China Economic Review 88 (2024) 102284

Contents lists available at ScienceDirect

China Economic Review

journal homepage: www.elsevier.com/locate/chieco

Who gains, who loses? – The impact of the belt and road initiative on bilateral agricultural trade

Yongzhi Zhao [a,b], Changjing Ji [c], Yangfen Chen [a,*], Xueqin Zhu [b,*]

[a] Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences, Beijing, China
[b] Environmental Economics and Natural Resources Group, Wageningen University and Research, Wageningen, the Netherlands
[c] Institute of Carbon Neutrality, ShanghaiTech University, Shanghai, China

ARTICLE INFO

JEL codes:
F13
F15
F17
Q17

Keywords:
Belt and Road Initiative
Bilateral agricultural trade
Trade creation effect
China
Structural gravity model

ABSTRACT

The Belt and Road Initiative (BRI), a global development strategy proposed by China, has received extensive attention from researchers in the field of international trade and development economics. However, little is known about the BRI's effect on bilateral agricultural trade. This paper quantifies the effect of BRI on global agricultural trade, especially between China and BRI participating countries, based on structural gravity models and the General Equilibrium Poisson Pseudo Maximum Likelihood (GEPPML) method. Our results show that BRI has a significant and positive impact on global agricultural trade. BRI not only improves the agricultural trade between China and its BRI partners but also stimulates agricultural trade between BRI participating and non-participating countries, indicating a pure trade creation effect. We find the heterogeneous effect of BRI in participating countries regarding per capita income, showing an increase in agricultural exports from China to non-high-income BRI countries but a reduction in exports from China to high-income BRI countries. It highlights the importance of considering specific economic status when formulating trade agreements with trade partners. We find the significant positive impact of BRI on welfare gains, particularly for consumers in China and producers in BRI participating countries. Meanwhile, BRI leads to a reallocation of China's agricultural imports away from the United States and Brazil towards neighboring BRI participating countries.

1. Introduction

The Belt and Road Initiative (BRI) is an ambitious global development strategy proposed by the Chinese government in 2013. Aiming to enhance regional integration and economic growth through extensive infrastructure projects and trade liberalization agreements, the BRI has attracted significant global attention (Huang, 2016). Between 2013 and 2018, the BRI-related investment in 50 participating countries reached $575 billion (Bandiera & Tsiropoulos, 2020). The total investment is projected to exceed $1 trillion, even to $8 trillion by 2050, covering infrastructure, transport, and energy projects (Bird, Lebrand, & Venables, 2020; Chen & Lin, 2020).[1] The BRI transport projects along could increase GDP by up to 3.35 % in participating countries, equivalent to the impact of a

---

* Corresponding authors.
E-mail addresses: yongzhi.zhao@wur.nl (Y. Zhao), jichj@shanghaitech.edu.cn (C. Ji), chenyangfen@caas.cn (Y. Chen), xueqin.zhu@wur.nl (X. Zhu).

[1] For example, the high-speed railway linking China and Thailand; China-Kyrgyzstan-Uzbekistan highway project; the port projects in Pakistan's Gwadar and Greece's Piraeus; fiber optic cable projects in Kyrgyzstan and Tajikistan.

https://doi.org/10.1016/j.chieco.2024.102284
Received 6 May 2024; Received in revised form 7 September 2024; Accepted 16 September 2024

one-third tariff reduction in BRI participating countries (de Soyres, Mulabdic, & Ruta, 2020). The improved transport connectivity could enhance regional trade and attract cross-border investment, benefiting both BRI participating and non-participating countries (Chen & Lin, 2020; Lim, Li, & Adi, 2021). Furthermore, trade agreements in the context of BRI have improved customs clearance efficiency and facilitated bilateral trade. The scope of BRI is remarkable, with 152 participating countries as of September 2023,[2] garnering attention from international bodies like the United Nations, WTO, and FAO for its potential impact on regional and global economic development. Often described as China's "Marshall Plan" (Ferdinand, 2016), the BRI effect on trade has become a focal point for researchers.

There is an emerging literature on the impacts of BRI on trade. For example, de Soyres et al. (2020) suggest that BRI increases the aggregated trade volume for most participating countries. Baniya, Rocha, and Ruta (2020) find that BRI significantly increases trade flows by up to 4.1 % among participating countries with larger effects for time-sensitive products, such as wood and vegetable products. Yu, Zhao, Niu, and Lu (2020) find that BRI significantly promotes China's export potential to the BRI participating countries, with a stronger effect for capital-intensive products than for labor-intensive products. However, the studies by de Soyres et al. (2020) and Baniya et al. (2020) might underestimate the BRI effect, because they only consider the BRI-related infrastructure projects without including trade agreements. The study by Yu et al. (2020) focuses on China's exports without considering the regional trade. Moreover, all of these studies use aggregated trade data and thus are unable to identify the sectoral trade effects, particularly, agricultural trade.

Agricultural trade, although constituting a smaller proportion of global trade, holds strategic importance for several reasons. First, the agricultural sector is highly sensitive to trade policies. Agricultural products are often subject to higher tariffs and non-tariff barriers compared to other goods, making them a critical area for understanding the broader implications of the BRI. Improved trade agreements and transport connectivity under the BRI can significantly enhance the efficiency and reliability of agricultural trade. Second, agricultural trade is often at the center of trade disputes, as seen in the Sino-American trade war, where tariffs on agricultural products led to significant market disruptions (Cheng, Hasanov, Poon, & Bouri, 2023; Elobeid, Carriquiry, Dumortier, Swenson, & Hayes, 2021). The BRI could potentially mitigate such impacts, offering a compensatory mechanism to stabilize agricultural trade during trade tensions (Jackson & Shepotylo, 2021). Third, agriculture plays a crucial role in global food security, and analyzing the BRI's impact on agricultural trade provides valuable insights into food security in participating countries. Ensuring a stable and reliable flow of agricultural products is essential for meeting the nutritional needs of populations and maintaining stability in food markets.

Against this background, our study aims to contribute to the understanding of the BRI effect on the sectoral level trade, particularly the agricultural sector, in all trading partners including both BRI participating and non-participating countries. Our central research question is: what are the BRI effects on bilateral agricultural trade in trading partner countries? Answering this question contributes to the literature with specific BRI effects in agricultural trade in a broader international context.

Various methods have been used so far. For example, de Soyres et al. (2020) develop a structural general equilibrium model to quantify the effect of BRI. de Soyres, Mulabdic, Murray, Rocha, and Ruta (2019) use network algorithms to compute the reduction in transport time based on completed and planned BRI transport projects. Baniya et al. (2020) employ the geographical information system (GIS) to compute the reduction of trade time caused by BRI and estimate the effect of trade time reduction based on a gravity model. Yu et al. (2020) assess the trade potential and investigate the effect of BRI on China's export potential based on Difference-in-Difference (DID) method.

These methods are suitable for different contexts. The general equilibrium modelling could evaluate the impact of a policy shock on the whole economic system and identify changes in trade volume, price and welfare. It is a mathematical modelling method which needs good calibrations based on the national input-output tables and applying such a model to a large number of trading countries is daunting. The DID model is a common econometric method for causal inference but it requires "no spillover effects", which is difficult to satisfy when the dependent variable is trade volume. The gravity model is the workhorse in trade literature and is used to assess the impact of trade policies on bilateral trade flows extensively. The General Equilibrium Poisson Pseudo Maximum Likelihood (GEPPML) method, proposed by Anderson, Larch, and Yotov (2018), enriches the gravity model and allows to conduct general equilibrium counterfactual analysis of trade policies.

Combining a gravity model and GEPPML method could best serve our purpose of investigating the impact of BRI in all trading partners. Therefore, in this paper we take the following approach to answer our research question. First, we utilize a structural gravity model to quantify the direct impact of BRI on bilateral agricultural trade among BRI-participating countries. Second, we explore the heterogeneous effect of BRI concerning the different economic indicators: agricultural economy size (i.e., agricultural GDP), development level (i.e., income level) and trade characteristics (a net exporting/importing country). Third, we delve into the trade creation effect to gain deeper insights into the trade reallocation between BRI participating and non-participating countries.[3] Fourth, we employ GEPPML method to identify the "full endowment" general equilibrium effect of BRI by allowing changes in price, output and expenditure in each country responding to the trade policy shock.

This paper contributes to the international trade literature in three aspects: *First*, to the best of our knowledge, it is the first study to comprehensively investigate the impact of BRI on agricultural trade. Previous research mainly focuses on aggregated trade volume and ignores the sectoral differences, for example, Baniya et al. (2020); Bird et al. (2020); Jackson and Shepotylo (2021); Yu et al. (2020).

---

[2] Due to the limitation of study periods (2001–2019), we consider 136 participating countries in the treatment group, which joined BRI before 2019.

[3] In this paper, the "promotion effect" refers to the increase in trade between participating countries while the "creation effect" refers to the increase in trade between participating countries as well as between participating countries and non-participating countries.

Our study extends the BRI literature by exploiting disaggregated trade data, particularly in agricultural sector, and discussing the heterogeneous BRI effect on agricultural trade regarding several economic indicators. Moreover, existing studies mainly focus on BRI infrastructural projects, which might underestimate the BRI effect due to the ignorance of BRI-related trade agreements. We consider the overall impact of BRI, including both infrastructure projects and trade agreements. *Second*, this paper contributes to the broad empirical literature that employs a structural gravity model. We employ GEPPML in the context of BRI and discuss the welfare effect of BRI from a general equilibrium perspective by comparing the estimates under different counterfactual scenarios. We also employ several latest estimation techniques to obtain more reliable estimates, including considering the impact of intranational trade flows, allowing adjustment time in response to trade policy and calculating the significance levels based on multi-way clustered standard errors (Baier, Yotov, & Zylkin, 2019; Weidner & Zylkin, 2021; Yotov, Piermartini, Monteiro, & Larch, 2016). *Third*, we consider the differential joining timing and construct the policy dummy variable according to the actual joining timing for each BRI participating country. As such, we can capture differences in outcomes between participating and non-participating countries, as well as among participating countries with different joining timing. The existing studies simplify this issue by assuming participants joining BRI in a given year (usually 2013 or 2014 since BRI was launched in 2013 and the first official BRI agreement was signed in 2014). Overall, this paper provides a more comprehensive analysis of the BRI effect on bilateral agricultural trade using novel combined methods.

The remaining parts are structured as follows. Section 2 introduces the structural gravity model, the model specification and GEPPML procedure. Section 3 presents the data sources and descriptive analysis results. Section 4 presents the econometric estimation results, including benchmark results, robustness check, heterogeneity discussion and trade creation effect. Section 5 discusses the results of counterfactual analysis and potential limitation. Section 6 summarizes the conclusion and offers remarks.

2. Methodology

In this section, we first introduce the framework of a structural gravity model. Based on the theoretical gravity model, we develop an estimable equation to assess the direct effect of BRI and describe the model specification for robustness checks and heterogeneity analysis. Then we outline the procedure for conducting the counterfactual analysis, which reveals the indirect effect of BRI and associated welfare gains.

2.1. Gravity model

A gravity model is the workhorse for empirical studies on bilateral trade flows. Anderson and van Wincoop (2003) developed a structural gravity model and defined Multilateral Resistance Terms (MRTs) based on the CES-Armington setting. This model enables us to estimate the impact of trade agreements on bilateral trade flows, considering different assumptions of the trade effect caused by the trade policy shock. We can estimate the direct (partial equilibrium) effect by assuming that trade policy only affects the two treatment countries involved in the trade agreements. In this case, bilateral trade flows are determined by the size of the two countries and bilateral trade barriers, as shown in Eq. (1.a). It informs the direct (partial equilibrium) effect of trade agreements on bilateral trade flows, holding all other elements constant except trade agreement variables. By assuming more countries exist in the economic system and considering the impact of trade agreements on trade flows between treatment countries and their other trade partners (third-party countries), we can obtain the conditional general equilibrium effect, informed by Eqs. (1.a) (1.b) and (1.c). MRTs, expressed in Eqs. (1.b) and (1.c), measure the exporter's and importer's ease of market access and bear the intuition that two countries will trade more with each other the more remote they are from the rest of the world. Conditional general equilibrium effect allows changes in MRTs in response to trade agreement changes. Furthermore, by relaxing the restrictions that output and expenditure are constant in each country and allowing changes in factory-gate price to respond to trade agreements and MRTs, informed by Eq. (1.d), we can obtain the full endowment general equilibrium effect. This approach provides various details on the impact of trade agreements on bilateral trade flows and welfare gains in exporting countries and importing countries by setting up different counterfactual scenarios. The canonical structural gravity model takes the form:

$$X_{ij} = \frac{Y_i E_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \tag{1.a}$$

$$\Pi_i^{1-\sigma} = \sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma}\left(\frac{E_j}{Y}\right) \tag{1.b}$$

$$P_j^{1-\sigma} = \sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma}\left(\frac{Y_i}{Y}\right) \tag{1.c}$$

$$p_i = \left(\frac{Y_i}{Y}\right)^{\frac{1}{1-\sigma}}\frac{1}{\alpha_i \Pi_i} \tag{1.d}$$

X_{ij} denotes trade flows from country i (exporter) to country j (importer); Y_i denotes total output in exporter i, representing the domestic production or nominal income. E_j denotes total expenditure in importer j, indicating the overall economic activity in the importing country. The relationship between total output and aggregate expenditure is given by $E_j = \varphi_j * Y_j$, where φ_j is an exogenous parameter that reflects trade deficit ($\varphi_j > 1$) or trade surplus ($\varphi_j < 1$). Y denotes the world output, which is equal to the sum of total production of all countries. t_{ij} denotes the bilateral trade costs between country i and country j. σ denotes the trade substitution elasticity ($\sigma > 1$). Π_i and P_j, referring to MRTs, denote multilateral barriers to trade faced by exporter i and importer j respectively. p_i is the factor-gate price in the exporting country i and suggests the underlying mechanism of trade effects. α_i is the CES preference parameter.

