



Nexus between green logistic operations and triple bottom line: evidence from infrastructure-led Chinese outward foreign direct investment in Belt and Road host countries

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Abstract

The Belt and Road initiative (BRI) mainly relies on the traditional and underdeveloped logistical trade routes including the terrestrial and oceanic Silk Road. The poor logistic infrastructure across the BRI region not only restricts trade potential and economic progress but also creates several social and environmental challenges. Therefore, this study investigates the relationship between green logistic operations, economic, environmental, and social indicators of countries along with the BRI. This study provides three key findings using feasible generalized least squares (FGLS) and system generalized method of moments (Sys-GMM) estimation techniques. First, Chinese outward foreign direct investment significantly improves the quality and quantity of green logistic operations in terms of transport infrastructure, customs services, cost, time, tracking, and reliability of international shipments. Second, a higher quality of transport-related infrastructure, customs clearance efficiency, and competency of logistics services significantly mitigate the level of carbon emissions due to the energy conservation in the supply chain process. Moreover, the application of renewable energy resources significantly improves the quality of logistics operations. These results indicate that higher quality of green logistic operations provides efficient infrastructure and greater information sharing among supply chain partners that increase trade volume, growth opportunities, and environmental sustainability. Third, a higher institutional quality helps to mitigate social concerns through improvement in the efficiency of logistic operations. Although BRI regional estimates show significant variations, the overall results imply that BRI participating countries should integrate with ongoing investment projects to promote the quality and quantity of green logistic infrastructure and ensuring environmental stewardship.

Keywords Chinese infrastructure-led foreign direct investment · Green logistic operations · Institutional quality · Environmental sustainability · Triple bottom line · Project management · Belt and Road initiative

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Introduction

The Belt and Road Initiative¹ (BRI) is a great vision for economic integration of China with Asia Pacific, Europe, and their adjoining oceans, established eco-tiered, multifaceted, and extensive connectivity network, realizing interdependent, diverse, and sustainable growth in 65 countries covering 35% of global trade, 30% of the world's GDP, 39% of global land, and 64% of the global population, become the world's largest cooperation network (Du and Zhang 2018; An et al. 2020). The BRI developing countries exhibited significant logistic infrastructure gaps in trade and transport-related logistic infrastructure, which is not only restricts their trade and economic progress but also creates several social and environmental challenges (Wiederer 2018). The BRI is building reliable infrastructure and logistics across the underdeveloped region (Swaine 2015) that encompasses highways, railway tracks, seaports, dry ports, and airport terminals, eventually creating the trading process swift, easier, and compatible and paves the way toward sustainable development (Huang 2016).

In the recent decade, researchers' and practitioners' emphasis has been diverted toward the integration of economic, social, and environmental concerns that can be addressed by green logistic operations (GLOs) (Khan et al. 2019; Yu et al. 2020a). The GLOs mainly comprise a range of interconnected activities including material handling, freight transportation, information processing, warehousing, and information sharing with supply chain participants involved in the movement of goods (Martel and Klibi 2016). GLOs are at the heart of economic activity, while poor logistics raised environmental and social concerns that emerged from carbon emissions (CO₂) and climate change (Cousins et al. 2019; Rehman Khan and Yu 2020). According to World Bank estimates, 23% of fuel-based CO₂ are attributed to transportation, while 7% of global CO₂ are linked to freight transportation (Arvis et al. 2018). Therefore, organizations are now introducing green practices in their operational network to achieve social, economic, and ecological benefits (Shahzad et al. 2020; Yu et al. 2020b). Due to inadequate environmental regulations and customer awareness, green practices generally add substantial costs to the system (Halkos and Skouloudis 2018; Sarkis and Zhu 2018). Supply chain participants play diverse and significant roles while executing green supply chain management (SCM) practices. Those involve government legislatures, community activists, non-government organizations (NGOs), and foreign competitors. All these factors encourage enterprises to adopt a certain level of dedication to protecting environmental sustainability (Hassini et al. 2012).

The conventional logistic operations consume a relatively higher quantity of fossil fuel, contributing to climate change and global warming (Hayami et al. 2015; Rehman Khan and Yu 2020). Transportation and global supply chain activities primarily

rely on energy consumption (Çankaya and Sezen 2019; Alinaghian et al. 2021). Primarily, the growth of logistics and transportation industry is mainly driven by higher energy consumption (Anable et al. 2012; Hao et al. 2020). Besides, it has also established that regulators have failed to implement effective policies to protect environmental pollution, causing severe socio-environmental damages. McMichael et al. (2008) cautioned about increasing environmental hazards and rising emissions causing several ecological and health problems such as asthma attacks, allergic infections, neurobehavioral disorders, bronchitis, and pulmonary cancer (Khasnis and Nettleman 2005; Maji et al. 2018; Razzaq et al. 2020b). Herold and Lee (2017) estimated that global CO₂ has almost doubled in the last five decades, which is mainly attributed to fossil fuel consumption by 78% of total CO₂ (IPCC 2014).

The BRI countries have a lower socio-economic status such as lower per capita income (US\$12,000), highest contribution in global carbon emissions, i.e., 54% (Fan et al. 2019), and significant logistics infrastructure gap, i.e., US\$22.5 trillion (Pascha 2020), that attracts more than US\$80 billion Chinese outward foreign direct investment (OFDI) in the last 5 years (MOFCOM 2018). These investment projects are not only improving logistics infrastructure and fueling trade and growth (Liu et al. 2017) but also reduced the level of carbon emissions at least by 48.69Mt in the last 5 years through green energy solutions (Gu and Zhou 2020). Figure 1 represents the global logistics performance indicator (LPI) score across lower to higher quantiles of LPI. The positive slope curve in Fig. 1 visualizes the global trends of LPI score in year 2018. The average LPI score of the BRI countries is 3.00 fall under the range of consistent performer; however, data descriptive shows significant variations across regional samples. East Asia and Western Europe fall under the range of top-performing countries with LPI scores 3.86 and 3.70, respectively. Central and Eastern Europe (3.07), Southeast Asia (2.96), Middle East and North African (MENA) Countries (2.93) fall in the grid of consistent performers while South Asia (2.46), Central Asia (2.44), Commonwealth of Independent States (CIS) (2.54) fall in the range of the fourth quantile of partial performers (see Appendix Table 6). Nevertheless, LPI score of BRI countries is steadily improving since the last five years (Arvis et al. 2018), signifying the relevance of the BRI policy in improving logistic operations and sustainable development (Chen and Lin 2018).

