



# Reconfiguring maritime networks due to the Belt and Road Initiative: impact on bilateral trade flows

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## Abstract

This paper aims to analyse the potential effects on bilateral trade movements of the reconfiguration of maritime networks brought about by the Belt and Road Initiative (BRI). The gravity model of international trade is applied to examine the hypothesized impact of maritime network reconfiguration on the bilateral trade between nine exporting countries (Egypt, Saudi Arabia, Israel, Panama, Colombia, Costa Rica, Singapore, Malaysia and Indonesia) and their 128 trading partners. The panel data on the five components of the Liner Shipping Bilateral Connectivity Index, the export value, the gross domestic product (GDP) of the nine exporting countries, the GDP of their trading partners and the maritime distance linking them to these 128 trading partners for each of the years from 2008 to 2016 are used in the analysis. The results show that the estimated coefficient for the number of transshipments is negative, revealing an inverse relationship between transshipments and bilateral exports, reconfirming that a redesign of the maritime supply chain network in response to the BRI could significantly improve bilateral export values. Furthermore, a reduction in the number of required transshipments, because of a reconfiguration of maritime networks with BRI trading partners, will improve the maritime network structure between countries located along the three strategic chokepoints: the Suez Canal, the Panama Canal, and the Strait of Malacca. In general terms, the BRI-driven reconfiguration of maritime supply networks is linked to an improvement in the productivity of nine exporting countries. An innovative gravity-based econometric model, estimated on a large set of panel data, is introduced below, aiming at the modelling of the effect of BRI on supply chain network reconfiguration.

**Keywords** Maritime network reconfiguration · Belt and Road Initiative · Bilateral exports · Gravity model · Poisson Pseudo Maximum Likelihood (PPML)

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## 1 Introduction

Maritime networks are logistics routes containing strategic locations as critical points of passage. These maritime networks support commercial shipping which serves the major markets of commercial trade in the world, such as Western Europe, North America, and East Asia (Rodrigue 2016). The most influential and critical maritime routes/hubs are known as chokepoints (or bottlenecks). They are not only vulnerable to global shocks, extreme weather events or social and political unrest, but also subject to capacity constraints and the possibility of severe disruption or even closure of business operations (Notteboom et al. 2020). The grounding of the large container ship “Ever Given” in late March 2021 provides irrevocable evidence for the strategic importance of these chokepoints; the ship blocked the Suez Canal to all traffic for a week, contributing to a further increase in the already very high freight rates<sup>1</sup> (due to COVID-19), deterioration in North American port congestion, and an expected—albeit temporary—negative impact on world trade. Supply chain reconfiguration of maritime networks involves the redesign of the physical infrastructure and the patterns of material flow.

Since the early 1990s, supply chain reconfiguration has been a widely practiced strategy among many global firms to help adapt to changing supply–demand dynamics in a deregulated global market. The main driving forces behind the reconfiguration strategy include growing international competitive pressure, changing preferences relating to market requirements, developments in information and communication technology (ICT) and global freight transport systems, and increasing uncertainties in supply chain decision making processes (Arntzen et al. 1995; Lemoine and Skjoett-Larsen 2004; Van Der Vorst and Beulens 2002; Govindan et al. 2015). The main objective of reconfiguration is to improve the efficiency of global supply chains, and their effectiveness in trade facilitation and sustainability. The key objective for firms is to improve internal capabilities to better, and more productively, integrate their local supply chains into global supply chains (Lemoine and Skjoett-Larsen 2004). Thus, reconfiguration is considered an effective strategy to obtain access to the required production capability and logistics functionality at an exact point of time and location (Koren 2010).

It is expected that China’s investment in strategic locations such as ports, airports and other associated transport infrastructure around the world, under its Belt and Road Initiative (BRI), will significantly transform the global maritime network. Haralambides and Merk (2020) identify four transport-linked adaptations within the BRI in order to evaluate the potential effect of the BRI on global maritime trade movements: (i) managing existing maritime routes to secure trade flows in all situations; (ii) the creation of alternative routes to avoid the possibility of over-dependence on existing routes; (iii) improving transport infrastructure to create new trade; and (iv) potential modal shifts. Cariou (2020) suggests that the new routes encompassed within the BRI could significantly impact future trade volume, direction and

<sup>1</sup> UNCTAD, based on data provided by Clarksons Intelligence Network.



modal shifts, particularly from ocean to rail. The BRI is likely to create a Sino-centric world order to facilitate the movement of goods via designated trade corridors. China's BRI is most likely, therefore, to constitute a major disruptor of the global maritime supply chain network and, arguably, the bilateral shipping connectivity of participating countries in the BRI is expected to improve, at least with China and other countries on the BRI. In a significant way, therefore, China's BRI has the potential to result in the reorganisation and redefining of the order of global trade connectivity and the international logistics network. Consequently, this will necessitate the re-engineering of the ways in which participating countries, whether directly or indirectly, link to and operate within global supply chains.