Eq. (1.a) shows that bilateral trade flows are determined by two terms: size of the countries, represented by $\frac{Y_iE_j}{Y}$, and *relative* trade barriers, expressed as $\left(\frac{t_{ij}}{\Pi_iP_j}\right)^{1-\sigma}$ (Olper & Raimondi, 2008). The *relative* trade barriers are positively correlated with the multilateral resistance terms (Π_i, P_j) and negatively correlated with bilateral trade costs (t_{ij}). Eq. (1.b) and (1.c) describe outward multilateral resistance terms (OMR) and inward multilateral resistance terms (IMR) respectively. These terms capture the average trade barriers between one country and its all of other trade partners, which can be used to measure the exporting and importing market access. These two terms are also general equilibrium trade costs indexes and could decompose the effect of trade policy changes into separate effects on producers and consumers in each country around the world (Yotov et al., 2016). Eq. (1.d) is the key to full endowment general equilibrium analysis because it indicates the underlying channel that trade costs affect factory-gate price via OMR, therefore affecting output and consumption in each country.

2.2. Model specification and estimation strategy

First, to estimate the direct effect (or partial effect) of BRI on bilateral agricultural trade, we proxy trade costs in Eq. (1.a) as a function of time-varying BRI policy variable and time-invariant country-pair fixed effects. We construct an exponential gravity function because the linear gravity equation could lead to inconsistent estimates when heteroskedasticity exists and fails to deal with zero-trade flows (Baier et al., 2019; Silva & Tenreyro, 2006). And it is usually hard to fulfill the condition that ensures the dependent variable is unrelated to the error term during log-linearization of a gravity model (Santos Silva & Tenreyro, 2022). The benchmark estimable equation is given by:

$$X_{ijt} = exp\left\{\pi_{it} + \chi_{jt} + \mu_{ij} + \beta_0 + \beta_1 BRI_{ijt}\right\} + \varepsilon_{ijt} \tag{2}$$

In this specification, X_{ijt} denotes the value of bilateral trade flows from exporter i to importer j in year t. BRI_{ijt} denotes the status of BRI policy between country i and country j in year t. Since BRI is proposed by China and mainly focuses on bilateral cooperation between China and BRI participating countries, we set BRI_{ijt} a dummy variable, taking value of one if exporter is China and importer is a BRI participating country, or exporter is a BRI participating country and importer is China, 0 otherwise. π_{it} is the exporter-year fixed effect and refers to output and OMR in the exporting country. χ_{jt} is the importer-year fixed effect and refers to consumption and IMR in the importing country. These two terms could control for the time-varying confounding factors at the country level (Fally, 2015; Olper & Raimondi, 2008). μ_{ij} is the country-pair fixed effect and indicates the bilateral trade costs. It could also absorb all time-invariant bilateral confounding factors, such as distance, common border and common language, and it could address potential endogeneity bias related to omitted variables (Agnosteva, Anderson, & Yotov, 2019; Baier & Bergstrand, 2007; Egger & Nigai, 2015). ε_{ijt} is the error term.

For robustness, we include another control variable, EIA_{ijt}, to account for the impact of other economic integration agreements between any two countries following Baier, Bergstrand, and Clance (2018); McFadden (2021). EIA_{ijt} is a dummy variable that equals to 1 when exporter i and importer j are included in the same economic integration agreements (except BRI), and zero otherwise. And we include lagged values of BRI_{ijt} to account for the phasing-in effects. The intuition is that trading partners gradually adjust to the new economic conditions under a recently implemented trade agreement and it takes time to observe the significant changes in trade flows responding to the trade agreements (Anderson & Yotov, 2016; Bergstrand, Larch, & Yotov, 2015). Including various lags could capture these differences and indicate BRI effects changing over time. We get Eq. (3) as follows:

$$X_{ijt} = exp\left\{\pi_{it} + \chi_{jt} + \mu_{ij} + \beta_0 + \beta_1 BRI_{ijt} + \beta_2 EIA_{ijt} + \beta_3 BRI_{ij,t-1} + \beta_4 BRI_{ij,t-2}\right\} + \varepsilon_{ijt} \tag{3}$$

Furthermore, we explore the heterogeneous effect of BRI depending upon country-pairs' economic characteristics, which we motivate later in the Section 4.3. Specifically, we estimate the heterogeneous BRI effect varying across three dimensions of economic status: agricultural economy size, development level and trade characteristics. We use agricultural GDP, income per capita, and the difference between exporting and importing volume to measure these three dimensions. Respectively, we construct *TopX* (*X* refers to 5 10 20 50,100), *North(South)_to_North(South)*, *imp(exp)_to_imp(exp)* dummy variables based on each indicator, denoted as Z_{ijt} in Eq. (4). The detailed description is provided in the heterogeneity discussion part (Section 4.3). We then interact them with the BRI policy dummy variable following Baier et al. (2018); McFadden (2021). The estimation equation is expressed as:

$$X_{ijt} = exp\left\{\pi_{it} + \chi_{jt} + \mu_{ij} + \beta_0 + \beta_1 BRI_{ijt} + \beta_2 BRI_{ijt} {}^* Z_{ijt} + \beta_3 Z_{ijt}\right\} + \varepsilon_{ijt} \tag{4}$$

Because of the non-linear equations, we employ the Poisson Pseudo-Maximum Likelihood (PPML) estimator to alleviate the potential impact of heteroskedasticity and zero-trade flows (Silva & Tenreyro, 2006). PPML estimator with the fixed effects is consistent with the theoretical multilateral resistance terms. It allows us to conduct the general equilibrium counterfactual simulation (Fally, 2015). Because our sample includes more than 200 countries, we employ the PPML algorithm suggested by Larch, Wanner, Yotov, and Zylkin (2018) to solve the computation burden resulting from high-dimensional fixed effects in the structural gravity model. We provide two kinds of standard errors (SEs) for comparison: two-way clustered SEs (clustered by exporter and importer) and country-pair SEs clustered at the country-pair level. Our choice of clusters is based on the work of Egger and Tarlea (2015), who compare four types of clustered standard errors and argue that multi-way clustered SEs could lead to more conservative inferences. In empirical research, Baier et al. (2019); Larch et al. (2018) employ multi-way standard errors (clustered by exporter, importer, and year) to control for the correlation of unobservable factors within clusters. However, due to the limited number of time periods (2001–2019) in our sample, it is difficult to take advantage of the clustered standard errors in the time dimension. So we choose two-way clustered standard errors, clustered by exporter and importer. We provide estimates using country-pair clustered SEs in the appendix. Additionally, we use 3-year interval data to account for the possible "phase-in" effect of trade agreements mentioned in Baier and Bergstrand (2007); Baier et al. (2019).[4]

2.3. Counterfactual analysis

To further explore the indirect effect (or general equilibrium effect) of BRI on trade and welfare (i.e. output), we conduct counterfactual simulation analysis based on the structural gravity model and the PPML estimator, which is GEPPML proposed by Anderson et al. (2018); Yotov et al. (2016). It could directly recover the conditional and full endowment general equilibrium indexes from the gravity model estimates and informs us the BRI effect from a general equilibrium perspective. In this paper, we analyze the counterfactual scenario in which BRI never happened.

The GEPPML procedure includes three main steps. First, solving the baseline gravity model to obtain the baseline estimates. We use the reality as the baseline scenario and obtain all estimates of Eq. (2). The key parameters, outward multilateral resistance terms (OMRs) and inward multilateral resistance terms (IMRs), could be calculated by the following equations,

$$\widehat{\Pi_{it}^{1-\sigma}} = E_{0t} Y_{it} exp\left(-\widehat{\pi_{it}}\right) \tag{5}$$

$$\widehat{P_{jt}^{1-\sigma}} = \frac{Y_{jt}}{E_{0t}} exp\left(-\widehat{\chi_{jt}}\right) \tag{6}$$

where E_{0t} is the total expenditure of the reference country in year t, Y_{jt} is the total expenditure of importer j in year t, Y_{it} is the total production of exporter i in year t, $\widehat{\pi}_{it}$ and $\widehat{\chi}_{jt}$ are estimated exporter-year and importer-year fixed effects based on Eq. (2). Note that the IMRs of the reference country is normalized to one and the importer-year fixed effect representing the reference country is excluded in the estimation (Anderson et al., 2018; Ridley, Luckstead, & Devadoss, 2022).[5] All results should be interpreted as the impact *relative* to the changes in the reference country's price level (Ridley & Devadoss, 2023). Here we select Luxembourg as the reference country because its production, expenditure and trade volume are relatively stable during the study periods. It enables us to interpret the results in counterfactual analysis based on a closely absolute reference trade volume (Ridley & Devadoss, 2023).[6]

Second, we define the counterfactual scenario and estimate the conditional general equilibrium effect. The term "conditional" implies that we take into account the changes in MRTs in response to trade costs but keeping output and expenditure constant (Anderson et al., 2018). In the counterfactual scenario, we assume that BRI did not happen at all by replacing all *BRI policy* dummy variables with zero value, denoted as BRI_{ijt}^{C} in Eq. (7). Other parameters ($X_{ijt}, \widehat{\mu}_{ij}, \widehat{\beta}_0, \widehat{\beta}_5$) remain the same as the baseline scenario. We re-estimate Eq. (7) to obtain new estimates of exporter-year and importer-year fixed effects. We re-calculate new OMRs and IMRs in the counterfactual scenario based on Eqs. (5) and (6), which is consistent with observed data on trade flows, output and expenditure. Then, we obtain the projected trade flows under the counterfactual scenario based on Eq. (7) and compare the actual trade (baseline scenario) with the projected trade (counterfactual scenario).

$$X_{ijt} = exp\left\{\pi_{it} + \chi_{jt} + \widehat{\mu}_{ij} + \widehat{\beta}_0 + \widehat{\beta}_5 BRI_{ijt}^{C}\right\} + \varepsilon_{ijt} \tag{7}$$

Third, we further loose the restrictions and allow for changes in endogenous price, output and expenditure to conduct full endowment general equilibrium analysis. Based on market clearing, the conditional general equilibrium index can be translated into "first-order" changes in factory-gate price, which would affect the output and expenditure. The endogenous changes in output and expenditure will trigger additional changes in the MRTs and therefore indirectly affect the bilateral trade flows (Anderson et al., 2018). Repeat the program in the second step and update the exporter-year and importer-year fixed effects to calculate the conditional OMRs and IMRs for each country, considering the changes in output and expenditure until convergence.

Finally, we compare the conditional and full endowment general equilibrium effects of BRI on bilateral agricultural trade. We calculate the difference of trade flows between baseline and counterfactual scenarios based on Eq. (8). In particular, we focus on the changes in China's trade volume with its main trade partners.

---

[4] We also provide estimates with 1-year, 2-year and 4-year interval data for benchmark estimation and robustness check (see Tables 1–4).

[5] Please see the argument on Ridley's paper (page 7) and Anderson's paper (page 9).

[6] Enlighten by the statement "*This suggests that the relative nominal trade impacts that we estimate in our counterfactual analysis should closely align with the absolute nominal trade impacts.*" in Ridley's 2023 paper on page 16.

$$\Delta X_{ijt} = X_{ijt}^{B} - X_{ijt}^{C} \tag{8}$$

3. Data and descriptive analysis

In this section, we present the data sources and conduct a descriptive analysis focusing on China's exports, especially comparing the exports to BRI participating and non-participating countries before and after the implementation of BRI.