Research gaps and objectives

Although a plethora of researchers analyzed the link between green logistic operations and environmental and financial performance of firms, few studies explored the link at macro/cross-country-level. Mostly, previous studies have used microeconomic approaches, firm, industry, or survey level analysis. A few studies also conducted country-level analysis from China (Khan et al. 2016), South Asian Association for Regional Cooperation

¹ Belt and Road Initiative, "BRI," the new buzzword previously known as OBOR (one belt one road). It is also known as the twentieth-century Maritime Silk Road and the Silk Road Economic Belt

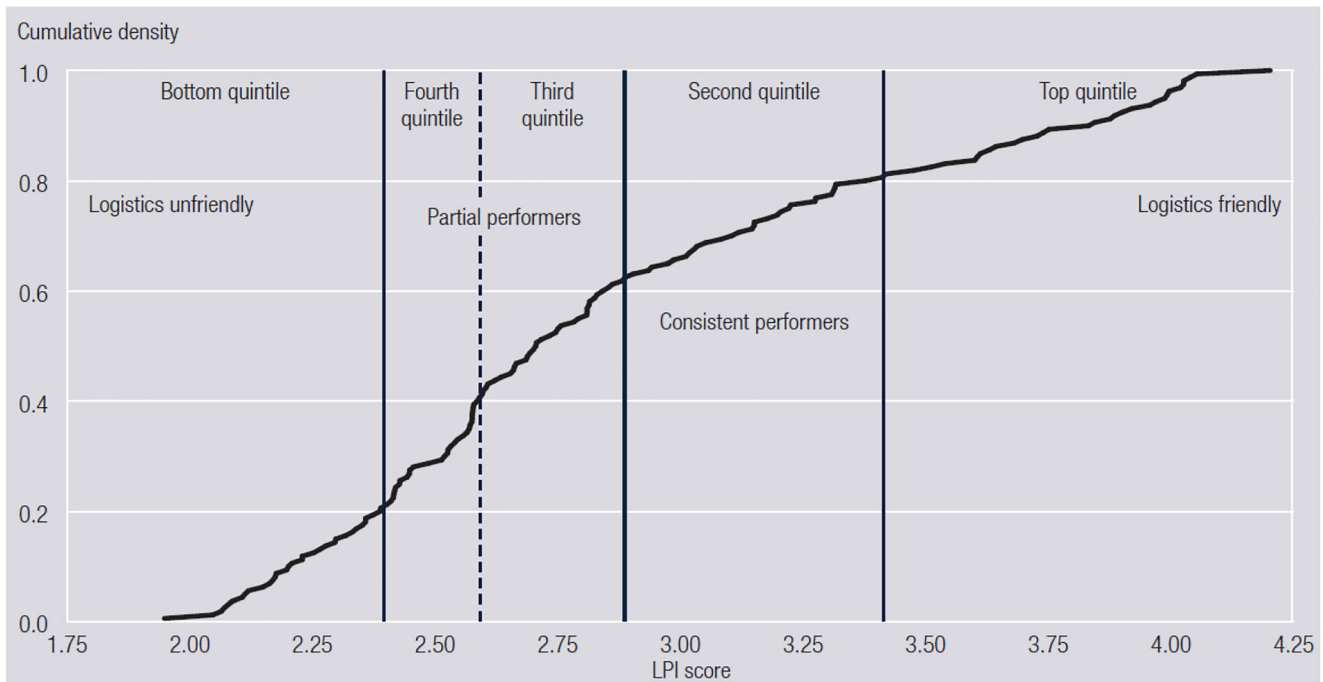


Fig. 1 Cumulative Distribution of LPI score on Global Scale 2018. Source: World Bank Logistic Performance Index, 2018

(SAARC) countries (Abdul et al. 2019), the UK (Khan and Qianli 2017a), selected developed and developing countries (Khan et al. 2018), and selected EU countries (Zaman and Shamsuddin 2017). The current study is different from the prevailing literature in several aspects. First, this study draws the correlation between logistics operations and the economic, environmental, and social indicators on a panel of 65 Belt and Road host countries (see Appendix Table 8) and spans from 2007 to 2018. Second, the study incorporates China-specific overseas foreign direct investment (FDI) in economic health indicators, which is mainly concentrated in trade and transport-related infrastructure at BRI host countries. This can help us to integrate the impact of BRI investment along with different logistic performance indicators. Third, the study performs region-wise analysis, which produces interesting and diverse insights at the disaggregated level. To the best of our knowledge, this is a pioneering study that examines the association among green logistic operations and environmental and socio-economic indicators across the BRI countries.

This paper is composed of four sections; The first section contains literature review and hypotheses development; the second section explains materials and methods, while the third section discusses empirical findings. The last section provides a conclusion and policy recommendations.

Literature review and hypotheses development

In the recent decade, researcher's emphasis has been diverted toward the integration of economic, social, and environmental

concerns that stress the reduction of emissions and waste (Hussain and Malik 2020; Yu et al. 2020a). This phenomenon is coined by Elkington (1998) 25 years ago, which is popularized with the name of triple bottom line (TBL). TBL provides a sustainability framework that examines a company's social, environmental, and economic impacts. A similar theoretical framework can be extended to evaluate the country's sustainable performance.