This study provides an insight into this likely re-globalisation of trade through an examination of the potential impact of the BRI-led reconfiguration of the maritime network on bilateral trade flows. For this analysis, the focus is on nine exporting countries, based on their strategic location along the major global maritime transport superhighways. These include countries with main ports along or near the Suez Canal (Egypt, Saudi Arabia and Israel), the Panama Canal (Panama, Colombia and Costa Rica) and the Strait of Malacca (Singapore, Malaysia and Indonesia). These countries have ports in the most strategic maritime locations and constitute, therefore, key logistics hubs in global trade. However, their connectivity index levels vary widely. For instance, in 2016, the liner shipping connectivity index for Egypt was 62.49, while Israel's index was 37.36. Similarly, the index for Malaysia was 106.7 in comparison to 27.18 for Indonesia.<sup>2</sup> Thus, the sample comprises countries with different levels of shipping connectivity.

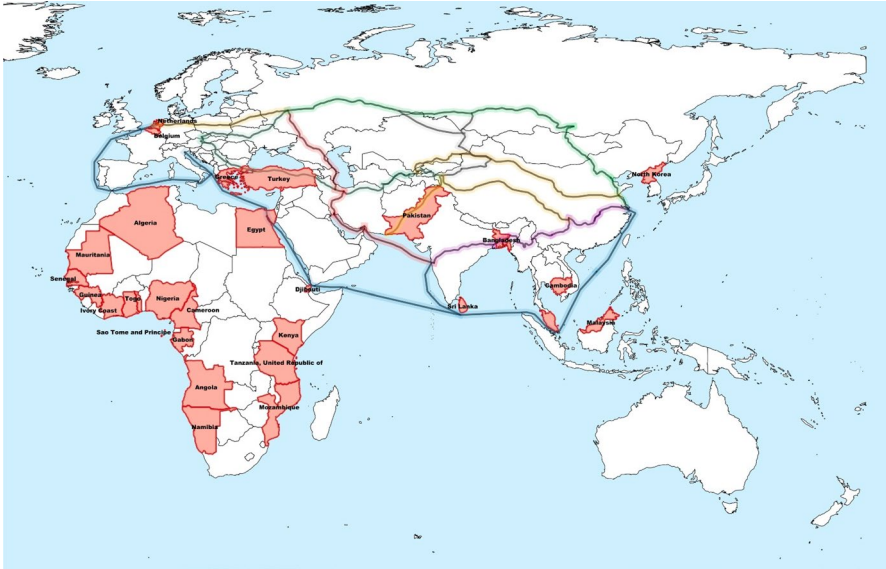
Out of their 128 trading partners, 28 have ports located along, and are part of, the BRI (see Fig. 1). These participating countries, as shown in the map in Fig. 1 in a light red colour, are Korea, Malaysia, Cambodia, Sri Lanka, Pakistan, Bangladesh, Egypt, Turkey, Belgium, the Netherlands, Greece, Djibouti, Kenya, Tanzania, Namibia, Angola, Mauritania, Nigeria, Algeria, Senegal, Guinea, Ivory Coast, Ghana, Togo, Sao Tome, Cameroon, Gabon and Mozambique (OECD 2018; Wang et al. 2021).<sup>3</sup>

In this study, two plausible scenarios are developed to evaluate the likelihood of potential connectivity improvements from BRI investments. The first scenario assumes that the minimum number of required transshipments in the trade between the nine exporting countries and these 28 trading partners will reduce by one, while the minimum number of required transshipments in the trade with the rest of their

<sup>2</sup> The values reported here are those from the UNCTAD Liner Shipping Connectivity Index (LSCI) published during the years covered by the study. UNCTAD has recently updated the methodology of the calculation (See Box 3.1 here <https://unctad.org/webflyer/review-maritime-transport-2019>) and the LSCI values published today for those years are slightly different (see <https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=92>). However, the order of magnitude and differences between the countries reported here has not changed. For our paper, we report on the LSCI and LSBCI that correspond to the components used and assessed in our model.

<sup>3</sup> Although China has signed an MoU, before December 2017, with 64 countries along the BRI (see Chen et al., 2021), only those 28 countries that have ports located along and are part of the BRI are included (see OECD 2018).





**Fig. 1** The Network Configuration of the Belt and Road Initiative (key trade corridors and selected participating countries). (Source: Authors' own compilation)

trading partners remains the same. The second scenario assumes that the minimum number of required transshipments in the trade with these 28 trading partners will be zero in the long run, while the minimum number of required transshipments in the trade with the rest of the trading partners remains the same.

## 2 Literature review

### 2.1 Supply chain reconfiguration

Supply chain reconfiguration is the design process of continuous and effective adjustment of business operations to maintain productivity, efficiency, resilience, and competitiveness of supply chains, especially in the context of a globally competitive and uncertain business environment (Tian and Guo 2019). Supply chain reconfiguration involves designing supply chains to optimise performance in response to the changing domestic or international trade landscapes. The process should result in a reorganisation and repositioning of operations within the supply chain to enhance performance and, as suggested by Meixell and Gargeya (2005), to respond to a supply chain design problem. They explain that a supply chain design involves decisions regarding “the number and location of production facilities, the amount of capacity at each facility, the assignment of each market region to one or more locations, and supplier selection for sub-assemblies, components and materials” (p. 2) (see also Chopra and Meindl 2004). It is these various elements, in the production and distribution process, that are re-examined in the process of reconfiguration.