3.1. Data sources

The data used in this paper are secondary data. Data on bilateral agricultural trade flows comes from the International Trade and Production Database for Estimation (ITPD-E), which contains international and domestic (intra-national) trade within the agricultural sector.[7] The inclusion of domestic trade data provides more reliable estimates because the domestic market could absorb the shock of trade policy on international trade to some extent (Yotov et al., 2016). This feature of the ITPD-E provides a significant advantage over other commonly used trade databases, such as CEPII BACI and UN Comtrade. An increasing number of studies, including those by Herman and Oliver (2023); Larch, Tan, and Yotov (2023), have used ITPD-E for their trade analysis and have been published in Top journals.

The bilateral agricultural trade data in this paper is a balanced panel dataset covering 239 countries over the years 2001–2019, which is collected from the latest version released by ITPD-E. Such dataset, up to 2019, could also avoid the impact of the COVID pandemic on global economic activities and potential delays in global trade. Additionally, we consider an alternative trade dataset covering a more recent research period from 2009 to 2022 as a robustness check. This dataset is obtained from CEPII BACI and used to re-estimate the benchmark model, Eq. (2). We reduce the sample before the implementation of BRI to control the potential imbalances between the treatment group and the control group. However, it is important to note that the BACI database only provides data on international trade and does not include domestic trade data. The exclusion of domestic trade in the estimation process may affect the precision of the results and lead to a downward bias.

The BRI policy dummy variable is constructed by authors based on the official BRI website.[8] We collect the joining timing of 136 BRI participating countries that joined before 2019 and match with trade data obtained from ITPD-E. Fig. 1 shows the number of new participating countries in each year. We find the joining peak is 2018, when 64 countries signed BRI-related documents with China.

Data on other economic integration agreements (EIA) is obtained from NSF-Kellogg Institute Database, which defines six types of economic integration agreements as indexes from 0 to 6.[9] In this study, we categorize these six indexes into two groups no EIA (EIA equals to 0) and existing EIA (EIA equals to 1, 2, 3, 4, 5, and 6) to construct the EIA_{ijt} dummy variable in Eq. (3). The latest version of this database, updated in July 2021, releases the EIA data up to 2017. To match it with trade data up to 2019, we extend the EIA database by filling in the missing values for 2018 and 2019 with the actual values in 2017. Meanwhile, we also restrict the whole sample to 2017 as the robustness check to assess the potential impact of the extension of EIA data.

Data used for heterogeneity analysis are obtained from the World Bank and ITPD-E database. Specifically, we use "agriculture, forestry and fishing, values added (% of GDP)" and "GDP (constant 2015 US$)" indicators in World Development Indicators (WDI) to calculate the agricultural GDP. The income per capita is based on gross national income (GNI) per capita and the World Bank classifies all economies into four income groupings: low, lower-middle, upper-middle and high.[10] The data on net exporting/importing status for a country's trade characteristics is calculated by the difference between total exports and total imports, based on trade data collected from the ITPD-E database.

3.2. Descriptive analysis of China's trade

China's agricultural exports have notably increased since 2001 while the trends in exports to different trade partners are quite different. As shown in Fig. 2a, China's exports to BRI participating countries experience a significant increase but the exports to non-participating countries have declined to approximately half of its level in 2013 by 2019. Moreover, the slope of the blue line is steeper compared to the black line in Fig. 2a, which indicates that China's exports to BRI countries have grown at a higher rate than China's overall exports. The difference in exports performance between BRI participating and non-participating countries preliminarily suggests the presence of trade diversion effects: increasing exports to BRI participating countries at the expense of a reduction in exports to other countries. However, we have to be cautious about these arguments because the number of BRI participating countries have been increasing while the non-BRI countries have been decreasing since 2014.

Given the fact that an increasing number of countries join BRI, the significant difference in the sum of China's exports to its BRI partners and others has limited implications. To further alleviate the influence of group sizes and compare the difference between BRI participants and non-participants, we calculate the median exports to BRI and non-BRI countries. As shown in Fig. 2b, the median of

---

[7] For more information, please see at https://www.usitc.gov/data/gravity/itpde.htm

[8] The Chinese government launched an official BRI website for related news, policies, and data. See at https://eng.yidaiyilu.gov.cn/

[9] Specifically, EIA equals 0 while no economic integration agreement; 1 denotes a one-way preferential trade agreement; 2 denotes a two-way preferential trade agreement; 3 denotes a free trade agreement; 4 denotes a customs union; 5 denotes a common market; 6 denotes an economic union.

[10] For more information at https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries

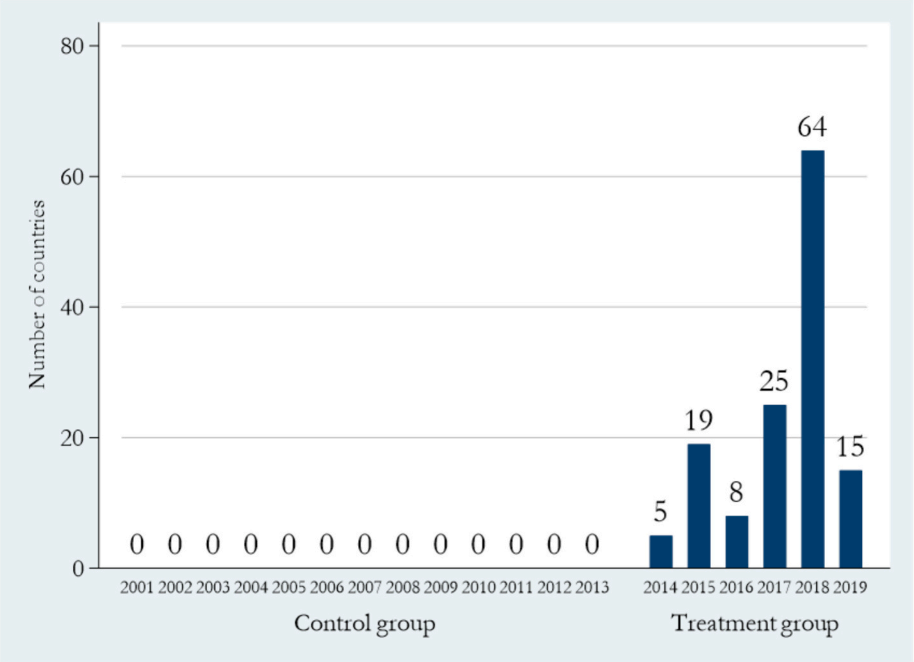

Fig. 1. Number of new BRI participating countries in each year.

China's exports to BRI participating countries are much more than those to BRI non-participating countries. China's exports to BRI participating countries experienced a surge from 2014 and reached a peak in 2015. Subsequently, a sharp drop followed in 2017 and 2018, which could be attributed to the considerable increase in BRI participating countries during these two years. Specifically, 25 new countries joined BRI in 2017 and 64 countries joined in 2018. The new participants include countries with small economy sizes and trade sizes, therefore leading to a reduction in median China's exports to BRI participating countries. For BRI non-participating countries, China's exports decreased steadily since 2014. The significant disparity in China's exports to BRI participating and non-participating countries, to some extent, suggests the correlation of China's agricultural exports with the launch of BRI policy.

4. Econometric results

The descriptive analysis in Section 3.2 provides us with some insights into the changes in agricultural trade and BRI policy. Now we turn to discuss the econometric estimation results for more insights, including benchmark estimates, robustness check, heterogeneity estimates and trade creation effect.

4.1. Benchmark gravity equation estimates

Table 1 presents the estimation results of Eq. (2) based on trade data at different year intervals. We compare the estimates with trade data at different year intervals and interpret the results mainly based on three-year interval. We report the two-way standard errors, clustered by importer and exporter, in the main text and provide country-pair clustered standard errors in Table A1 of the appendix.

The results in Table 1 suggest a strong positive impact of BRI on agricultural exports between China and BRI participating countries and the BRI effect is consistent considering different year intervals. The coefficients of BRI policy variable are statistically significant and robust even using country-pair clustered SEs (see appendix Table A1). The average partial effect of BRI on agricultural exports is 0.327, which indicates that BRI leads to a 38.7 % (exp (0.327)-1 $\approx$ 0.3868) increase in agricultural exports between China and BRI participating countries (Column 3). Similar effects are observed with trade data at different year intervals since the coefficients of BRI policy variables are all positive and significant. The magnitude of BRI effect is close (33.0 %, one-year interval; 34.2 %, two-year interval; 35.0 %, four-year interval) and increases with expanding in time intervals. It indicates the cumulative effect of BRI on agricultural trade, which could be explained by the response time to trade policy and the increasing policy intensity of BRI. First, some papers highlighted the "phase-in" effects associated with trade agreements (Baier et al., 2019; Baier & Bergstrand, 2007; Yotov et al., 2016). It means that exporters need some time to adjust domestic production and supply chains in response to the changes in trade policy, which leads to a delay in observable changes in bilateral trade volume. Second, the BRI effect might augment over time. Because BRI involves a bunch of infrastructure investment projects and trade agreements. The effect of infrastructure improvement projects usually could not be observable immediately given the construction periods. Moreover, with the implementation of BRI, participating countries might adjust domestic industrial policy and optimize the industrial structure. These measures might further

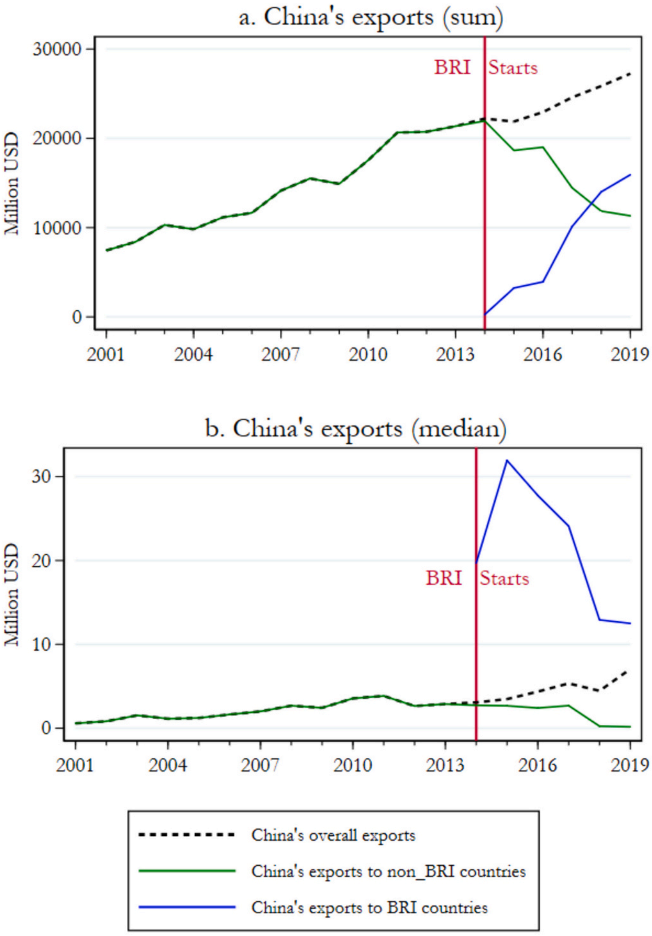

Fig. 2. China's exports to BRI and non-RBI countries.

Table 1
Gravity model estimates.

	(1)	(2)	(3)	(4)
	1-year interval	2-year interval	3-year interval	4-year interval
BRI_policy	0.285***	0.294***	0.327***	0.300**
	(0.078)	(0.073)	(0.073)	(0.069)
N	500,350	242,738	159,941	109,282
Pseudo R2	0.995	0.995	0.994	0.994
Time period	2001–2019	2001–2019	2001–2019	2003–2019

Dependent variable is the value of aggregate agricultural exports, measured in million dollars. Estimation includes exporter-year, importer-year and country-pair fixed effects. Standard errors clustered by exporter and importer are in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

enhance the impact of BRI on agricultural trade.

4.2. Robustness check

For robustness check, we employ various ways. First, we re-estimate the benchmark model, Eq. (2), using an alternative dataset with trade data up to 2022. Second, we include BRI lags to control for the phasing-in effect and include the EIA covariate to control for the impact of other economic integration agreements, as shown in Eq. (3). Since the latest EIA data is only available up to 2017, we also restrict the whole sample to 2017 and use the raw EIA data to estimate Eq. (3). Then we extend EIA data to 2019 to match the trade data in the ITPD-E database and re-estimate Eq. (3). Trade data is used at one-, two-, three- and four-year intervals, which is consistent with the benchmark estimation. We present two-way clustered standard errors as the baseline results and provide country-pair clustered standard errors in the appendix.

