24.536
Edible_fats_oils	1,451	13.922	4.022	2.303	22.709
Foodstuffs	2,479	14.560	4.145	1.386	22.017
Mineral_products	2,700	17.724	4.354	1.099	25.632
Chemicals	2,661	14.984	5.233	0	23.980
Plastics_rubbers	2,835	14.253	4.973	0	23.437
Hides_leather_furs	2,400	13.925	4.006	1.609	21.962
Wood_products	2,470	14.514	4.326	0	22.269
Paper_printed_materials	2,371	12.787	5.137	0	22.571
Textiles	2,789	14.789	4.364	0.693	22.396
Footwear_headgear	2,037	11.307	4.317	0	21.800
Construction_glass	2,120	11.985	4.768	0	21.809
Precious_metals_jewelry	1,979	13.035	4.764	0	24.368
Basic_metals	2,947	15.621	4.841	0	23.972
Machinery_electrical	3,231	13.815	5.309	1.609	25.614
Transport_equipment	2,152	12.815	5.540	0.693	24.186
Precision_instruments	2,506	13.018	5.285	0.693	23.953
Arms_ammunition	318	9.657	3.467	1.946	15.768
Miscellaneous_manufactures	2,276	12.215	4.625	0	21.452
Art_antiques	1,684	10.196	3.339	0	20.095

Note: All product category data are presented in their logarithmic form. Source: United Nations Statistics Division (2024)