Thus, as supply chains become more competitive and globally complex, characterised by limited visibility, and increased uncertainty and unpredictability, the need for continuous adjustment of supply chain configuration is necessary to ensure optimal productivity, performance and flexibility at all times (Beamon 1998; Oh et al. 2013; Dev et al. 2016). For this reason, over the past three decades an increasing amount of research has been dedicated towards supporting and informing businesses on how to ensure adaptability and performance through supply chain reconfiguration (Dev et al. 2016; Beamon 1998; Kristiano et al. 2012; Kirkwood et al. 2005; Chan and Chan 2010; Graves and Willems 2005; Lee 1996).

There has been a large number of studies investigating various aspects of supply chain reconfiguration. However, the majority of this research has focused on the reconfiguration of commodity supply chains (see, for example, Chunxia and Shensheng 2001; Lee et al. 2008; Osman and Demirli 2010; Kristianto et al. 2012; Dev et al. 2016; Martins et al. 2017; Jiang et al. 2018; Mondragon et al. 2018; Tian and Guo 2019; Tziantopoulos et al. 2019; Feitó-Cespón et al. 2021). This leaves the reconfiguration of *services* supply chains largely unexplored (Lemoine and Skjoett-Larsen 2004).

While most studies on supply chain reconfiguration have focused on manufacturing, only a few have been dedicated to examining the reconfiguration of distribution, particularly in relation to transport network reconfiguration. The exception is Derigs and Illing (2013) who examine how cargo airlines may reconfigure routes in order to meet the EU's CO2 emissions regulation whilst maintaining profitability. They conclude that the proposed regulation will result in little or no effect towards reducing emissions and that only "drastic network reconfiguration by hub relocation" might succeed in bringing about emissions reduction as well as cost reduction (p. 526). Zhao et al. (2016) also focus on transport network reconfiguration and investigate the possibility of an integrated approach to accomplishing transport network reconfiguration and routing for synchronous evacuation during disaster situations. Similarly, the Lemoine and Skjoett-Larsen's (2004) study focuses on transport services but, rather than examining how transport routes and networks reconfigure, they examine the implications of supply chain reconfiguration on transport service demand.

Interestingly, the majority of extant literature on (transport) network reconfiguration is on internet distribution networks (e.g. Aguado et al. 2016; Ping et al. 2005; Shen and Zukerman 2012), while a search for maritime network reconfiguration highlights studies relating to shipboard electric power systems (e.g., Atteya et al. 2017; Zhao, et al. 2016; Huijuan et al. 2014; Zhang et al. 2017; Agnello et al. 2017). However, some recent research, albeit limited, has been developed which more closely focuses on maritime network reconfiguration.

A few studies have focussed on the nature of port competitiveness and its impact on the configuration of container shipping networks. In this respect, a port's accessibility to maritime networks (a more holistic concept than 'connectivity') has been identified as an important contributor to its competitive position. As such, outcomes from this body of research typically recommend that ports implement policies and actions which seek to influence the reconfiguration of maritime networks (e.g. Berli et al. 2018; Cullinane and Wang 2009, 2012; Ducruet and Notteboom 2012; Guo



and Yang 2018; Wang and Cullinane 2008, 2014, 2016; Wilmsmeier and Notteboom 2011; Xu et al. 2020).

Dai et al. (2018) investigate shipping lines' operational cost and CO<sub>2</sub> emissions under different geo-network configurations when an emission charge is imposed and conclude that “shipping firms' network configuration is influenced by emission charges, fuel price, port loading and unloading cost, and demand pattern of cargo transport across different markets” and that if the charge is above a certain threshold, shipping lines “will reconfigure shipping networks to minimize their costs including emission charge payments”. On the other hand, Fan et al. (2010) explore the reconfiguration impact of nodal constraints (such as congestion) within the logistics channel. They suggest that the optimisation of ship size, route, port and hinterland shipping corridors have a significant impact on shipping flows.

It can be concluded, therefore, that whereas there is a large body of literature on various aspects, (e.g., maritime transport efficiency, operations optimisation, port and hinterland logistics efficiency and competitiveness, shipping operations cost, etc.) so far, there exists only a limited number of studies with a specific focus on maritime (transport) network reconfiguration, leaving a gap in the literature. More research is therefore needed to examine how international maritime transportation may be reconfigured to enhance efficiency and cost reduction in the face of growing international trade complexity and increasing international consumer demands. This research paper seeks to contribute to filling this gap by investigating the reconfiguration impact of China's Belt and Road Initiative (BRI), through which significant investment has been directed towards transport infrastructure development in key countries along the BRI, including ports and connecting hinterland roads and rail infrastructure.