Table 2 presents the results for the robustness check by re-estimating the benchmark equation with trade data up to 2022. The coefficients of BRI policy variable are still significant and positive across different time intervals. It reveals the significant promotion effect of BRI on agricultural trade between China and BRI participating countries. However, the coefficients of BRI policy variable are smaller than the benchmark estimates in Table 1. According to Table 2, the average partial effect of BRI on agricultural exports is 0.134, which indicates that BRI leads to a 14.3 % (exp (0.134)-1 ≈ 0.1434) increase in agricultural exports between China and BRI participating countries (Column 3). It is almost half of the 38.7 % indicated by the result in Table 1, highlighting the large underestimation of BRI effect caused by the exclusion of domestic trade data. The largest coefficient of BRI policy variable still occurs at the three-year interval and it is consistent with the benchmark results in Table 1. The results suggest that the BRI effect increases over time and it takes approximately three years to observe the largest BRI effect on agricultural exports.

Table 3 and Table 4 present the results for robustness check by including BRI lags and EIA covariate. The results remain consistent with previous analyses and suggest the significant and positive effect of BRI on agricultural trade even after accounting for the BRI lags and other economic agreements. The magnitude of BRI effect is slightly smaller compared to the benchmark estimates and the largest estimate of BRI policy variable still occurs at three-year interval. Considering the impact of BRI lags and EIA covariate, BRI would lead to agricultural trade increase by 35.0 % (exp (0.300)-1 ≈ 0.3499) between China and BRI participating countries. Although the BRI effect is slightly smaller than the estimate of the benchmark results (38.7 %), it still shows a substantial impact on bilateral agricultural trade. The coefficients of BRI lags show some evidence of the phasing-in effect of BRI, but the results are sensitive to the dataset used. The estimates of "*BRI_Lag1*" in Column (1) of Table 3 indicate a positive and significant effect one year after the implementation of BRI, whereas the estimates of "*BRI_Lag1*" in Column (1) of Table 4 become negative and significant when the sample is restricted to 2017. Moreover, the estimates of BRI lags are insignificant when we try different year intervals. This could be due to the limited observations in our sample and we might not have enough treatment groups for a robust estimation. It also points to potential gains from more research in that direction and we leave this for future work. As for the EIA covariate, the coefficients are significant and positive, indicating the contribution of other economic agreements to the increase in agricultural trade between China and BRI participating countries. The inclusion of EIA covariate does not undermine the significance and robustness of the BRI effect, which suggests the reliability of our estimation results. The coefficients of BRI and EIA variables are similar based on country-pair clustered standard errors (see Tables A2 and A3 of the appendix).

4.3. *Heterogeneity discussion*

The trade promotion effect of BRI could vary across different economic status, with small countries usually gaining more from freer international trade than large countries (Eaton & Kortum, 2002). The heterogeneous effect could be explained by the variable and fixed trade costs. For example, developing countries face higher trade costs resulting from poor infrastructure and high border costs. Baier et al. (2018) argue that 10 % reduction in per capita income could increase the partial effect of an economic integration agreement by 60 %. McFadden (2021) finds that trade agreements have a more significant impact on member countries with non-high-income levels compared to those with high-income levels. He (2021) suggests that regional trade agreements decrease agricultural protection for domestic producers in non-member countries, with a more pronounced effect for net-importing non-member countries than for net-exporting ones. Following Baier et al. (2018); He (2021); McFadden (2021), we analyze heterogeneity from three aspects: agricultural economy size (i.e., agricultural GDP), development level (i.e., income) and trade characteristics (i.e., net exporting/importing status). During the heterogeneity estimation, we use a three-year interval as the baseline, which is consistent with the interpretation of benchmark estimation results. Two-way clustered standard errors are reported in the main text and we provide the estimates using country-pair clustered SEs in the appendix.

First, we consider the heterogeneous BRI effect resulting from the size of agricultural economy. In general, the high agricultural GDP is related to the large size of agricultural economy and indicates some comparative advantages in the agricultural sector. Countries with high agricultural GDP usually have more complete and robust industrial chains, which could quickly adjust domestic production in response to changes in global trade patterns. So following McFadden (2021), we categorize the full sample into 5 groups according to the agricultural GDP rankings. We generate *TopX (*i.e. Top5, Top10, Top20, Top50, and Top100*)* dummy variables to indicate whether both trade partners (the exporting and importing country) are within the same TopX group. The coefficients of these

Table 2
Robustness check based on an alternative dataset.

	(1)	(2)	(3)	(4)
	1-year interval	2-year interval	3-year interval	4-year interval
BRI_policy	0.092*	0.121***	0.134**	0.082**
	(0.048)	(0.042)	(0.064)	(0.041)
N	312,098	153,334	107,316	84,584
Pseudo R2	0.988	0.988	0.988	0.989
Time period	2009–2022	2009–2021	2009–2021	2009–2021

Dependent variable is the value of aggregate agricultural exports, measured in thousands current USD. Estimation includes exporter-year, importer-year and country-pair fixed effects. Standard errors clustered by exporter and importer are in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table 3
Robustness check by including BRI lags and EIA covariate.

	(1) 1-year interval	(2) 2-year interval	(3) 3-year interval	(4) 4-year interval
BRI_policy	0.238***	0.279***	0.300***	0.312***
	(0.052)	(0.038)	(0.060)	(0.051)
BRI_Lag1	0.079***	0.016	0.074	−0.139
	(0.021)	(0.064)	(0.154)	(0.153)
BRI_Lag2	−0.048	−0.073	–	–
	(0.085)	(0.126)	–	–
EIA	0.235***	0.234***	0.273***	0.256***
	(0.059)	(0.059)	(0.065)	(0.064)
N	500,350	242,738	159,941	109,282
Pseudo R2	0.995	0.995	0.994	0.994
Time period	2001–2019	2001–2019	2001–2019	2003–2019

We estimated the Eq. (3) with trade data at different year-intervals, hence BRI lags, $BRI_{ij,t-1}$ and $BRI_{ij,t-2}$, in different columns represent different-year lags. For example, BRI lags are two-year and four-year lags in Column (2) while BRI lags represent three-year and six-year lags in Column (3). Given the limited years in the treatment group, some lags will be omitted automatically in Column (3) and Column (4). Dependent variable is the value of aggregated agricultural exports, measured in million dollars. Estimation includes exporter-year, importer-year and country-pair fixed effects. The estimates use two-way clustered standard errors, clustered by exporter and importer, reported in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table 4
Robustness check by restricting the whole sample to 2017.

	(1) 1-year interval	(2) 2-year interval	(3) 3-year interval	(4) 4-year interval
BRI_policy	0.193**	0.192**	0.201**	0.247**
	(0.078)	(0.082)	(0.089)	(0.100)
BRI_Lag1	−0.183***	−0.187	0.295	–
	(0.071)	(0.158)	(0.251)	–
BRI_Lag2	−0.002	–	–	–
	(0.083)	–	–	–
EIA	0.174***	0.166***	0.199***	0.208***
	(0.055)	(0.055)	(0.061)	(0.064)
N	437,710	213,244	133,852	107,579
Pseudo R2	0.996	0.996	0.996	0.996
Time period	2001–2017	2001–2017	2002–2017	2001–2017

The meanings of BRI lags are similar with those in Table 3. Because of the shorter research period (2001–2017), more BRI lags will be omitted. Dependent variable is the value of aggregated agricultural exports, measured in million dollars. Estimation includes exporter-year, importer-year and country-pair fixed effects. The estimates use two-way clustered standard errors, clustered by exporter and importer, reported in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

TopX dummy variables suggest the group effect. Then we interact this *TopX* dummy variable with *BRI policy* dummy variable, denoted as *BRI_TopX* in Table 5. The estimates of this interaction term could indicate the heterogeneous BRI effect in terms of different sizes of agricultural economies.

Second, we investigate the heterogeneity varying with development level. Developing countries usually benefit more from trade agreements than developed countries because of substantial reductions in export costs (Baier et al., 2018). Per capita income is a representative indicator to measure development level. Based on gross national income per capita, we construct *Global North* (high income) and *Global South* (upper middle, lower middle and low income) dummy variables to indicate the development levels following McFadden (2021). We create four directional variables to inform the direction of trade flows: *North_to_North, North_to_South, South_to_North, South_to_South*. For example, the *North_to_South* variable represents exporting from high-income (Global North) countries to non-high-income (Global South) countries and the *South_to_South* variable indicates exporting from non-high-income (Global South) countries to other non-high-income (Global South) countries. Likewise, we interact these directional variables with the *BRI policy* dummy variable, noted as *BG* in Table 6, to estimate the heterogeneous BRI effect with respect to development level.

Third, we consider the country's trade characteristics in the heterogeneity analysis of BRI effect. China is a net-importing country from 2001 to 2019 and its trade structure is more likely to be complementary to trade partners with net-exporting trade characteristics. We calculate the difference between the total value of imports and exports to distinguish the net-importing and net-exporting countries. Based on this, we construct *exp/imp* dummy variables to indicate the trade characteristics in each country. Then we obtain four directional variables for trade flows between any two countries: *exp_to_exp, exp_to_imp, imp_to_exp, imp_to_imp*. For example, *exp_to_exp* indicates exports from a net-exporting country to a net-exporting country. Likewise, we interact these four directional dummy variables with the *BRI policy*, denoted as *BEI*, to estimate the heterogeneous BRI effect regarding trade characteristics.

Table 5
Heterogeneous effect of BRI varying with agricultural GDP.

	(1)	(2)	(3)	(4)	(5)
BRI_policy	0.336***	0.413***	0.377**	0.540***	0.280
	(0.073)	(0.059)	(0.148)	(0.177)	(0.177)
Top5	−0.304***				
	(0.010)				
BRI_Top5	−0.087				
	(0.495)				
Top10		0.230***			
		(0.080)			
BRI_Top10		−0.396			
		(0.430)			
Top20			0.125***		
			(0.043)		
BRI_Top20			−0.102		
			(0.361)		
Top50				0.051	
				(0.079)	
BRI_Top50				−0.252	
				(0.247)	
Top100					−0.144
					(0.317)
BRI_Top100					0.050
					(0.233)
N	154,592	154,592	154,592	154,592	154,592
Pseudo R2	0.994	0.994	0.994	0.994	0.994

According to agricultural GDP ranking, China is always a top 5 country. Estimation includes exporter-year, importer-year and country-pair fixed effects. Two-way clustered standard errors are reported in parentheses, clustered by exporter and importer. Country-pair SEs are provided in appendix Table A4. Time period is 2001 to 2019 with three years interval.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table 6
Heterogeneous effect of BRI varying with income.

	(1)	(2)	(3)	(4)	(5)	(6)
BRI_policy	0.327***	0.278***	0.384***	0.333	0.166	0.499***
	(0.073)	(0.090)	(0.110)	(0.284)	(0.116)	(0.119)
North_to_North	0.288**					
	(0.133)					
BG1	–					
	–					
North_to_South		−0.304**				
		(0.126)				
BG2		0.477***				
		(0.142)				
South_to_North			−0.284**			
			(0.132)			
BG3			−0.478**			
			(0.235)			
South_to_South				0.288**		
				(0.130)		
BG4				−0.008		
				(0.412)		
China_to_South					−0.167	
					(0.130)	
CBG1					0.513**	
					(0.228)	
South_to_China						−0.069
						(0.108)
CBG2						−0.370
						(0.265)
N	154,592	154,592	154,592	154,592	154,592	154,592
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994

Estimation includes exporter-year, importer-year and country-pair fixed effects. Two-way clustered standard errors are reported in parentheses, clustered by exporter and importer. Time period is 2001 to 2019 with three years interval.
* $p < .10$, ** $p < .05$, *** $p < .01$.

4.3.1. Heterogeneity regarding agricultural economy size

Table 5 shows the estimation results of heterogeneity in terms of agricultural economy size. First, almost all coefficients of *BRI policy* variable are positive and significant except Column 5. It suggests that BRI has an overall promotion effect on agricultural exports between China and BRI participating countries, which is consistent with the benchmark estimation results in Table 1. Second, the coefficients of *TopX* variables are mixed. Agricultural export is lower if both trade partners are countries with top 5 largest agricultural economy, but trade volume is higher if they are top 10 and top 20 countries. With the expanding of sample countries to top 50 and top 100, the coefficients of *TopX* variables become insignificant. It is hard to give consistent arguments about the differences in the group effect. Third, there is little evidence of significant heterogeneous effect of BRI on agricultural trade across different agricultural GDP groups. Most coefficients of the interaction terms (*BRI_TopX*) are negative except for Column 5. It indicates a potential negative impact of BRI on agricultural trade between China and BRI participating countries, especially those with large and middle agricultural economies. However, these coefficients are statistically insignificant, which shows the heterogeneous BRI effect could be affected by other factors, such as social and political factors. These confounders might make difficulties for us to identify the heterogeneous effect of BRI regarding agricultural GDP.