The economic progression of the country is improved by industrial development and global supply chain operations. However, this growth is not persistent without environmental and social problems that emerged from CO₂ and climate change (Jayaraman et al. 2012). Recognizing the same, organizations are now introducing green practices in their operational networks such as green sourcing, green storage, green distribution, green transport, and ecological design of the products to achieve social, economic, and ecological sustainability (Rehman Khan and Yu 2020). The relationship between logistics and energy demand has been broadly debated under SCM. Green energy resources are required in logistics operations to achieve a sustainable environment (Centobelli et al. 2018). Zaman and Shamsuddin (2017) revealed that supply chain operations mainly consumed energy and resources, considered as a significant contributing factor to global warming and ecological deprivation.

In order to improve sustainable ecology, Cousins et al. (2019) suggested that firms must implement renewable energy sources and ecological design in their supply chain processes. Environmental stewardship can be obtained through energy conservation in the supply chain process, and green logistics operations help to simultaneously achieve socio-economic and environmental objectives (Dev et al. 2020). Worldwide

energy consumption projected to the year 2040 specifies a persistent development pattern toward green energy consumption (EIA 2019). Renewable energy resources are comparatively cheap, thus encouraging organizations to utilize renewable sources of energy. Bhattacharya et al. (2016) highlighted that green energy solution is the only way to minimize the environmental hazards, which can be enforced under the domain of green regulations. In recent years, green energy solution has continued to grow faster as can be observed from Fig. 2. The next section contains a comprehensive literature review, which helps to build research hypotheses.

The link between GLOs and economic health indicators

The mitigation of waste and resource conservation is emphasized in GLO, which is strongly linked with ecological sustainability and firms economic performance (Arora et al. 2020; Mardani et al. 2020). At the national level, economic growth and trade potential have closely associated with sustainable logistics activities and green SCM practices (de Medeiros and Ribeiro 2017; Aldakhil et al. 2018). Green practices in SCM are not only supposed to play a critical role in promoting market-share but also enhance consumer satisfaction and improve firms financial performance (Jayaraman et al. 2012; Yu et al. 2020a). Based on the requirement of integrated development across BRI region, the logistic performance of participating countries and realizing inter-regional logistic coordination is an imperative problem. Unfortunately, the logistics performance of the BRI region is comparatively lower than the global average (Arvis et al. 2018).

Yan and Wang (2016) identified two major constraints: logistics infrastructure and customs efficiency limiting the overall LPI performance in the BRI region. However, the BRI investment is mainly concentrated in infrastructure development, significantly improving the quality and availability of logistics facilities across the BRI countries (Chen and Lin 2018). BRI is helping to remove trade barriers and stimulate growth (Shahriar et al. 2019) and renewable energy consumption (Gu and Zhou 2020). Undoubtedly, supply chains and logistics have played an imperative role in the economic growth of host countries. However, the logistics industry also caused severe CO₂ accounted for 13% of

the total global CO₂ (World Economic Forum 2016). Likewise, international logistics and supply chain activities facilitate global trade across countries and thus can be considered as a key source of CO₂ (Herold and Lee 2017). Khan and Qianli (2017c) articulated that infrastructure and logistics capability substantially improves economic performance, and logistics operations encourage sectoral development and FDI inflows. Similar findings are echoed by Zhu and Sarkis (2004), indicating that green logistics operations stimulate the long-term profitability of Chinese firms.

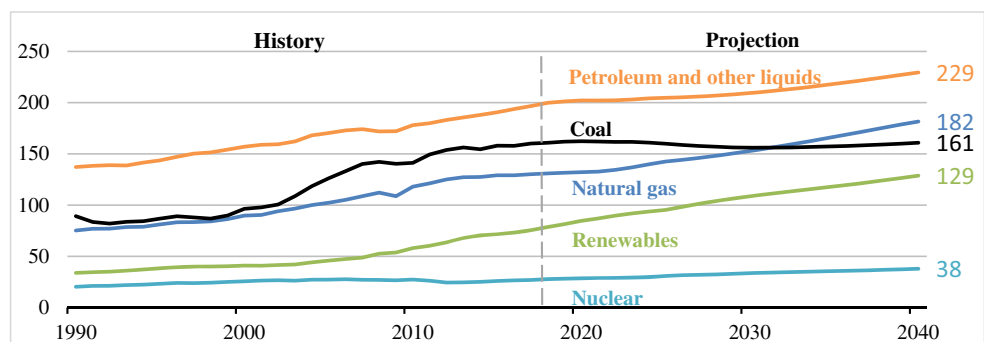
Werikhe and Jin (2016) stated that conventional logistics practices impede overseas investments. It also creates heavy logistics and supply chain operational costs due to the inefficient customs clearance process and fewer export opportunities. Thus, green logistic operations help to fight climate change while improving the operational and financial performance of firms by embracing sustainable practices and an efficient waste management system (Hartmann et al. 2015; Khan et al. 2020). Similarly, Zaman and Shamsuddin (2017) argued that green logistics operations attract more foreign investment and can also be a significant driver of environmental sustainability. Their findings confirmed that renewable energy resources and inward foreign investment are both positively and significantly interrelated with the green SCM process. Also, a higher green logistic performance is negatively correlated with CO₂ and fuel consumption. Gani (2017) found that higher values of logistics performance indicators stimulate both imports and exports at the global level. In a nutshell, green logistic performance indicators are positively correlated with GDP, trade, and FDI, among others (Zaman and Shamsuddin 2017; Khan et al. 2019). Based on these studies, we develop the following hypothesis:

- H1: GLOs are positively correlated with macro-economic indicators.

The link between GLOs and macro-level environmental aspects

The green SCM provides an opportunity for environmental protection from the adverse impact of conventional non-green SCM practices. Rehman Khan and Yu (2020) con-

Fig. 2 World energy consumption by energy source (units in quadrillion Btu). Source: EIA, International Energy Outlook 2018



firmed that green SCM practices significantly improve firms' environmental and socio-economic performance through resource conservation in business operations. Similar results are documented in the Chinese context by Hartmann et al. (2015). Another study by Narasimhan and Schoenherr (2012) concluded that green SCM practices significantly mitigate system waste, reduces production cost, improve efficiency that saves the environment, and boost firms' financial performance (Razzaq et al. 2021; Zhu and Sarkis 2004). Without adequate green policies, freight transportation and related supply chain activities will have a negative impact on the global atmosphere (Yu et al. 2020b). Dey and Cheffi (2013) argued that transportation and logistics operations are the main source of climate change, global warming, and environmental pollution. Enterprises that began to adopt green logistics and supply chain processes to boost their efficiency also have to overcome the intricacy of performance evaluation and related executive decisions.