## 2.2 The Belt and Road Initiative

The Belt and Road Initiative (BRI) was introduced in 2013 and officially published in 2015 by the Chinese government (NDRC 2015), with the objective of boosting regional economic cooperation through infrastructure development, in the first instance, and to enhance trade partnerships and transport connectivity, particularly to Europe but also with the rest of the world (Georgiev 2015; Lee et al. 2018; Huang 2016). Huang (2016) explains that the BRI is essentially a redefinition of the 19th Century land-based Silk Road Economic Belt (the Belt), which includes a maritime aspect—the 21st Century Maritime Silk Road (the road) (see also Du 2016; Cullinane et al. 2018).

The ambitious scale of the BRI is clear from the projected US 1 trillion commitment by the Chinese government and the involvement of at least 138 participating countries, representing over 60% of the total world population (Oliveira et al. 2020; Huang 2016). Although the broader rhetoric is about economic cooperation, the core conceptualisation of the BRI is transport infrastructure development, as well as the promotion of regional and international trade connectivity, as expressed in China's National Development and Reform Commission (see NDRC 2015, 2, see also Lee et al. 2018):



The B&R aims to promote the connectivity of Asian, European and African continents and their adjacent seas, establish and strengthen partnerships among the countries along the Belt and Road, set up omni-dimensional, multi-tiered and composite connectivity networks, and realize diversified, independent, balanced and sustainable development in these countries.

As illustrated on the map shown in Fig. 1, several key transport routes form the BRI. According to the OECD (2018), the land-based “Belt” revolves around six ‘corridors’ for economic development, namely; 1. The New Eurasian Land Bridge Economic Corridor (NELBEC); 2. The China–Mongolia–Russia Economic Corridor (CMREC); 3. the China–Central Asia–West Asia Economic Corridor (CCWAEC); 4. the China–Indochina Peninsula Economic Corridor (CICPEC); 5. the Bangladesh–China–India–Myanmar Economic Corridor (BCIMEC) and 6. The China–Pakistan Economic Corridor (CPEC). The maritime-based “Road” is a more nebulous concept, but is generally held to comprise three corridors, including first, China to the Indian Ocean, extending to Africa and Europe; China to the Pacific Ocean through the South China Sea; and a cluster of corridors including the China–Pakistan and Bangladesh–China–India–Myanmar economic corridors (Huang 2016; Lee et al. 2018; OECD 2018).

Most of the initial studies on the BRI initiative focused more on the geopolitical implications, as pointed out in Ferrari and Tei’s (2020) review of the literature (see also OECD (2018) and Haralambides and Merk (2020) for an overview of the broader objectives of the BRI). However, in recent years more studies on the implications for trade and transport operations have emerged with many attempting to predict the potential impacts in terms of trade volumes and flows, and transport costs and efficiency. As pointed out by Lee et al. (2018), the BRI will most likely lead to the reconfiguration of maritime networks and alter the ways goods are transported, including changing the designations of key ports and regional hinterland corridors. When fully implemented, the BRI will not only open up and link remote and landlocked countries in developing regions like the Indian sub-continent (Palit 2017; Ranjan 2015; Karim; 2015), South-East Asia (Wang 2014; Yuzhu 2013) and Africa (Lee 2016; Brewster 2017; Chen et al. 2020), but also increase regional and international trade. Ferrari and Tei (2020, p. 15) argue that “the estimated amount of investment has the capability of reshaping most of the current transport infrastructure in both Asia and Europe.”

One of the key outcomes sought in the BRI plan is to improve global maritime (logistics) connectivity, in particular for the countries along the BRI (Haralambides and Merk 2020). This in turn may change the patterns of transshipment to enable an efficient and cost-effective cargo movement internationally (Du 2016). For example, Lee et al. (2018) observe that the BRI-associated infrastructure developments will “have a major impact on container and liquid cargo movements in the Middle East and Europe, as well as on Shanghai’s transshipment trade through the Malacca Strait” (see also Li et al. 2015; Ranjan 2015; Chen and Yang 2019). It is important to note, however, that most discussions of impacts are merely predictions and projections (see e.g., Du 2016; Lee et al. 2018; Tan and



Zhou 2015), since the BRI's short period in existence means that many projects initiated are unlikely to have yet resulted in major outcomes.