4.3.2. Heterogeneity regarding development level

According to the World Bank's classification, China was classified as a lower middle-income country from 2001 to 2009 and became a upper middle income country since 2010. Therefore, China belongs to Global South group throughout the study periods. Since we set *BRI policy* dummy variable equal to 1 only for the trade flows between China and BRI participating countries, the interaction of *BRI policy* with *North_to_North* is always equal to 0 and will be dropped in the estimation.

BG2, the interaction of *North_to_South* with *BRI policy*, represents the exports from high-income (Global North) BRI countries to China. *BG3*, the interaction of *South_to_North* with *BRI policy*, represents the exports from China to high-income (Global North) BRI countries. *BG4*, the interaction of *South_to_South* with *BRI policy*, represents the trade between China and non-high-income (Global South) BRI countries, including both exports from China to non-high-income (Global South) BRI countries and exports from non-high-income (Global South) BRI countries to China. To further distinguish these two kinds of exports, we construct *China_to_South* and *South_to_China* dummy variables and interact them with BRI policy dummy variable, denoted as *CBG1* and *CBG2*. The estimation results are shown in Table 6.

First, focusing on the coefficients of *BRI_policy* variable in Table 6, we find a significant positive effect of BRI on agricultural exports between China and BRI participating countries. It is consistent with our previous analysis. Second, we find significant group effect that varies across different income groups. Agricultural trade is more likely to occur between countries with similar income levels and the trade volume is less when both trade partners are from different income groups. Specifically, agricultural export is 33.4 % higher if the

Table 7

Heterogeneous effect of BRI varying with trade characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)
BRI_policy	0.324***	0.325***	0.299***	0.365***	0.310**	0.369***
	(0.074)	(0.079)	(0.085)	(0.121)	(0.151)	(0.053)
exp_to_exp	0.043					
	(0.113)					
BEI1	–					
	–					
exp_to_imp		−0.043				
		(0.115)				
BEI2		−0.001				
		(0.168)				
imp_to_exp			−0.050			
			(0.114)			
BEI3			0.288			
			(0.200)			
imp_to_imp				0.047		
				(0.117)		
BEI4				−0.075		
				(0.138)		
China_to_imp					0.256***	
					(0.044)	
BEI5					−0.007	
					(0.271)	
imp_to_China						0.113
						(0.193)
BEI6						−0.237*
						(0.135)
N	154,592	154,592	154,592	154,592	154,592	154,592
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994

Estimation includes exporter-year, importer-year and country-pair fixed effects. Two-way clustered standard errors are reported in parentheses, clustered by exporter and importer. Country-pair SEs are provided in appendix Table A6. Time period is 2001 to 2019 with three years interval.
* $p < .10$, ** $p < .05$, *** $p < .01$.

exporter and importer are both high-income countries (Column 1). This argument still stands when exporting and importing countries are both non-high-income countries (Column 4). Agricultural exports are 26.2 % lower from high-income to non-high-income countries and are 24.7 % lower from non-high-income countries to high-income countries. It indicates the presence of higher trade barriers between two countries across different income levels. Third, the coefficients of interaction terms show a significant heterogeneous effect of BRI associated with income level. BRI significantly increases agricultural exports from high-income BRI countries to China by 61.1 % (Column 2) and decreases agricultural exports from China to high-income BRI countries by 38.0 % (Column 3). The insignificance of the interaction terms in Column 4 could be attributed to the mix of trade flows data between China and non-high-income BRI countries. After decomposition, the coefficients of *CBG1* and *CBG2* reveal that BRI leads to a significant 67.0 % increase in agricultural exports from China to non-high-income BRI countries, but BRI effect is insignificant for agricultural exports in the opposite direction (from non-high-income BRI countries to China). All results are robust even if we use country-pair clustered SEs (Appendix A5).

4.3.3. Heterogeneity regarding trade characteristics

Since China is a net-importing country from 2001 to 2019, the interaction of *exp_to_exp* with *BRI policy* (*BEI1*) is always 0 and will be omitted. *BEI2* (the interaction term of *exp_to_imp*) represents the exports from net-exporting BRI countries to China, *BEI3* (the interaction term of *imp_to_exp*) represents the exports from China to net-exporting BRI countries, *BEI4* (the interaction term of *imp_to_imp*) represents the trade between China and net-importing BRI countries, including both exports from China to net-importing BRI countries and exports from net-importing BRI countries to China. Similarly, we construct another two dummy variables, *China_to_imp* and *imp_to_China*, to distinguish these two kinds of exports and interact them with *BRI policy* dummy variable, denoted as *BEI5* and *BEI6* respectively.

The estimation results are presented in Table 7 and we find little heterogeneity with respect to trade characteristics. First, the positive coefficients of *BRI policy* variable indicate that BRI could positively affect agricultural trade between China and BRI participating countries, which is consistent with our previous results. Second, the group effects vary across different groups but are statistically insignificant. The group effects suggest that bilateral trade volume could be higher when both trade partners have similar trade characteristics, which aligns with the group effect regarding income level. One country is more likely to trade with another country with similar trade characteristics with itself rather than looking for trade partners with complementary trade structures. Third, the coefficients of interaction terms are only significant in Column 6, which shows BRI decreases agricultural exports from net-importing BRI countries to China by 21.1 %. Although the estimates suggest that BRI increases agricultural exports from China to net-exporting BRI participating countries, the effect is statistically insignificant (Column 3). The insignificance of most interaction terms could be caused by many reasons. BRI policy is a broad concept that includes trade agreements and infrastructure investment, rather than a specific policy targeted at agricultural trade. As a result, it might be difficult to observe significant differences in heterogeneity based on the trade characteristics measured by an agricultural indicator (the difference between total value of agricultural exports and imports). More rigorous analysis and discussion are needed in the future.

4.4. Trade creation effect

Trade policy is expected to affect trade flows between participating countries while it could also influence trade between participating and non-participating countries through international markets. When a trade policy increases bilateral trade between participants as well as trade between participants and nonparticipants, it can be identified as the trade creation effect. Conversely, if trade policy increases trade between participating countries at the expense of a reduction in trade between non-participating countries, it suggests the trade diversion effect.

To measure the impact of BRI on agricultural trade in non-participating countries, we include another two dummy variables to indicate the "single member" in Eq. (2), following Sun and Reed (2010); Yang and Martinez-Zarzoso (2014). Specifically, we define

Table 8
Trade creation effect.

	(1)	(2)	(3)	(4)
	1-year interval	2-year interval	3-year interval	4-year interval
BRI_policy	0.756***	0.833***	0.891***	0.692***
	(0.056)	(0.069)	(0.071)	(0.055)
BRI_single_i	0.379***	0.401***	0.417***	0.314***
	(0.055)	(0.058)	(0.067)	(0.063)
BRI_single_j	0.580***	0.634***	0.617***	0.466***
	(0.127)	(0.144)	(0.159)	(0.117)
N	511,689	247,450	163,387	111,060
Pseudo R2	0.980	0.978	0.976	0.977
Time period	2001–2019	2001–2019	2001–2019	2003–2019

Dependent variable is the value of aggregate agricultural exports, measured in million dollars. Estimation includes only country-pair fixed effects. Exporter-year and importer-year fixed effects are excluded due to collinearity with "single member" dummy variables. The estimates use two-way clustered standard errors, clustered by exporter and importer, reported in parentheses. Country-pair SEs are provided in appendix Table A7.
* $p < .10$, ** $p < .05$, *** $p < .01$.

two dummy variables *BRI_single_i* and *BRI_singel_j*. *BRI_single_i* takes value of one when the exporter is a BRI country (including China) and the importer is not, zero otherwise. It indicates exports from BRI participating countries to non-participating countries. *BRI_single_j* takes a value of one when the importer is the BRI country (including China) and the exporter is not, zero otherwise. It indicates exports from BRI non-participating countries to participating countries. The coefficients of these two dummy variables inform the broader effects on non-participating countries, highlighting the BRI's influence on global agricultural trade flows.

The estimation results are presented in Table 8. First, the coefficients of *BRI policy* variable are significant and positive, which further verifies our previous analysis of BRI's positive impact on agricultural trade between China and BRI participating countries. Second, the coefficients of "single member" indicate the pure trade creation effect of BRI in terms of exports and imports. The coefficients of *BRI_single_i* indicate that BRI policy leads to an increase of up to 51.7 % (Column 3) in agricultural exports from BRI participating countries to non-participating countries. The coefficients of *BRI_single_j* reveal that agricultural exports from non-participating countries to BRI participating countries experience a magnificent increase up to 85.3 % (Column 3). These results show that BRI contributes to the growth of global agricultural trade, not only positively affecting agricultural trade between China and BRI participating countries but also improving agricultural trade between BRI participating countries and non-participating countries.

5. Counterfactual analysis results

5.1. Main results

Table 9 presents the general equilibrium effects of BRI on agricultural trade. In Column 2 to 6, we observe the percentage differences in several key variables between the baseline and counterfactual scenarios. First, the results reveal that China experiences the largest increase in agricultural exports, and its surrounding BRI participating countries also benefit in agricultural exports magnificently, including Mongolia, Bangladesh, Malaysia, Vietnam, South Korea, and Indonesia. This finding could be attributed to the fact that the main focus of BRI is in Asia at the beginning stage. There are numerous projects aiming at enhancing trade and economic connectivity in the Asian BRI countries. Railway network constructions, including the establishment of increasing freight train routes, and trade agreements notably reduce transportation costs and thus promote regional agricultural trade. Besides, some African BRI countries benefit a lot from BRI and experience a significant increase in agricultural exports, including Niger, Gambia and Mali.

Second, we find slight differences between the full endowment general equilibrium effect of BRI and the conditional general equilibrium effect of BRI. Some countries experience larger gains in the "full endowment" scenario compared to the "conditional" scenario. It suggests that parts of the decrease in bilateral trade costs lead to higher producers' prices in BRI participating countries, therefore increasing additional benefits for producers in these countries. Consumers in China benefit from BRI and enjoy lower factory-gate prices. In addition, BRI also leads to a positive effect on welfare (i.e. output) in most participating countries and slightly a negative effect in some non-participating countries, as reported in Table 9 Column 3.

Figs. 3 and 4 show the changes in China's exports and imports with its main trade partners after the implementation of BRI. As described in Fig. 3, China's exports to main destination countries experience a significant increase and its surrounding BRI countries, such as Vietnam, South Korea and Indonesia, benefit the most. BRI significantly promotes China's agricultural exports, especially exports to its neighbors. Among China's main exporting destinations, China-Vietnam exports experience the most substantial increase, with a total export of around $640 million. Other benefiters include South Korea, Indonesia, Malaysia, and Thailand. The China's exports to these countries have experienced a notable growth due to the trade facilitation effect of BRI.

Fig. 4 suggests a reallocation of China's imports away from the United States and Brazil towards China's neighboring BRI countries. Such reallocation of imports pattern is a result of the China's efforts to enhance trade cooperation among BRI participating countries. China's imports from Thailand experiences the largest increase, with around $1180 million. China's agricultural imports from Russia, Vietnam and New Zealand increase by $600 million, $430 million and $420 million respectively. The results also suggest the

Table 9
General equilibrium effect of BRI (short version).

	(1)	(2)	(3)	(4)	(5)	(6)
	Conditional GE	Full endowment general equilibrium				
	% Δ Xi CDL	% Δ Xi_Full	% Δ Real_output	% Δ IMR	% Δ OMR	% Δ Price
China	16.60	16.20	0.07	−0.47	0.46	−0.40
Mongolia	6.91	8.32	0.89	0.78	−1.97	1.66
Niger	7.54	7.98	0.13	0.14	−0.32	0.27
Bangladesh	7.02	6.87	0.02	−0.18	0.19	−0.16
Gambia	4.74	6.10	0.66	0.93	−1.87	1.57
Malaysia	5.70	5.97	0.23	−0.03	−0.24	0.20
Vietnam	5.86	5.83	0.28	−0.36	0.09	−0.08
Korea, South	5.02	4.46	0.05	−0.54	0.57	−0.49
Mali	3.40	4.39	0.04	0.64	−0.80	0.68
Indonesia	4.37	4.32	0.07	−0.17	0.11	−0.09
…						

For brevity, this table only presents the top ten countries that experiences the largest effects. The complete version can be found in appendix Table A8.