Büyükköçkan and Çifçi (2011) estimated that enterprises can decrease about 80% of adverse environmental impact during the operational activities by adopting green SCM practices. Khan and Qianli (2017b) quantified green supply chain and logistics practices through five constructs: green manufacturing, green procurement, environmental design, green information systems, and customer cooperation in Pakistan. Their findings revealed that green practices in logistics operations have a beneficial effect on the environmental efficiency of the firms. Yu et al. (2020a, b) advised that incorporating sustainable environmental initiatives into a firm's strategic planning would foster inclusive competence to counteract potential hazards and improve the firm's goodwill and market share. Luthra et al. (2016) emphasized that implementing green strategies in logistics and supply chain activities contributes to waste reduction, promotes energy conservation, and strengthens a sustainable environment with a reduction in CO₂ (Herold and Lee 2017; Hussain and Malik 2020).

From the Chinese market data, Lai and Wong (2012) articulated that green logistic activities lead to environmental sustainability. Consumer pressure and regulatory bodies encourage green practices such as the deployment of renewables in logistics and supply chain operations. Recently, Dogan et al. (2020) confirmed positive economic fallout of renewable energy consumption at lower level of economic growth. Aldakhil et al. (2018) stated that environmental conservation is profoundly influenced by worldwide logistics services, which is primarily affected by energy and fossil fuel consumption (Tirkolae et al. 2020). Khan and Qianli (2017c) found that green and sustainable practices in logistics operations have a positive and significant correlation with renewable energy consumption (REC). Their findings endorsed that environmental stewardship and sustainable growth are significantly improved due to green practices in logistics operations (Khan et al. 2018; Winkelhaus and Grosse

2020). A major strand of literature highlighted that a significant portion of carbon emissions are mainly attributed to poor logistic operations, which agonies the global health and climate. It cannot be fixed without taking appropriate steps like implementing stringent eco-friendly technologies and policies, incentivizing enterprises to implement green initiatives, and encouraging consumer awareness (Werikhe and Jin 2016; Nawaz et al. 2020; Shahzad et al. 2020). Based on the abovementioned studies, following hypothesis is constructed:

- H2: GLOs are positively correlated with greater environmental sustainability.

The link between GLOs and macro-level social indicators

The domestic and international logistic operations are regulated by governing and enforcement bodies. Therefore, the efficiency of logistic operations mainly relied on the quality of institutions, which not only facilitate the local movement of goods through an efficient national transport network but also facilitate cross-border trade through the integration of local and international supply chain logistics operations (Arvis et al. 2018). The quality of institutions is mainly expressed in the form of political stability, rule of law, control of crime, violence and terrorism, and public and private corruption in host countries. According to North (1990) and Wegenast (2013), "institutions are the rules of the game in a society, or, more formally, are the humanly devised constraints that shape human interaction in the business environment." From developing countries, Seabra et al. (2016) analyzed that customs officials are mainly involved in corruption, and they deliberately delay the shipment clearance process to charge higher bribe money. Also, they considered fabricated documents to clear illegal consignments. Thus, corruption leads toward weaker investor confidence and lose country's attractiveness for international trade and FDI (Wegenast 2013).

Wong and Tang (2018) investigated the core determinants of logistic performance on a global scale. They found that stable political institutions and control over corruption significantly improve the logistic performance of host countries. Doh et al. (2012) and Bach and Allen (2010) argued that market growth and business environment rely on social and economic factors of host countries. Arvis et al. (2016) observed that corruption adversely affects and distorts the efficiency of all logistic operations. Similar results are empirically tested by Heble et al. (2007). On the other hand, Uca et al. (2016) analyzed that a higher score of green logistic performance indicators is correlated with a lower level of corruption. Guner and Coskun (2012) articulated that a higher level of political stability, democracy, and regulatory quality significantly improves logistic performance. Higher political stability is attributed to consistent

policies in which logistics service providers perform formally and smoothly in a country. Some recent examples also show that political turmoil and ethnic tensions in the Middle East, North Africa, and Ukraine endanger international supply chains and lead to business unrest.

Due to the intrinsic nature of business operations (water and air pollution), most of the firms have an adverse impact on society (Zaman and Shamsuddin 2017; Khan et al. 2020). Unremitting pollution emerged from conventional logistics operations, and other economic activities caused several ecological and health problems. These hazards main include premature deaths, asthma, mesothelioma, neurobehavioral disorders, bronchitis, pulmonary cancer, liver, and other forms of cancer, and respiratory diseases (Khasnis and Nettleman 2005; McMichael et al. 2008; Maji et al. 2018). Rodríguez et al. (2014) argued that social concerns can be reduced by attaining long-term political stability. In the recent decade, firms are also paying attention to CSR (corporate social responsibility) to minimize their adverse effects on living creatures (Shahzad et al. 2020; Yu et al. 2020b).