Many countries along the BRI route anticipate improved maritime connectivity, which has the potential to boost their international trade, lower trade costs, and generally improve accessibility and integration into the global supply chain network (Hoffmann et al. 2020). After analysing the impact of five components of the LSBCI on the bilateral trade of South Africa with its 142 trading partners, Hoffmann et al. (2020, p. 496) conclude that “the number of necessary transshipments affects bilateral trade flows negatively [...] as each transshipment implies additional costs, time and risk of delays and damages” (see also Fugazza and Hofmann 2017). In their simulation of the potential trade benefits of the BRI on European trade, Herero and Jianwei (2017) find that the benefits will mostly be reaped in relation to faster and cheaper transportation accruing from BRI-related new transport infrastructure development and/or the improvement of existing facilities; for example, in port terminals and connecting rail and road corridors. In this regard, they observe that EU countries, particularly land-locked ones, will benefit by an 8% increase in trade value. Similarly, a study by Yang et al. (2020) suggests that the impact of the new China–Europe Railway Express will be greater transport accessibility for trade, leading to higher cargo volume flows and an increased accumulation of value adding activity at an expanded Chongqing International Logistics Centre. Baniya and Rocha (2019) examine the overall impact of the BRI and suggest that, among other benefits, the associated investment and infrastructure improvement across some 71 countries will increase trade flows among participating countries by 4.1%.

From a maritime transport perspective, therefore, the development of new strategic container ports, or the enhancement of existing ones alongside hinterland connectivity improvements, may lead to the reconfiguration of maritime transport routes, which could reduce or increase the minimum number of required transshipments for different countries. In this respect, this study examines the ways in which the international maritime network is likely to reconfigure in response to BRI-related infrastructure investment and the potential impact on bilateral trade flows.

### 3 Methodology

#### 3.1 Gravity model

The gravity model of international trade is applied for the analysis. This model has been extensively used by researchers, especially in applied international economics (see, for example, Krisztin and Fischer 2015; Kahouli 2016; Afesorgbor 2017). The following five characteristics of the gravity model make it one of the most influential and widely used tools to examine the various determinants of international trade: First, the model is a highly intuitive tool. By applying the well-known Newton's Law of Universal Gravitation, the gravity model of trade argues that international trade between two trading partners is directly related to the product of their economic sizes, and negatively related to the square of the distance between them. Second, the gravity model is based on a sound and well-established theoretical framework





that makes it particularly useful for examining the impact of trade policies. Third, the gravity model possesses a unique ability to simultaneously incorporate multiple units (countries, sectors, and firms) and to demonstrate the possibility of linkages between them. In this context, the model can be applied to analyse the impact of trade policy changes in the rest of the world. The fourth characteristic is its flexibility in terms of the possibility for integration within a wide range of broader general equilibrium models. Finally, one of the most salient features of the gravity model is its predictive power (Van Bergeijk and Brakman 2010; Yotov et al. 2016).

We estimate the following equation:

$$\ln(Y_{ijt}) = \alpha_{it} + \beta_{jt} + \delta X_{ijt} + \varepsilon_{ijt} \quad (1)$$

where the subscripts  $i$  and  $j$  correspond to the exporter and importer countries.  $\ln(Y_{ijt})$  is the dependent variable, which is the value of bilateral exports from country  $i$  to  $j$ . The parameters  $\alpha_{it}$  and  $\beta_{jt}$  are exporter-time and importer-time fixed effects. These effects are included to manage the unobservable multilateral resistances, plus any other noticeable and unobservable time-varying features that are country-time (exporter and importer) specific, such as national policies and exchange rates (Anderson and van Wincoop 2003; Yotov et al. 2016). Multilateral resistances indicate the hurdles which each exporter and importer country encounter in their trade with the rest of the world, including domestic trade (Adam and Cobham 2007). Thus, exporter-time fixed effects ( $\alpha_{it}$ ) capture outward multilateral resistance (exporter  $i$ 's ease of market approach), and importer-time fixed effects ( $\beta_{jt}$ ) account for inward multilateral resistance (importer  $j$ 's ease of market approach) (Yotov et al. 2016). "For instance, demand conditions prevailing at destination, or supply capacity capability characterizing source countries are controlled for" (Fugazza and Hoffmann 2017, p. 11).  $X_{ijt}$  is the vector of the independent variables, which are the five components of the LSBCI; the export value, the gross domestic product (GDP) of the nine exporting countries, the GDP of their trading partners, the maritime distance, and two hypothetical variables.

### 3.2 Data

For each of the nine sample countries, therefore, data on the five components of the liner shipping bilateral connectivity index (LSBCI) were collected, as well the following additional variables: the export value to the 128 trading partners, the gross domestic product (GDP) of the nine exporting countries, and their 128 trading partners, and the maritime distances linking them for each of the years from 2008 to 2016. The United Nations Conference on Trade and Development (UNCTAD) provided the data for the five components of the LSBCI and the maritime distances. The data on export values and GDP were extracted from UN COMTRADE<sup>4</sup> and World Bank<sup>5</sup> websites.

<sup>4</sup> See <https://comtrade.un.org/data/> accessed 6th November, 2020.

<sup>5</sup> See <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD> Accessed 6th November.