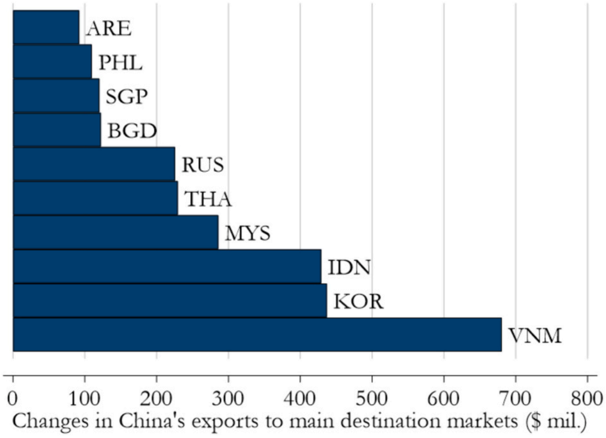

Fig. 3. Counterfactual impacts on China's exports to main destination markets.

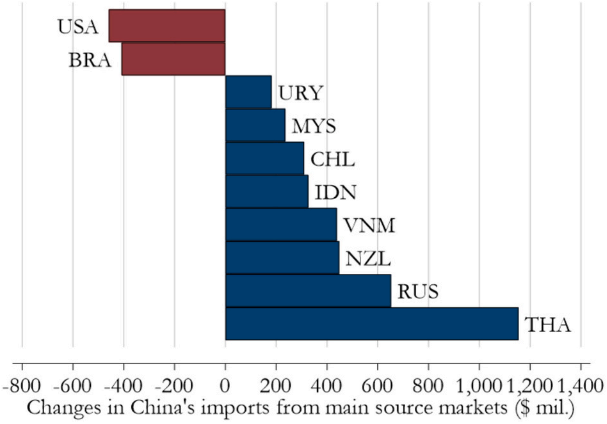

Fig. 4. Counterfactual impacts on China's imports from the main partners.

cumulative effect of BRI over time. As early members of BRI, Asian countries near China have experienced substantial increases in trade cooperation with China. This finding is consistent with previous results that BRI effect increases over time, highlighting gradually deeper trade integration and economic cooperation in the context of BRI.

5.2. Limitation of current counterfactual analysis

We study the counterfactual scenarios only for the agricultural sector, holding all other elements in the world trading system constant. It means that indirect impacts of BRI on other sectors are ignored and thus estimation biases might occur from such assumption. Because BRI not only leads to a decrease in trade costs of agricultural sector but also affects trade costs in the non-agricultural sectors, such as energy sector. Considering the relatively factor prices changes, production factors, including capital and labor, would flow across countries and sectors. When trade costs are higher in agricultural sector than other sectors, production factors (capital and labor) would flow from agricultural sector to other sectors with relatively lower factor prices. It would lead to a decrease in total agricultural output and the total counterfactual output in our model would be higher than simulated results from a global general equilibrium perspective. Nevertheless, our counterfactual analysis does show a direction of the changes of the BRI effects on international trade.

6. Conclusion and policy implications

This paper estimates the effect of BRI on agricultural trade and explores the heterogeneity in BRI effect regarding different economic status of participating countries. Our benchmark estimation results provide robust evidence for that BRI has significantly increased agricultural trade between China and BRI participating countries. This BRI effect augments over time, likely due to the gradual impact of infrastructure investment and the adjustment time needed for domestic industrial policy in the BRI participating countries. These findings highlight the non-instantaneous nature of BRI's trade promotion effect. Another notable result is the pure trade creation effect of BRI, which means BRI has not only improved agricultural trade between China and BRI participating countries, but also significantly promoted trade between BRI participating and non-participating countries. BRI positively affects global agricultural trade and fosters trade cooperation worldwide. Further discussion on the underlying mechanism and robustness would be an interesting research topic in the future.

Zooming in China's trade with the BRI participating countries, we find heterogeneous BRI effect on agricultural trade depending on the development level in participating countries. BRI has significantly increased China's imports from high-income BRI countries, and increased China's exports to non-high-income BRI countries. Meanwhile, BRI leads to a significant reduction in China's exports to high-income BRI countries. These results stand across different time intervals and different clustered standard errors. Heterogeneous BRI effect suggests the importance of considering economic status and the direction of trade flows when conducting trade policy evaluation and more generally formulating trade agreements in practice.

Furthermore, BRI also leads to a positive effect on welfare (i.e. output) in most participating countries and a slight negative effect in some non-participating countries. And BRI increases additional benefits for producers in participating countries and reduces prices for consumers in China by decreasing bilateral trade costs. The counterfactual analysis further confirms trade gains from BRI and identifies main benefiters. China's exports to all trade partners increase significantly due to BRI and its surrounding BRI countries obtain relatively larger trade gains. China also imports more agricultural products from neighboring BRI countries, leading to a reduction in agricultural imports from the United States and Brazil.

The Belt and Road Initiative has demonstrated its significant positive impacts on global agricultural trade and offers valuable lessons for developing countries. By promoting geographical and economics connectivity through infrastructural development and trade agreements, such as the construction of railways, roads, and ports, BRI has substantially reduced transportation costs and enhanced trade efficiency. Developing countries could draw inspirations from BRI's comprehensive approach, including infrastructure development, trade facilitation, and policy cooperation, to improve trade integration and foster economic growth. Embracing similar initiatives tailored to their unique needs and capacities can help unlock their trade potential and boost economic development. Moreover, BRI's success in fostering trade collaboration between China and its BRI partners highlights the importance of recognizing the varying development level of participating countries. These findings underscore the significance of considering the specific economic contexts of participating countries when formulating trade policies and agreements. Despite the increasing trade disputes and protectionist tendencies, the need for freer international trade has never been more crucial in driving economic growth and prosperity on a global scale. BRI stands as a prime example of how strategic trade initiatives can pave the way for enhanced cooperation and economic integration among nations, creating a conducive environment for mutual development and shared benefits.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data are publicly available through online databases described in the paper. Additional data are available from the corresponding author upon request.

Acknowledgments

We thank Suphi Sen, William Ridley, Xizhao Wang, Jingfei Qian, Tom Zylkin and Yotov Yoto for their helpful suggestions and comments. This work was supported by the National Social Science Fund of China, grant number 21&ZD093; the National Natural Science Foundation of China, grant number 72073129, 71961147001; and The Agricultural Science and Technology Innovation Program, grant number CAAS-CSAERD-202402, 10-IAED-RC-09-2024, 10-IAED-04-2024.

Appendix A. Appendix

Table A1 Gravity model estimates (country-pair SEs).

	(1)	(2)	(3)	(4)
	1-year interval	2-years interval	3-years interval	4-years interval
BRI_policy	0.285***	0.294***	0.327***	0.300***
	(0.097)	(0.102)	(0.104)	(0.115)
N	500,350	242,738	159,941	109,282
Pseudo R2	0.995	0.995	0.994	0.994
Time period	2001–2019	2001–2019	2001–2019	2003–2019

Dependent variable is the value of aggregate agricultural exports, measured in million dollars. Estimation includes exporter-year, importer-year and country-pair fixed effects. Standard errors clustered by country-pair are in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A2. Robustness check by including BRI lags and EIA covariate (country-pair SEs).

	(1)	(2)	(3)	(4)
	1-year interval	2-year interval	3-year interval	4-year interval
BRI_policy	0.238***	0.238***	0.300***	0.312***
	(0.076)	(0.076)	(0.085)	(0.096)
BRI_Lag1	0.079***	0.079***	0.074	−0.139
	(0.028)	(0.028)	(0.189)	(0.180)
BRI_Lag2	−0.048	−0.048	–	–
	(0.078)	(0.078)	–	–
EIA	0.235***	0.235***	0.273***	0.256***
	(0.038)	(0.038)	(0.041)	(0.045)
N	500,350	242,738	159,941	109,282
Pseudo R2	0.995	0.995	0.994	0.994
Time period	2001–2019	2001–2019	2001–2019	2003–2019

We estimated the Eq. (3) with trade data at different year-intervals, hence BRI lags, $BRI_{ij,t-1}$ and $BRI_{ij,t-2}$, in different columns represent different-year lags. For example, BRI lags are two-year and four-year lags in Column (2) while BRI lags represent three-year and six-year lags in Column (3). Given the limited years in the treatment group, some lags will be omitted automatically in Column (3) and Column (4). Dependent variable is the value of aggregated agricultural exports, measured in million dollars. Estimation includes exporter-year, importer-year and country-pair fixed effects. The estimates use two-way clustered standard errors, clustered by exporter and importer, reported in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A3. Robustness check by including BRI lags and EIA covariate (restrict to 2017).

	(1)	(2)	(3)	(4)
	1-year interval	2-year interval	3-year interval	4-year interval
BRI_policy	0.193*	0.192*	0.201**	0.247**
	(0.103)	(0.108)	(0.099)	(0.100)
BRI_Lag1	−0.183*	−0.187	0.295*	–
	(0.109)	(0.148)	(0.178)	–
BRI_Lag2	−0.002	–	–	–
	(0.066)	–	–	–
EIA	0.174***	0.166***	0.199***	0.208***
	(0.036)	(0.038)	(0.041)	(0.043)
N	437,710	213,244	133,852	107,579
Pseudo R2	0.996	0.996	0.996	0.996
Time period	2001–2017	2001–2017	2002–2017	2001–2017

The meanings of BRI lags are similar with those in Table A2. Because of the shorter research period (2001–2017), more BRI lags will be omitted. Dependent variable is the value of aggregated agricultural exports, measured in million dollars. Estimation includes exporter-year, importer-year and country-pair fixed effects. The estimates use two-way clustered standard errors, clustered by exporter and importer, reported in parentheses.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A4 Heterogeneous effect of BRI varying with agricultural GDP (country-pair SEs).

	(1)	(2)	(3)	(4)	(5)
BRI_policy	0.336***	0.413***	0.377***	0.540***	0.280**
	(0.112)	(0.085)	(0.105)	(0.116)	(0.126)
Top5	−0.304**				
	(0.151)				
BRI_Top5	−0.087				
	(0.179)				
Top10		0.230***			
		(0.053)			
BRI_Top10		−0.396			
		(0.333)			
Top20			0.125***		
			(0.045)		
BRI_Top20			−0.102		
			(0.200)		
Top50				0.051	
				(0.064)	
BRI_Top50				−0.252	
				(0.159)	
Top100					−0.144
					(0.159)

(*continued on next page*)

(*continued*)

	(1)	(2)	(3)	(4)	(5)
BRI_Top100					0.050 (0.166)
N	154,592	154,592	154,592	154,592	154,592
Pseudo R2	0.994	0.994	0.994	0.994	0.994

According to agricultural GDP ranking, China is always a top 5 country. Estimation includes exporter-year, importer-year and country-pair fixed effects. Standard errors are clustered at country-pair level. Time period is 2001 to 2019 with three years interval.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A5 Heterogeneous effect of BRI varying with income (country-pair SEs).

	(1)	(2)	(3)	(4)	(5)	(6)
	value	value	value	value	value	value
BRI_policy	0.327*** (0.107)	0.278** (0.113)	0.384*** (0.117)	0.333** (0.168)	0.166 (0.148)	0.499*** (0.112)
North_to_North	0.288*** (0.080)					
BG1	– –					
North_to_South		−0.304*** (0.077)				
BG2		0.477** (0.186)				
South_to_North			−0.284*** (0.080)			
BG3			−0.478*** (0.170)			
South_to_South				0.288*** (0.080)		
BG4				−0.008 (0.207)		
China_to_South					−0.167* (0.098)	
BG5					0.513** (0.246)	
South_to_China						−0.069 (0.332)
BG6						−0.370 (0.278)
N	154,592	154,592	154,592	154,592	154,592	154,592
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994

Estimation includes exporter-year, importer-year and country-pair fixed effects. Standard errors are clustered at country-pair level. Time period is 2001 to 2019 with three years interval.
* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A6 Heterogeneous effect of BRI varying with trade characteristics (country-pair SEs).