The signaling theory proposes that information anomalies can be removed by sharing information with peer firms in an industry. Particularly, firms need to signal their CSR in the presence of weak regulations and poor institutions in developing countries (Rodríguez et al. 2014). Pursuing the same, Visser (2008) explicated that the firm’s social responsibility should involve health care, persuading political reforms and preserving traditional cultural traditions to serve society. Aldakhil et al. (2018) explored that logistic activities are the main contributors of CO₂, while green practices have a profound impact to mitigate social and environmental issues. Moreover, green practices in business and logistic operations can help the governments to control several diseases, including asthma, lung infection, and a range of neural disorders that emerged from contaminated air. On the other hand, Khan et al. (2018) found that green logistic operations lead toward the lower socio-environmental problem in the form of lower public health spending. From the above studies, following hypothesis is constructed:

- H3: GLOs are positively correlated with social indicators

Materials and methods

The study establishes the link among green logistics performance indicators (GLPI) with macroeconomic (Eco), environmental (Env), and social (Soc) factors in a panel of 65 BRI host countries (see Appendix Table 8). Chinese OFDI improves logistics performance of the BRI host countries from both quantitative and qualitative aspects such as the construction of physical infrastructure (ports, highways, railways) and

improving the logistic quality (deliver time, efficiency) (Ye and Haasis 2018). There is also no question that the supply chain and logistics operations stimulate economic development. However, it also yields several environmental and social hazards in the absence of green policies and practices. Therefore, this study connected international logistics operations with environmental and social indicators under national scale economic factors, particularly Chinese OFDI that sponsor and improve GLOs across the BRI region. Based on our hypotheses, the following basic equation is derived.

$$GLPI_i = a_i + \beta_1 Eco_i + \beta_2 Env_i + \beta_3 Soc_i + \vartheta_i + \varepsilon_i \quad (1)$$

where GLPI shows cumulative green logistics performance index is composed of over six indicators of logistic performance including track and trace consignments (LPITTC), competence and quality of logistics services (LPICQL), competitively priced shipments (LPICPS), efficiency of the customs clearance process (LPICCP), frequency with which shipments reach consignee within scheduled or expected time (LPICCT), and quality of trade and transport-related infrastructure (LPITINF). Eco shows the economic health indicators of countries including Chinese outward foreign direct investment (real Chinese outward FDI stocks in BRI host countries), TO (trade openness percentage of GDP), and GDP (real GDP per capita USD constant 2010). Env indicators are covering CO₂ (carbon emissions metric tons per capita) and REC (percentage of renewable energy consumptions to total energy consumption). Soc shows social indicators such as institutions (weighted index; quality of public and private institutions, accountability and corruption, business cost of crime, violence, and terrorism) and HS (Per capita health expenditure). MVD (manufacturing value-added percentage of GDP) is included as a control variable, and *i* represents Belt and Road host countries, *t* represents time, *a_i* denotes constant term, and *ϑ_i* captures the country-specific that is relatively stable and does not change over time, such as geography (country size, natural resource endowments, and location dynamics).

In this study, the data of 65 Belt and Road host countries, spanning from 2007 to 2018, are extracted from the World Bank Logistics Performance dashboard except for Chinese outward FDI and weighted institutional quality index which are sourced from the annual statistical bulletin of China and global competitiveness index world bank, respectively. The data of all countries are taken from same sources, which provide empirical data in standardized format (same measurement unit and scale). Moreover, all model variables are transformed into logarithms except indexes by following Razzaq et al. (2020a). The following equation examines the performance of green logistics operations.

$$GLPI_{it} = a_{it} + \beta_1 Eco_{it} + \beta_2 Env_{it} + \beta_3 Soc_{it} + \vartheta_i + \varepsilon_{it} \quad (2)$$

We expand the basic Eq. 2 and replace the dependent variable with six distinct logistic performance indicators from

Eqs. 3–8, while Eq. 9 shows the cumulative indicator of logistic performance.

$$\begin{aligned} \text{LPITTC}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (3)$$

where LPICQL represents logistic performance in terms of tracking and tracing of consignments. FDI, TO, GDP, CO₂, REC, HLT, INST, and MVA represent Chinese outward foreign direct investment, trade openness, economic growth, carbon emissions, renewable energy consumption, health expenditure, cumulative institutional quality index, and manufacturing value-added, respectively. Here, i represents Belt and Road host countries, t represents time, a is constant term, β represents parameter coefficient, ε exhibits error term, and ϑ_i captures the country-specific effects.

$$\begin{aligned} \text{LPICQL}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (4)$$

where LPICQL index represents logistic performance in terms of competence and quality of logistics services. For the sake of brevity, the descriptions of right-hand-side variables and parameters are generalized from the above explanation for Eq. 3.

$$\begin{aligned} \text{LPICPS}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (5)$$

where LPICPS index represents competitively priced shipments index, while the descriptions of right-hand-side variables and parameters are same as explained in the above section for Eq. 3.

$$\begin{aligned} \text{LPICCP}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (6)$$

where LPICCP index represents efficiency of the customs clearance process, while the descriptions of right-hand-side variables and parameters are the same as explained in the above section for Eq. 3.

$$\begin{aligned} \text{LPICCT}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (7)$$

where LPICCT index denotes frequency in which shipments reach consignee within scheduled or expected time, while the descriptions of right-hand-side variables and parameters are the same as explained in the above section for Eq. 3.

$$\begin{aligned} \text{LPITINF}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (8)$$

where LPITINF index represents quality of trade and transport-related infrastructure, while the description of right-hand-side variables and parameters are the same as explained in the above section for equation 3.

$$\begin{aligned} \text{GLPI}_{it} = & a_{it} + \beta_1 \text{LnFDI}_{it} + \beta_2 \text{LnTO}_{it} + \beta_3 \text{GDP}_{it} \\ & + \beta_4 \text{CO2}_{it} + \beta_5 \text{REC}_{it} + \beta_6 \text{HLT}_{it} \\ & + \beta_7 \text{INST}_{it} + \beta_8 \text{MVA}_{it} + \vartheta_i + \varepsilon_{it} \end{aligned} \quad (9)$$

where GLPI index represents cumulative green logistics performance index composed of the above six distinct indicators of logistic performance, while the descriptions of right-hand-side variables and parameters are the same as explained in the above section for Eq. 3.

Usually, the panel data inherently hold the problem of heteroskedasticity, auto-correlation, and endogeneity and caused estimation errors. These issues are not encountered by standard models like fixed effect (FE), random effect (RE), and ordinary least square (OLS) (Ibrahim and Law 2014). The first problem, auto-correlation, refers to the correlation between the error term and a model variable by the error term associated with other variables in this model (Attari et al. 2016). The second problem in the panel data is heteroskedasticity, which appears when the error terms' variance varies across observations (Simpson 2012). Lastly, the issue of endogeneity can be expressed as a correlation between the parameters and error term (Khan et al. 2018).