The following variables are included in the model:

- *Transshipment*: The minimum number of transshipments needed for shipment between two countries  $i$  and  $j$ ;
- *Directtrans*: The total number of common direct services that countries  $i$  and  $j$  have with third countries. This is equal to the number of alternatives a shipper faces for moving cargo from country  $i$  to country  $j$  with one transshipment (Hoffmann et al. 2020);
- *Geometricavg*: The geometric average of the total number of direct connections. This variable reflects the average of the two countries' positions in the international shipping network (Fugaza and Hoffmann 2017);
- *Competition*: The degree of competition, as reflected by the total number of carriers that provide services along the shipping connection between the two countries (for routes that require transshipment, the Max–Min rule is applied, i.e., the largest number on the leg with the lowest number);
- *Shipsize*: The size, measured in TEUs, of the largest container vessel operating on the shipping route between the country-pair (again, for routes with transshipment the Max–Min rule is applied). The five components of the LSBCI reflect how an improvement in connectivity boosts trade. For instance, more direct connections, increased competition, and greater ship size mean more containers can be moved between the country-pair.
- *GDP\_nine*: GDP per capita of nine exporting countries.
- *GDP\_rest*: GDP per capita of all importing countries.
- *Newtrans 1*: this is a hypothetical variable to analyse the impact of supply chain network redesign when the transshipments with BRI importing countries reduce by one.
- *Newtrans 2*: this is a hypothetical variable when there is no transshipment with BRI importing countries.
- *Exports*: bilateral export values of nine countries with their trading partners (only highly containerisable products, traded via the maritime mode) is taken as a dependent variable.

## 4 Analysis and results

The descriptive statistics for each of the variables are presented in Table 1. Table 2 shows the values of the correlation coefficients between the variables and their significance. There is a high correlation (0.91) between two variables, “Directtrans”, and “Geometricavg” which is why “Geometricavg” has been excluded from the analysis.

Ordinary Least Square (OLS) and Poisson Pseudo Maximum Likelihood (PPML) estimation with fixed effects are applied to estimate the gravity models. In the literature, it is recommended to use the PPML estimator to account for the information contained in zero trade links and to control for the problem of heteroscedasticity in panel data (Silva and Tenreyro 2011).



**Table 1** Descriptive statistics for the panel data including two hypothetical variables

Variables		Mean	Standard deviation	Minimum	Maximum	Observations
Export (US\$ 000 s)	Overall	7.00e+08	3.72e+09	2	6.82e+10	$N=9891$
	Between		3.59e+09	402	5.82e+10	$n=1157$
	Within		5.86e+08	- 1.97e+10	1.54e+10	$T\text{-bar}=8.54883$
Transshipment	Overall	0.6515	0.5200	0	2	$N=10,413$
	Between		0.4757	0	2	$n=1157$
	Within		0.2104	- 0.2372	2.0960	$T=9$
Directtrans	Overall	16.5696	13.4456	0	86	$N=10,413$
	Between		12.9621	0.1111	72.4444	$n=1157$
	Within		3.5911	2.2363	39.1252	$T=9$
Geometricag	Overall	37.6172	16.4550	4.6904	102.966	$N=10,413$
	Between		15.8272	6.2036	89.8350	$n=1157$
	Within		4.5232	20.3112	61.0028	$T=9$
Competition	Overall	7.5312	7.1613	0	70	$N=10,413$
	Between		6.5071	0.7777	60.4444	$n=1157$
	Within		2.9958	- 12.6909	27.9757	$T=9$
Shipsize	Overall	4213.541	3551.137	0	19,224	$N=10,413$
	Between		3226.267	226.6667	15,370.78	$n=1157$
	Within		1486.53	- 6090.681	15,637.87	$T=9$
GDP_nine	Overall	20,165.18	15,865.08	2300.371	56,559.39	$N=10,413$
	Between		15,554.44	3239.457	50,278.19	$n=1157$
	Within		3153.702	8635.508	26,446.39	$T=9$
GDP_rest	Overall	16,216.46	19,470.48	86.0401	103,110.4	$N=10,341$
	Between		19,281.7	119.3133	92,546.28	$n=1149$
	Within		2757.358	- 3469.111	29,694	$T=9$
Distance	Overall	5420.288	2961.469	75	11,437	$N=10,377$
	Between		2962.611	75	11,437	$n=1153$
	Within		0	5420.288	5420.288	$T=9$
Newtrans1	Overall	0.5378	0.5359	0	2	$N=10,413$
	Between		0.4977	0	2	$n=1157$
	Within		0.1989	- 0.3510	1.9823	$T=9$
Newtrans2	Overall	0.5354	0.5360	0	2	$N=10,413$
	Between		0.4984	0	2	$n=1157$
	Within		0.1977	- 0.3534	1.9799	$T=9$

The results are presented in Table 3. Model 1a applies OLS estimation with importer-time and exporter-time fixed effects. Models 1b and 1c add the transshipment variables (Model 1b when transshipment with BRI countries reduces by one figure; and Model 1c when transshipment with BRI countries is zero) and apply OLS estimation with importer-time and exporter-time fixed effects. Model 2a applies PPML estimation with importer-time and exporter-time fixed effects. Models 2b and 2c include the transshipment variables (Model 2b when transshipment with BRI