	(1)	(2)	(3)	(4)	(5)	(6)
BRI_policy	0.324*** (0.104)	0.325*** (0.116)	0.299*** (0.113)	0.365*** (0.131)	0.310* (0.160)	0.369*** (0.085)
exp_to_exp	0.043 (0.099)					
BEI1	0.000 (.)					
exp_to_imp		−0.043 (0.099)				
BEI2		−0.001 (0.191)				
imp_to_exp			−0.050 (0.099)			
BEI3			0.288 (0.182)			
imp_to_imp				0.047 (0.099)		
BEI4				−0.075 (0.145)		
China_to_imp					0.256 (0.197)	
BEI5					−0.007	

(*continued on next page*)

(*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
					(0.255)	
imp_to_China						0.113
						(0.278)
BEI6						−0.237
						(0.244)
N	154,592	154,592	154,592	154,592	154,592	154,592
Pseudo R2	0.994	0.994	0.994	0.994	0.994	0.994

Estimation includes exporter-year, importer-year and country-pair fixed effects. Standard errors are clustered at country-pair level. Time period is 2001 to 2019 with three years interval.

* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A7 Trade creation effect.

	(1)	(2)	(3)	(4)
	1-year interval	2-year interval	3-year interval	4-year interval
BRI_policy	0.756***	0.833***	0.891***	0.692***
	(0.103)	(0.110)	(0.108)	(0.119)
BRI_single_i	0.379***	0.401***	0.417***	0.314***
	(0.025)	(0.026)	(0.029)	(0.029)
BRI_single_j	0.580***	0.634***	0.617***	0.466***
	(0.070)	(0.071)	(0.079)	(0.067)
N	511,689	247,450	163,387	111,060
Pseudo R2	0.980	0.978	0.976	0.977
Time period	2001–2019	2001–2019	2001–2019	2003–2019

Dependent variable is the value of aggregate agricultural exports, measured in million dollars. Estimation includes only country-pair fixed effects. Exporter-year and importer-year fixed effects are excluded due to collinearity with "single member" dummy variables. The estimates use Country-pair SEs reported in parentheses.

* $p < .10$, ** $p < .05$, *** $p < .01$.

Table A8 General equilibrium effect of BRI (complete version).

	(1)	(2)	(3)	(4)	(5)	(6)
	Conditional GE	Full endowment general equilibrium				
	% Δ Xi CDL	% Δ Xi_Full	% Δ Real_output	% Δ IMR	% Δ OMR	% Δ Price
China	16.60	16.20	0.07	−0.47	0.46	−0.40
Mongolia	6.91	8.32	0.89	0.78	−1.97	1.66
Niger	7.54	7.98	0.13	0.14	−0.32	0.27
Bangladesh	7.02	6.87	0.02	−0.18	0.19	−0.16
Gambia	4.74	6.10	0.66	0.93	−1.87	1.57
Malaysia	5.70	5.97	0.23	−0.03	−0.24	0.20
Viet Nam	5.86	5.83	0.28	−0.36	0.09	−0.08
Republic of Korea	5.02	4.46	0.05	−0.54	0.57	−0.49
Mali	3.40	4.39	0.04	0.64	−0.80	0.68
Indonesia	4.37	4.32	0.07	−0.17	0.11	−0.09
Above in the main text						
Philippines	3.78	3.87	0.09	−0.06	−0.04	0.03
Russian Federation	3.31	3.79	0.16	0.28	−0.51	0.43
Thailand	2.57	3.50	0.18	0.75	−1.11	0.94
Equatorial Guinea	0.39	3.18	1.87	1.04	−3.44	2.86
Lao People's Dem. Rep.	1.42	3.08	0.14	1.71	−2.19	1.84
Senegal	2.56	3.02	0.15	0.21	−0.43	0.37
Zambia	1.83	3.00	0.05	0.86	−1.07	0.91
Congo	1.44	2.97	0.21	1.60	−2.14	1.80
Mozambique	1.67	2.96	0.15	1.27	−1.68	1.42
Solomon Islands	0.01	2.91	2.98	−0.01	−3.47	2.88
Nepal	3.03	2.81	0.00	−0.25	0.28	−0.24
Uruguay	1.37	2.63	0.38	1.13	−1.79	1.51
Gabon	0.01	2.48	2.21	0.31	−2.95	2.46
Cabo Verde	1.86	2.35	0.11	0.26	−0.43	0.37
Togo	1.28	2.31	0.03	0.91	−1.11	0.94
Sierra Leone	1.59	2.30	0.13	0.54	−0.79	0.67
Kyrgyzstan	2.28	2.28	0.06	−0.15	0.11	−0.10
Guinea	2.30	2.25	0.04	−0.12	0.09	−0.08
Papua New Guinea	0.18	2.17	2.03	0.00	−2.37	1.99

(*continued on next page*)

(*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	Conditional GE	Full endowment general equilibrium				
	% Δ Xi CDL	% Δ Xi_Full	% Δ Real_output	% Δ IMR	% Δ OMR	% Δ Price
Lesotho	0.10	2.10	1.72	0.29	−2.36	1.98
Benin	1.05	1.96	0.07	0.90	−1.14	0.97
Zimbabwe	0.39	1.94	0.76	0.86	−1.90	1.60
Venezuela	1.94	1.88	0.02	−0.19	0.19	−0.16
Myanmar	0.45	1.79	3.01	−1.66	−1.55	1.31
New Zealand	0.47	1.65	0.32	1.00	−1.56	1.32
British Virgin Islands	0.00	1.41	0.57	−0.83	0.30	−0.26
Uzbekistan	0.10	1.38	1.64	−0.38	−1.47	1.25
Nigeria	0.94	1.31	0.03	0.22	−0.29	0.25
Pakistan	1.16	1.23	0.09	−0.06	−0.04	0.03
Algeria	1.15	1.12	0.01	−0.10	0.11	−0.09
Iran	1.07	1.03	0.01	−0.06	0.05	−0.05
Belarus	0.83	1.03	0.01	0.05	−0.07	0.06
Suriname	0.49	0.98	0.11	0.44	−0.65	0.56
Morocco	0.98	0.92	0.08	−0.18	0.12	−0.10
Sri Lanka	0.87	0.92	0.09	−0.08	0.00	0.00
Kazakhstan	0.48	0.92	0.05	0.04	−0.10	0.09
Cameroon	0.31	0.85	0.02	0.59	−0.71	0.61
Chile	0.40	0.77	0.10	0.34	−0.52	0.44
Egypt	0.74	0.76	0.02	−0.02	0.00	0.00
Cambodia	0.04	0.69	−0.04	0.66	−0.73	0.62
Seychelles	0.69	0.68	0.17	−0.24	0.08	−0.07
Trinidad and Tobago	0.66	0.67	0.09	−0.17	0.09	−0.08
Tajikistan	0.37	0.65	0.02	0.15	−0.19	0.16
Barbados	0.59	0.65	0.03	−0.07	0.04	−0.03
Sudan	0.19	0.61	0.01	0.47	−0.57	0.49
South Africa	0.36	0.60	0.06	0.16	−0.25	0.21
Ethiopia	0.04	0.57	−0.03	0.60	−0.67	0.57
Grenada	0.29	0.54	0.01	0.19	−0.24	0.20
Poland	0.51	0.54	0.03	−0.04	0.01	−0.01
Liberia	0.03	0.53	1.47	−0.98	−0.56	0.48
United Republic of Tanzania	0.07	0.53	−0.02	0.53	−0.59	0.50
Guyana	0.19	0.51	0.19	0.14	−0.39	0.33
Panama	0.40	0.50	0.10	0.00	−0.12	0.10
Angola	0.17	0.44	0.00	0.12	−0.14	0.12
Peru	0.23	0.41	0.02	0.15	−0.20	0.17
Singapore	0.31	0.40	0.53	−0.47	−0.07	0.06
Kuwait	0.43	0.40	0.06	−0.13	0.08	−0.07
Ghana	0.20	0.40	0.00	0.13	−0.15	0.13
United Arab Emirates	0.46	0.38	0.15	−0.24	0.10	−0.09
Yemen	0.34	0.38	0.01	−0.01	0.00	0.00
Bosnia Herzegovina	0.35	0.37	0.01	−0.03	0.03	−0.02
Burundi	0.13	0.36	0.00	0.10	−0.12	0.11
Greece	0.31	0.36	0.01	0.01	−0.03	0.02
Portugal	0.33	0.35	0.02	−0.01	−0.01	0.01
The Former Yugoslav Republic of Macedonia	0.28	0.32	0.02	−0.04	0.01	−0.01
Czechia	0.26	0.31	0.04	0.00	−0.05	0.04
Croatia	0.32	0.31	0.03	−0.06	0.04	−0.04
Lebanon	0.38	0.30	0.02	−0.09	0.08	−0.07
El Salvador	0.28	0.30	0.02	−0.07	0.05	−0.04
Italy	0.29	0.30	0.02	−0.03	0.02	−0.01
Latvia	0.13	0.29	0.05	0.10	−0.17	0.14
Ukraine	0.14	0.29	0.01	0.14	−0.17	0.15
Azerbaijan	−0.09	0.29	0.00	0.20	−0.23	0.20
Lithuania	0.15	0.28	0.06	0.02	−0.10	0.08
Qatar	0.32	0.28	0.02	−0.09	0.07	−0.06
Vanuatu	0.04	0.26	0.10	0.05	−0.18	0.15
Chad	0.01	0.26	0.00	0.20	−0.24	0.20
Ecuador	0.08	0.25	0.04	0.09	−0.15	0.13
Fiji	−0.19	0.25	−0.03	0.27	−0.28	0.24
Estonia	0.08	0.24	0.02	0.12	−0.16	0.14
Dominican Republic	0.25	0.24	0.02	−0.07	0.05	−0.04
Mauritania	0.02	0.24	0.59	−0.41	−0.21	0.18
Bahrain	0.23	0.23	0.10	−0.12	0.02	−0.02
Paraguay	0.01	0.20	0.01	0.06	−0.08	0.07

(*continued on next page*)

(*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	Conditional GE	Full endowment general equilibrium				
	% Δ Xi CDL	% Δ Xi_Full	% Δ Real_output	% Δ IMR	% Δ OMR	% Δ Price
Slovakia	0.13	0.19	0.02	0.02	−0.05	0.04
Bulgaria	0.15	0.17	0.04	−0.04	0.00	0.00
Republic of Moldova	0.04	0.17	0.01	0.05	−0.07	0.06
Uganda	0.01	0.17	0.05	0.10	−0.17	0.14
Turkey	0.06	0.16	0.00	0.04	−0.05	0.04
China, Macao Special Administrative Region	0.32	0.14	0.05	−0.21	0.19	−0.16
Iraq	−0.02	0.14	0.00	0.04	−0.05	0.04
Afghanistan	0.02	0.14	0.08	0.02	−0.12	0.10
Slovenia	0.12	0.14	0.03	−0.03	−0.01	0.01
Swaziland	−0.04	0.13	−0.13	0.23	−0.12	0.10
Libya	0.01	0.12	0.10	−0.01	−0.10	0.09
Austria	0.09	0.11	0.02	−0.02	0.00	0.00
Cyprus	0.05	0.10	0.01	0.01	−0.03	0.02
Cook Islands	−0.01	0.10	−0.02	0.08	−0.07	0.06
Côte d'Ivoire	0.01	0.10	0.00	0.08	−0.08	0.07
Hungary	0.06	0.09	0.01	0.01	−0.02	0.02
Luxembourg	0.04	0.09	0.04	0.00	−0.04	0.04
Madagascar	0.00	0.09	−0.01	0.09	−0.09	0.07
Costa Rica	0.08	0.08	0.08	−0.09	0.02	−0.01
Kiribati	0.00	0.08	−0.12	0.14	−0.03	0.02
Federated State of Micronesia	0.01	0.08	0.06	−0.03	−0.03	0.03
Plurinational State of Bolivia	−0.01	0.08	−0.01	0.06	−0.06	0.05
Wallis and Futuna Islands	0.00	0.07	−0.14	0.07	0.08	−0.07
Israel	0.01	0.07	0.00	0.02	−0.03	0.02
Jamaica	−0.06	0.07	0.00	0.04	−0.04	0.04
Saint Vincent and the Grenadines	−0.03	0.07	−0.01	0.04	−0.04	0.03
Iceland	0.00	0.07	0.00	0.03	−0.03	0.03
Sao Tome and Principe	0.00	0.06	−0.05	0.09	−0.04	0.03
Saint Helena	0.00	0.05	−0.04	0.05	−0.01	0.01
Samoa	−0.06	0.05	−0.07	0.10	−0.04	0.03
Norway, Svalbard and Jan Mayen	0.00	0.05	0.00	0.02	−0.02	0.02
Dominica	0.00	0.05	−0.01	0.04	−0.03	0.03
Malawi	−0.02	0.05	−0.02	0.04	−0.03	0.02
Cuba	0.01	0.05	0.48	−0.46	−0.02	0.02
Comoros	−0.08	0.05	−0.10	0.14	−0.06	0.05
Kenya	−0.04	0.04	−0.02	0.07	−0.07	0.06
Somalia	−0.05	0.04	−0.27	0.32	−0.07	0.06
Anguilla	0.00	0.04	0.05	−0.05	0.00	0.00
San Marino	0.00	0.02	−0.01	0.00	0.00	0.00
Netherlands	0.00	0.02	−0.03	0.04	−0.01	0.01
Tonga	−0.04	0.01	−0.68	0.70	−0.03	0.02
Djibouti	−0.03	0.01	−0.17	0.20	−0.03	0.02
Bermuda	0.00	0.01	0.05	−0.08	0.03	−0.03
Greenland	0.00	0.01	−0.13	0.11	0.03	−0.02
Ireland	−0.01	0.01	0.00	0.01	0.00	0.00
Spain	−0.01	0.01	0.00	0.00	0.00	0.00
Colombia	0.02	0.00	0.00	−0.04	0.04	−0.04
Norfolk Islands	0.00	0.00	−0.29	0.26	0.04	−0.03
Cayman Islands	−0.01	0.00	−0.16	0.14	0.02	−0.02
Bahamas	0.00	0.00	0.08	−0.11	0.03	−0.02
Andorra	0.00	−0.01	−0.05	0.02	0.03	−0.03
Belize	−0.08	−0.01	−0.08	0.08	0.00	0.00
Honduras	0.01	−0.01	0.01	−0.04	0.04	−0.04
Brunei Darussalam	−0.20	−0.01	−0.01	0.04	−0.04	0.03
Belgium	−0.05	−0.02	−0.03	0.05	−0.02	0.02
Maldives	−0.02	−0.02	−0.02	0.00	0.02	−0.02
Bhutan	−0.10	−0.02	−0.18	0.19	−0.02	0.02
Germany	−0.04	−0.02	−0.01	0.01	0.00	0.00
Syria	−0.01	−0.02	−0.06	0.04	0.02	−0.02
Sweden	−0.07	−0.03	−0.01	0.03	−0.03	0.02
Turks and Caicos Islands	0.00	−0.03	−0.13	0.08	0.06	−0.05
Palau	−0.02	−0.03	−0.14	0.12	0.02	−0.02
Haiti	0.00	−0.03	0.00	−0.06	0.06	−0.05
Guatemala	0.00	−0.04	0.02	−0.08	0.06	−0.06
Namibia	−0.21	−0.04	−0.07	0.17	−0.12	0.10