The problems of auto-correlation and heteroskedasticity can be addressed by the feasible generalized least square (FGLS) estimator (Judge et al. 1988; Maddala and Lahiri 1992). The FGLS models allow heteroskedasticity but no cross-sectional correlation (Davidson and Mackinnon 1993; Green et al. 2012). Moreover, the FGLS models are asymptotically efficient and more suitable for a larger sample size, which leads to overcoming the problem of auto-correlation and heteroskedasticity (Rao and Griliches 1969). The problem of auto-correlation can also be addressed by controlling the year fixed effect by incorporating time dummies during estimations. However, the possible endogeneity and reverse causality between logistic operations and growth indicators may

lead to inefficient estimates if not appropriately handled. For example, higher economic growth affect logistic operations as well as higher logistic operations affect growth. Logistic operations may also be affected by their own lag terms, which can only be addressed using dynamic estimators.

In order to deal with dynamic trends, reverse causality and endogeneity, generalized method of moments (GMM) is considered as most appropriate technique. The GMM estimator fits testing the hypotheses, as explanatory variables correlated with the error term distort the real estimation. The use of lagged endogenous as explanatory variables is highly recommended by Arellano & Bond (1991). Thus, the transformed basic equation by GMM is stated as:

$$Ly_{i,t} = \alpha_1 + \gamma y_{i,t-1} + \beta X_{i,t} + \delta_i + \lambda_t + \mu_{i,t} \tag{10}$$

The δ_i records the ignored country-specific effects; λ shows the period-specific effect, and X denotes the set of variables. The country-specific effects are removed by differencing of variables.

$$y_{i,t} - y_{i,t-1} = \alpha_1 (x_{i,t-1} - x_{i,t-2}) + \beta (X_{i,t} - X_{i,t-1}) + (\lambda_t - \lambda_{t-1}) + (\mu_{i,t} - \mu_{i,t-1}) \tag{11}$$

The lagged endogenous variable $y_{i,t-1} - y_{i,t-2}$ associates with error $\mu_{i,t} - \mu_{i,t-1}$ as considered in difference GMM and imposes bias the estimation (Arellano and Bond 1991; Khan et al. 2019). The usage of the lagged level of the independent variables as instruments by GMM estimator, which rectifies the term of disturbance as it is not auto-correlated/serially correlated and they are independent (Arellano and Bond 1991).

The research approach does bear a drawback, as highlighted by Blundell and Bond (1998), that the results of difference GMM may not reveal true estimations. The exceptionality may occur due to the small sample size and when the data has continuous endogenous and exogenous variables, which may not measure as a reliable instrument (Masron and Subramaniam 2019). As a remedy to the issue, the most appropriate method is system GMM (system-generalized method of moments) (Arellano and Bover 1995; Ibrahim and Law 2014). Thus, the problem of serial correlation, endogeneity, unobserved panel effects, and dynamic nature of logistic performance indicators are countered by the second usual transformation presented by Arellano and Bover (1995), namely, system GMM or forward orthogonal deviations. The system estimators employ the first difference of all the exogenous variables as standard instruments and the lags of the endogenous variables to produce Sys-GMM type instruments (Roodman 2009). This technique is more suitable for larger sample sizes and lower time dimension.

Both the estimators FGLS and Sys-GMM are suitable candidates for larger panels (65 countries) and shorter time dimensions (11 years) (Abdul et al. 2019). However, the study first employs pooled OLS (P-OLS), FE, and RE techniques and then utilizes FGLS and Sys-GMM approaches to concurrently deal with the problems of auto-correlation, endogeneity, and heteroskedasticity. Nevertheless, these estimators have the capability to encounter heterogeneity problem, but BRI countries have diverse characteristics. Therefore, we have further expanded the same models at a disaggregated level (see Appendix Table 7), consisting of South Asia, southeast Asia, east Asia, central Asia, MENA countries, central and eastern Europe, western Europe, and CIS countries.

Empirical results and discussion

From Table 1, it can be observed that all dependent and independent variables follow a positive mean and standard deviation, which have a substantial distribution peak. However, data shows significant variation across the regions along BRI. The value of logistic performance indicators is ranged from 5 to 1 showing higher to lower logistic performance. A higher logistics performance score corresponds to healthy economic activities that improve GDP, trade, and MVD, and particularly, Chinese OFDI significantly boosts green logistic indicators. The environmental sustainability and HS are substantially influenced by positive means and standard deviation values of CO₂ that can be mitigated with the replacement REC. Also, the use of more green and clean energy resources in national logistics will decrease health spending. The host country’s institutional quality provides a conducive environment to stimulate trade and logistics activities, producing positive spillovers for environmental, social, and other financial indicators of host countries. Interestingly, the mean value of sub-

samples reflect that countries that received higher Chinese FDI have a relatively higher logistic performance score. It indicates that the BRI investment significantly improves green logistic performance while improving GDP, trade, and environmental quality.