Table 2 Correlation coefficients among variables

	Export	Transshipment	Directtrans	Geometricag	Shipsize	Competition	GDP_rest	GDP_ten	Distance
Export	1.0000								
Transshipment	-0.2085***	1.0000							
Directtrans	0.3992***	-0.6772***	1.0000						
Geometricag	0.3257***	-0.5724***	0.9081***	1.0000					
Shipsize	0.2953***	-0.3763***	0.7203***	0.6955***	1.0000				
Competition	0.4974***	-0.1875***	0.6161***	0.5472***	0.6120***	1.0000			
GDP_rest	0.1022***	-0.1395***	0.1865***	0.1627***	0.1446***	0.0805***	1.0000		
GDP_ten	0.1315***	-0.1263***	0.1386***	0.1750***	0.1433***	0.0967***	-0.0217**	1.0000	
Distance	-0.1327***	0.3944***	-0.2327***	0.0178*	-0.0299***	-0.1477***	0.0265***	-0.0481***	1.0000

\*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.10$



**Table 3** Results of traditional gravity models

	Model 1a	Model 1b	Model 1c	Model 2a	Model 2b	Model 2c
Dependent variable = LogExport						
Transshipment	- 0.5268*** (0.0779)	- 0.6086*** (0.0728)	- 0.6478*** (0.0727)	- 0.5812*** (0.0898)	- 0.7995*** (0.0972)	- 0.8015*** (0.0973)
Directtrans	0.0432*** (0.0047)	0.0465*** (0.0044)	0.0456*** (0.0044)	0.0153*** (0.0035)	0.0142*** (0.0034)	0.01424*** (0.0034)
Competition	- 0.0354*** (0.0055)	- 0.0363*** (0.0051)	- 0.0351*** (0.0051)	- 0.0043 (0.0041)	- 0.0030 (0.0037)	- 0.0030 (0.0037)
Shipsize	7.57e-06 (0.0000)	2.81e-06 (0.0000)	3.18e-06 (0.0000)	0.0000*** (9.74e-06)	0.0000*** (9.66e-06)	0.0000*** (9.66e-06)
Log_GDP_nine	0.2265 (0.8557)	0.2421 (0.8545)	0.2419 (0.8540)	Omitted	Omitted	Omitted
Log_GDP_rest	- 0.4873 (0.3250)	- 0.4825 (0.3245)	- 0.4815 (0.3243)	Omitted	Omitted	Omitted
Log_Distance	- 1.6499*** (0.0373)	- 1.6387*** (0.0359)	- 1.6320*** (0.0357)	- 0.8279*** (0.0383)	- 0.8046*** (0.0363)	- 0.8044***
Constant	30.3911*** (8.6767)	30.1975*** (8.6643)	30.1668*** (8.6594)	27.9940*** (0.3640)	27.8215*** (0.3468)	27.8196*** (0.3465)
Number of observations	9794	9794	9794	9782	9782	9782
R-squared	0.7580	0.7587	0.7590	-	-	-
Adjusted R-squared	0.7168	0.7177	0.7180	-	-	-
Pseudo R <sup>2</sup>				0.9379	0.9389	0.9389
Log pseudolikelihood				- 1.08851e+12	- 1.07160e+12	- 1.07141e+12
Importer-time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Exporter-time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Two GDP variables are excluded because of collinearity with the dummy variable “year (time)”

In Models 1a, 1b, the natural log of the dependent variable is used. Since the PPMLE is applied in Models 2a and 2b, the dependent variable is taken as a level, not as a natural log



countries reduces by one figure, and Model 2c when transshipment with BRI countries is zero) and apply PPML estimation with importer-time and exporter-time fixed effects. As expected, the estimated coefficient for the number of transshipments is negative, revealing an inverse relationship.

The results show that out of five components of maritime connectivity, only two—the number of transshipments (*Transshipment*) and the number of common direct connections (*Directtrans*)—have a significant impact on bilateral trade in all six models. The OLS estimates show that a reduction in transshipment by one increases export value by 52% (Model 1a). The export value increases by 60.8% when transshipment with BRI countries is reduced by one (Model 1b), and by 64.7% when transshipment with BRI countries is zero. This indicates the potential impact of the BRI on export values, purely as a consequence of improved shipping connectivity. The PPML estimates yield similar results in all three models, but the values of the coefficients are higher compared to the OLS estimates. Given that the BRI purports to enhance global maritime connectivity between countries that, in turn, is likely to increase the number of common direct connections, and yield a consequent reduction in required transshipments between nations, the plan may prove to actually promote bilateral trade.