(*continued on next page*)

(*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	Conditional GE	Full endowment general equilibrium				
	% Δ Xi CDL	% Δ Xi_Full	% Δ Real_output	% Δ IMR	% Δ OMR	% Δ Price
Mexico	0.00	−0.05	0.00	−0.07	0.09	−0.08
Albania	−0.18	−0.06	0.00	0.05	−0.05	0.04
Oman	0.00	−0.06	0.01	−0.09	0.09	−0.08
Georgia	−0.26	−0.06	−0.02	0.14	−0.15	0.13
Marshall Islands	−0.07	−0.07	−0.07	0.05	0.02	−0.02
Tokelau	0.00	−0.07	−0.25	0.15	0.11	−0.10
Eritrea	−0.21	−0.08	−0.07	0.13	−0.07	0.06
Guinea-Bissau	−0.15	−0.08	−0.08	0.10	−0.02	0.02
Denmark	−0.08	−0.08	−0.02	0.01	0.02	−0.01
France, Monaco	−0.10	−0.08	−0.01	0.01	0.00	0.00
Nicaragua	−0.06	−0.09	−0.03	−0.02	0.05	−0.05
Switzerland, Liechtenstein	−0.13	−0.11	−0.01	0.02	−0.01	0.01
Armenia	−0.45	−0.13	−0.01	0.16	−0.18	0.15
United Kingdom	−0.16	−0.13	−0.02	0.03	−0.02	0.01
Jordan	−0.17	−0.13	−0.04	0.04	0.00	0.00
Argentina	−0.02	−0.13	−0.02	−0.13	0.17	−0.14
Burkina Faso	−0.13	−0.14	−0.07	−0.01	0.10	−0.08
Malta	−0.20	−0.15	−0.02	0.05	−0.03	0.03
Tunisia	−0.23	−0.16	−0.01	0.03	−0.02	0.02
Central African Republic	−0.13	−0.19	−0.30	0.21	0.10	−0.08
Antigua and Barbuda	−0.33	−0.20	−0.10	0.15	−0.05	0.04
Finland	−0.33	−0.20	−0.03	0.10	−0.08	0.07
Brazil	−0.01	−0.21	−0.01	−0.19	0.24	−0.21
Saint Kitts and Nevis	−0.29	−0.21	−0.16	0.19	−0.03	0.02
Canada	−0.12	−0.22	−0.05	−0.06	0.13	−0.11
Saint Lucia	−0.35	−0.23	−0.05	0.13	−0.09	0.08
India	−0.16	−0.24	−0.03	−0.07	0.12	−0.10
Nauru	−0.22	−0.25	−0.24	0.16	0.08	−0.07
Botswana	−0.48	−0.26	−0.21	0.33	−0.14	0.12
Mauritius	−0.48	−0.29	−0.05	0.12	−0.08	0.07
French Polynesia	−0.47	−0.30	−0.38	0.50	−0.14	0.12
Saudi Arabia	−0.28	−0.32	0.00	−0.03	0.03	−0.03
China, Hong Kong Special Administrative Region	−0.02	−0.36	−0.41	0.08	0.39	−0.34
Australia	−0.28	−0.40	−0.07	−0.08	0.18	−0.15
Democratic People's Republic of Korea	−0.01	−0.40	−0.30	−0.09	0.45	−0.39
Turkmenistan	−0.52	−0.41	−0.06	0.11	−0.06	0.05
Rwanda	−0.75	−0.45	−0.01	0.15	−0.17	0.14
USA, Puerto Rico and US Virgin Islands	−0.37	−0.46	−0.04	−0.07	0.12	−0.11
New Caledonia	−1.01	−0.71	−0.17	0.36	−0.23	0.20
Japan	−0.88	−0.83	0.00	−0.03	0.04	−0.03

References

Agnosteva, D. E., Anderson, J. E., & Yotov, Y. V. (2019). Intra-national trade costs: Assaying regional frictions. *European Economic Review, 112*, 32–50.

Anderson, J. E., Larch, M., & Yotov, Y. V. (2018). GEPPML: General equilibrium analysis with PPML. *The World Economy, 41*, 2750–2782.

Anderson, J. E., & van Wincoop, E. (2003). Gravity with gravitas: A solution to the border puzzle. *American Economic Review, 93*, 170–192.

Anderson, J. E., & Yotov, Y. V. (2016). Terms of trade and global efficiency effects of free trade agreements, 1990–2002. *Journal of International Economics, 99*, 279–298.

Baier, S. L., & Bergstrand, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics, 71*, 72–95.

Baier, S. L., Bergstrand, J. H., & Clance, M. W. (2018). Heterogeneous effects of economic integration agreements. *Journal of Development Economics, 135*, 587–608.

Baier, S. L., Yotov, Y. V., & Zylkin, T. (2019). On the widely differing effects of free trade agreements: Lessons from twenty years of trade integration. *Journal of International Economics, 116*, 206–226.

Bandiera, L., & Tsiropoulos, V. (2020). A framework to assess debt sustainability under the belt and road initiative. *Journal of Development Economics, 146*, Article 102495.

Baniya, S., Rocha, N., & Ruta, M. (2020). Trade effects of the new silk road: A gravity analysis. *Journal of Development Economics, 146*, 102467.

Bergstrand, J. H., Larch, M., & Yotov, Y. V. (2015). Economic integration agreements, border effects, and distance elasticities in the gravity equation. *European Economic Review, 78*, 307–327.

Bird, J., Lebrand, M., & Venables, A. J. (2020). The belt and road initiative: Reshaping economic geography in Central Asia? *Journal of Development Economics, 144*, 102441.

Chen, M. X., & Lin, C. (2020). Geographic connectivity and cross-border investment: The belts, roads and skies. *Journal of Development Economics, 146*, Article 102469.

de Soyres, F., Mulabdic, A., & Ruta, M. (2020). Common transport infrastructure: A quantitative model and estimates from the belt and road initiative. *Journal of Development Economics, 143*, 102415.

Eaton, J., & Kortum, S. (2002). Technology, geography, and trade. *Econometrica, 70*, 1741–1779.

Egger, P. H., & Nigai, S. (2015). Structural gravity with dummies only: Constrained ANOVA-type estimation of gravity models. *Journal of International Economics, 97*, 86–99.

Egger, P. H., & Tarlea, F. (2015). Multi-way clustering estimation of standard errors in gravity models. *Economics Letters, 134*, 144–147.

Elobeid, A., Carriquiry, M., Dumortier, J., Swenson, D., & Hayes, D. (2021). China-U.S. trade dispute and its impact on global agricultural markets, the U.S. economy, and greenhouse gas emissions. *Journal of Agricultural Economics, 72*, 647–672.

Fally, T. (2015). Structural gravity and fixed effects. *Journal of International Economics, 97*, 76–85.

Ferdinand, P. (2016). Westward ho—The China dream and 'one belt, one road': Chinese foreign policy under xi Jinping. *International Affairs, 92*, 941–957.

He, X. (2021). Regional trade agreements and excluded countries. *American Journal of Agricultural Economics, 104*, 428–449.

Huang, Y. (2016). Understanding China's Belt & Road Initiative: Motivation, framework and assessment. *China Economic Review, 40*, 314–321.

Jackson, K., & Shepotylo, O. (2021). Belt and road: The China dream? *China Economic Review, 67*, 101604.

Larch, M., Tan, S. W., & Yotov, Y. V. (2023). A simple method to ex-ante quantify the unobservable effects of trade liberalization and trade protection. *Journal of Comparative Economics, 51*, 1200–1213.

Larch, M., Wanner, J., Yotov, Y. V., & Zylkin, T. (2018). Currency unions and trade: A PPML re-assessment with high-dimensional fixed effects. *Oxford Bulletin of Economics and Statistics, 81*, 487–510.

McFadden, J. R. (2021). International trade and standards harmonization: The case of tractors and the OECD tractor codes. *American Journal of Agricultural Economics, 104*, 1512–1539.

Olper, A., & Raimondi, V. (2008). Agricultural market integration in the OECD: A gravity-border effect approach. *Food Policy, 33*, 165–175.

Ridley, W., & Devadoss, S. (2023). Competition and trade policy in the world cotton market: Implications for US cotton exports. *American Journal of Agricultural Economics, 105*, 1365–1387.

Ridley, W., Luckstead, J., & Devadoss, S. (2022). Wine: The punching bag in trade retaliation. *Food Policy, 109*, Article 102250.

Santos Silva, J. M. C., & Tenreyro, S. (2022). The log of gravity at 15. *Portuguese Economic, 21*, 423–437.

Silva, J. M. C. S., & Tenreyro, S. (2006). The log of gravity. *The Review of Economics and Statistics, 88*, 641–658.

de Soyres, F., Mulabdic, A., Murray, S., Rocha, N., & Ruta, M. (2019). How much will the belt and road initiative reduce trade costs? *International Economics, 159*, 151–164.

Sun, L., & Reed, M. R. (2010). Impacts of free trade Agreements on agricultural trade creation and trade diversion. *American Journal of Agricultural Economics, 92*, 1351–1363.

Weidner, M., & Zylkin, T. (2021). Bias and consistency in three-way gravity models. *Journal of International Economics, 132*, 103513.

Yang, S., & Martinez-Zarzoso, I. (2014). A panel data analysis of trade creation and trade diversion effects: The case of ASEAN–China free trade area. *China Economic Review, 29*, 138–151.

Yotov, Y., Piermartini, R., Monteiro, J., & Larch, M. (2016). *An advanced guide to trade policy analysis: The structural gravity model*.

Yu, L., Zhao, D., Niu, H., & Lu, F. (2020). Does the belt and road initiative expand China's export potential to countries along the belt and road? *China Economic Review, 60*, Article 101419.

Lim, G., Li, C., & Adi, S. E. (2021). Why is it so hard to push Chinese railway projects in Southeast Asia? The role of domestic politics in Malaysia and Indonesia. *World Development, 138*, 105272.

Herman, P. R., & Oliver, S. (2023). Trade, policy, and economic development in the digital economy. *Journal of Development Economics, 164*, 103135.

Cheng, N. F. L., Hasanov, A. S., Poon, W. C., & Bouri, E. (2023). The US-China trade war and the volatility linkages between energy and agricultural commodities. *Energy Economics, 120*, 106605.