Table 2 demonstrates the pairwise correlation matrix, indicating a distinct impact on logistics performance from the economic, environmental, and social indicators. FDI, TO, and GDP positively correlated with green logistic performance indicators. REC may substantially decrease environmental deprivation and improve ecological sustainability, hence improving green logistic performance. Similarly, a higher value of green logistics performance indicators leads to lower CO₂. The cumulative institutional quality index positively and significantly correlated with green logistic operators, economic health indicators, and REC while inversely correlated with CO₂ emissions. The BRI sample contains the

Table 1 Descriptive statistics for Belt and Road host countries (full sample)

	LPITTC	LPICQL	LPICPS	LPICCP	LPICCT	LPITINF	GLPI	FDI	TO	GDP	CO2	REC	HS	INST	MVA
Mean	3.02	2.93	2.98	2.78	3.43	2.87	3.00	14.36	4.44	8.94	7.00	2.32	5.97	4.01	14.01
SD	0.59	0.58	0.49	0.57	0.53	0.66	0.54	2.65	0.70	1.30	7.44	1.31	1.47	0.83	7.65
Min	0.93	1.60	1.50	1.58	1.25	1.15	1.71	8.59	-1.79	6.26	0.10	0.10	1.95	1.68	0.14
Max	4.27	4.31	5.19	4.18	4.53	4.44	4.23	23.01	6.09	11.15	51.93	4.53	8.64	6.19	65.01
Obs	780	780	780	780	780	780	780	780	780	780	780	780	780	780	780

Source: Authors' estimations

maximum number of developing countries striving to improve their institutional quality, logistic operation, and growth. Therefore, strong institutions improve the economic and social development of host countries, while ecological deprivation can be minimized through the adoption of REC and green logistics practices.

Table 3 shows the findings of P-OLS, FE, and RE models. The coefficient values of FDI are positively associated with all green logistic operators. This indicates that Chinese OFDI significantly improves green logistic performance across all specifications. TO, GDP, and REC positively correlated to higher green logistic performance, while CO₂ is negatively correlated with poor logistic performance indicators. This specifies that poor logistics operations (lower quality of transport-related infrastructure, customs clearance, etc.) are the substantial contributors to ecological deprivation such as severe air pollution, water-waste emissions, and global warming. Weak institutional quality of the host country is the main cause of weak logistics performance and operations in terms of poor logistic services, inefficient transport systems, and corruption in the customs clearance process. Precisely, greater efficiency of logistic operators is positively correlated with economic health, environmental sustainability, and social status of the host country.

Table 4 reports the findings of FGLS and Sys-GMM estimators. From three economic indicators, Chinese FDI significantly improves green logistic operations of the host country: consignments tracking (LPITTC) by 0.059%, logistics competence and quality (LPICQL) by 0.061%, competitively priced shipments (LPICPS) by 0.033%, efficiency of customs clearance (LPICCP) by 0.029%, time efficiency of consignments delivery (LPICCT) by 0.046%, and trade and transport-related infrastructure (LPITINF) by 0.051%, at 1% level of significance. Also, the FDI significantly improves cumulative GLPI by 0.046%. These findings endorsed the key objectives of BRI, which is persuaded to improve the logistics performance of host countries to remove trade barriers (Huang 2016; Du and Zhang 2018; Wiederer 2018; Ye and Haasis 2018). Amid removing logistic operations constraints, TO and GDP also boost significantly with the improvement in logistic infrastructure (Shahriar et al. 2019). This also implies that a

lower value of logistic performance indicators corresponds to the lower value of GDP and TO. These findings are also in line with the earlier studies (Ruparathna and Hewage 2015; Werikhe and Jin 2016; Yune et al. 2016; Khan et al. 2019). These studies emphasized that trade potential significantly reduced by incompetent customs clearance procedures and massive pollution from logistics operations. Rehman Khan and Yu (2020) highlighted that firm's performance is significantly influenced by logistics operation, which helps to stimulate a firm's overall performance. Barysienė et al. (2015) and Benitez-Amado et al. (2015) observed a strong association between green logistics operations and the financial performance of a firm. Moreover, green practices in logistics activities excite the host country's per capita GDP (Khan and Qianli 2017c). Another study by Zhu et al. (2012) exhibited that the adoption of green practices in the logistics and transport sector not only decelerates ecological degradation but also improves the financial performance of firms. Similar findings were endorsed by Khan et al. (2019) from SAAR countries, who revealed a positive correlation between FDI, TO, GDP, and green logistic operations.

For environmental health, the study utilizes two indicators, i.e., CO₂ emissions and renewable energy consumption, under the influence of logistics performance indicators. From Table 4, the results reveal that CO₂ are significantly and negatively correlated with logistic performance indicators. A 1% improvement in competence and quality of logistics services (LPICQL), competitively priced shipments (LPICPS), customs clearance efficiency (LPITCCP), and quality of trade and transport-related infrastructure (LPITINF) mitigates CO₂ by 0.008%, 0.005%, 0.014%, and 0.012%, respectively. These results suggest that poor logistics operations

contribute to higher carbon emissions due to non-green practices in logistics and supply chain. Although it is hard to calculate CO₂ from all logistics operations, transportation provides a good measure; about 24% fuel-based CO₂ are attributed to transportation, while 7% of global CO₂ are linked to freight transportation, which is estimated to emit 3.20 GT of CO₂ in 2015 (Arvis et al. 2018). Dekker et al. (2012) articulated that the transportation industry is primarily responsible for air and water pollution. Similarly, Bektas et al. (2016)

Table 2 Pairwise correlations for Belt and Road host countries (full sample)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) LPITTC	1.000														
(2) LPICQL	0.926***	1.000													
(3) LPICPS	0.865***	0.814***	1.000												
(4) LPICCP	0.869***	0.898***	0.849***	1.000											
(5) LPICCT	0.906***	0.890***	0.798***	0.806***	1.000										
(6) LPITINF	0.901***	0.914***	0.864***	0.948***	0.837***	1.000									
(7) GLPI	0.963***	0.960***	0.914***	0.948***	0.922***	0.964***	1.000								
(8) FDI	0.342***	0.386***	0.306***	0.315***	0.305***	0.360***	0.357***	1.000							
(9) TO	0.306***	0.288***	0.349***	0.361***	0.290***	0.325***	0.338***	-0.034	1.000						
(10) GDP	0.711***	0.700***	0.664***	0.740***	0.691***	0.777***	0.754***	0.116***	0.367***	1.000					
(11) REC	0.348***	0.294***	0.351***	0.340***	0.342***	0.402***	0.365***	0.031	0.217***	0.664***	1.000				
(12) CO2	-0.204***	-0.192***	-0.224***	-0.255***	-0.194***	-0.326***	-0.246***	-0.113***	-0.318***	-0.554***	-0.676***	1.000			
(13) HS	0.713***	0.714***	0.633***	0.727***	0.684***	0.763***	0.749***	0.015	0.373***	0.945***	0.526***	-0.443***	1.000		
(14) INST	0.659***	0.682***	0.653***	0.729***	0.630***	0.743***	0.724***	0.322***	0.368***	0.699***	0.541***	-0.493***	0.625***	1.000	
(15) MVA	0.187***	0.211***	0.211***	0.215***	0.270***	0.210***	0.229***	0.105***	-0.020	0.085**	0.076**	0.009	0.084**	0.186***	1.000