A further detailed disaggregate analysis<sup>6</sup> was conducted to examine the impact of a reduction in transshipment on the bilateral trade of individual nations. This analysis was carried out by dropping each of the 28 BRI countries one at a time, to estimate the impact on the aggregate model. The results show that the top five BRI countries, which benefit the most from a reduction in transshipment, are Kenya, Pakistan, Tanzania, Sri Lanka and Angola. In contrast, the five BRI countries which benefit the least are Bangladesh, S. Korea, Cameroon, Belgium and Malaysia. One reason for this difference might be because the countries in the former category seem to be more closely linked to the BRI network, while those in the latter group are relatively more distanced, e.g., Belgium, Cameroon, and S. Korea. Another reason could be that the former category of countries already enjoy better bilateral maritime connectivity with the sample exporting countries than countries in the second category. For instance, the Liner Shipping Bilateral Connectivity Index (LSBCI) of Pakistan with the sample exporting countries for 2016 is higher compared to Bangladesh.<sup>7</sup>

The OLS estimates for the number of common direct connections (*Directtrans*) indicate that an increase by one unit increases the export value by 4.3% (Model 1a), by 4.6% (Model 1b) and by 4.5% (Model 1c). The results obtained from PPML estimation also demonstrate the positive effect of common direct connections, but the values of the coefficients are lower compared to the OLS estimates. The variable *Competition* has a negative and significant impact on trade when estimated by OLS, but its sign is negative and insignificant in PPML estimation. Having a larger number of carriers that provide services on the shipping connection between two countries may not increase export values. The variable size of the ship (*Shipsize*) has an insignificant effect, as the values of the coefficients are negligible. It might

<sup>6</sup> Results can be provided upon request.

<sup>7</sup> See <https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx> Accessed 24th November 2020.



be inferred, therefore, that countries with sufficient port infrastructure to accommodate larger ships do not necessarily enhance export volumes. The variable maritime distance (*Log Distance*) has a negative and significant effect in all six models. This validates the hypothesis that the international trade between two trading partners is negatively related to the square of the distance between them. The greater the distance between two countries, the lower the trade, even in a highly connected globalised marketplace. However, like the variable *Directtrans*, the values of its coefficients are lower when estimated by PPML.

## 5 Conclusion

The sustenance of global economic order and international economic prosperity is underpinned by the rate, volumes and patterns of international trade. Considering that over 80% of international trade is carried by ocean transportation, any major re-configuration of international maritime connectivity is likely to significantly impact on global supply chains and, by extension, globalisation itself. China's BRI, by its scale, scope and capacity, has the potential for such disruption in maritime transportation networks and trade. BRI's projects related to port development in Pakistan (Gwadar), Djibouti, Myanmar (Kyaukpyu), Greece (Piraeus), and Sri Lanka (Hambantota and Colombo) are facilitating the improvement in port infrastructure in Africa, Asia, and Europe. Chinese port operators and investors like China Ocean Shipping continue to expand their operations internationally. Because of the BRI initiative, China Ocean Shipping successfully acquired port facilities in Greece, Italy, and Spain and signed a concession agreement with Zeebrugge Port Authority to open a container terminal (Drewry Maritime Research 2017; Wei 2018).

In this regard, this paper has examined the ways in which the international maritime network is likely to be reconfigured in response to BRI-related infrastructure investment and to evaluate the potential impact on bilateral trade flows. This is the first study that examines the maritime network reconfiguration in response to the BRI and its impact on bilateral exports. The underlying study focused on nine countries, strategically located along the major global trade routes and/or along the BRI, and a selection of their exporting country partners. The nine countries considered are Egypt, Saudi Arabia, Israel, Panama, Colombia, Costa Rica, Singapore, Malaysia and Indonesia, together with their 128 trading partners.

The traditional gravity model of trade has been applied to analyse the influence of potential improvements in bilateral maritime connectivity, brought about by the BRI, on the bilateral exports of these nine countries and their 128 maritime trading partners. Justified by previous research which proved that the minimum number of required transshipments is the most influential variable in terms of its significance and magnitude (see Hoffmann et al. 2020; Saeed et al. 2020), the value of this variable has been changed in two plausible scenarios to reflect the potential improvement in maritime connectivity brought about by the BRI.

The results confirm that the reduction in transshipments under these two plausible scenarios (by one and by setting it equal to zero) significantly improves bilateral export values. Furthermore, a decrease in transshipments will change and enhance



the maritime network structure between countries located along the three strategic chokepoints and their trading partners. In more general terms, the resulting supply chain network reconfiguration is associated with improvements in productivity and efficiency and that, more specifically, maritime network reconfiguration, as an outcome of the BRI, has the capacity to improve productivity, as manifested as gains in bilateral export values.

The study demonstrates that the maritime network reconfiguration resulting from the implementation of the BRI will have an important impact on the maritime connectivity of the selected countries. Whether the impact is great, as in the cases of Kenya, Pakistan, Tanzania, Sri Lanka and Angola, or small, as in the cases of Bangladesh, Korea, Cameroon, Belgium and Malaysia, there is evidence that the BRI will reduce the number of required transshipments between the sample nations and their trading partners and thus enhance the efficiency, and by extension, reduce the cost of trade for these countries. It, therefore, has the potential to transform the trade fortunes of many countries in significant ways, by enhancing their connectivity to the global trade superhighways. The likely eventual result is that, as other countries respond (mostly those that are not participating in the BRI), the established patterns of global trade will change.

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