Source: Authors' estimations

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3 Empirical results of Belt and Road host countries (full sample) from pooled OLS (P-OLS), fixed effects (FE), and random effects (RE) estimators

Variables	LPITTC			LPICQL			LPICPS			LPICCP		
	P-OLS	FE	RE	P-OLS	FE	RE	P-OLS	FE	RE	P-OLS	FE	RE
	FDI	0.059*** (0.007)	- 0.006 (0.008)	0.009 (0.009)	0.061*** (0.005)	0.020*** (0.007)	0.020*** (0.007)	0.033*** (0.005)	0.015 (0.009)	0.032*** (0.009)	0.015 (0.009)	0.015 (0.009)
TO	0.047*** (0.01)	0.004 (0.022)	0.006 (0.021)	0.014 (0.012)	0.007 (0.018)	0.003 (0.018)	0.104*** (0.014)	0.028 (0.024)	0.043* (0.022)	0.028 (0.024)	0.028 (0.024)	0.060*** (0.017)
GDP	0.140*** (0.054)	0.253*** (0.102)	0.218*** (0.062)	0.066* (0.037)	0.448*** (0.084)	0.388*** (0.053)	0.268*** (0.046)	0.055 (0.111)	0.206*** (0.062)	0.055 (0.111)	0.055 (0.111)	0.260*** (0.047)
CO ₂	- 0.001 (0.003)	0.003 (0.007)	0.004 (0.005)	- 0.007*** (0.002)	- 0.015** (0.006)	- 0.014*** (0.004)	- 0.005** (0.002)	0.018** (0.008)	0.007 (0.005)	0.018** (0.008)	0.007 (0.005)	- 0.014*** (0.003)
REC	0.136*** (0.0159)	0.138*** (0.045)	0.112*** (0.029)	0.110*** (0.012)	0.090** (0.037)	0.076*** (0.025)	0.091*** (0.011)	0.147*** (0.048)	0.114*** (0.027)	0.147*** (0.048)	0.114*** (0.027)	0.091*** (0.013)
HS	0.149*** (0.044)	0.182*** (0.042)	0.107** (0.042)	0.205*** (0.029)	- 0.007 (0.034)	- 0.039 (0.035)	- 0.045 (0.036)	0.081* (0.045)	0.023 (0.043)	0.081* (0.045)	0.023 (0.043)	0.027 (0.039)
INST	0.200*** (0.025)	- 0.031 (0.035)	0.056* (0.031)	0.251*** (0.020)	0.043 (0.029)	0.113*** (0.026)	0.179*** (0.019)	0.017 (0.038)	0.085*** (0.032)	0.017 (0.038)	0.017 (0.038)	0.287*** (0.021)
MVA	0.004 (0.002)	- 0.014*** (0.004)	- 0.001 (0.003)	0.006*** (0.002)	- 0.016*** (0.003)	- 0.004 (0.002)	0.004 (0.002)	- 0.013*** (0.004)	- 0.001 (0.003)	- 0.013*** (0.004)	- 0.001 (0.003)	0.006*** (0.001)
Constant	15.06 (12.72)	- 0.271 (0.736)	33.62 (76.45)	18.62* (9.526)	- 1.391** (0.608)	49.14 (62.49)	15.58 (11.71)	1.303 (0.799)	82.55 (82.29)	1.303 (0.799)	1.303 (0.799)	- 3.854 (11.08)

Variables	LPICCT			LPITINF			GLPI					
	P-OLS	FE	RE	P-OLS	FE	RE	P-OLS	FE	RE			
	FDI	0.032*** (0.009)	0.003 (0.008)	0.046*** (0.006)	-0.001 (0.010)	0.030*** (0.008)	0.051*** (0.005)	0.021** (0.008)	0.046*** (0.004)	0.009 (0.008)	0.046*** (0.004)	0.014** (0.006)
TO	0.001 (0.022)	0.0155 (0.020)	0.043*** (0.015)	0.001 (0.025)	0.018 (0.022)	0.015 (0.012)	0.021 (0.022)	0.048*** (0.01)	0.017 (0.021)	0.048*** (0.01)	0.009 (0.015)	0.015 (0.015)
GDP	0.687*** (0.104)	0.470*** (0.057)	0.144*** (0.054)	0.257** (0.115)	0.319*** (0.061)	0.220*** (0.044)	0.603*** (0.102)	0.374*** (0.071)	0.396*** (0.059)	0.183*** (0.030)	0.374*** (0.071)	0.341*** (0.045)
CO ₂	9.00e-05 (0.007)	- 0.012*** (0.004)	1.79e-05 (0.003)	- 0.008 (0.008)	- 0.004 (0.004)	- 0.01*** (0.002)	0.012 (0.007)	- 0.006*** (0.001)	- 0.002 (0.004)	- 0.006*** (0.001)	0.001 (0.005)	- 0.001 (0.003)
REC	0.038 (0.045)	0.065*** (0.025)	0.123*** (0.015)	0.075 (0.050)	0.106*** (0.027)	0.050*** (0.012)	0.075* (0.044)	0.098*** (0.03)	0.055** (0.027)	0.101*** (0.010)	0.098*** (0.03)	0.084*** (0.021)
HS	- 0.145*** (0.042)	- 0.132*** (0.040)	0.118*** (0.045)	0.040 (0.047)	0.001 (0.043)	0.105*** (0.036)	- 0.001 (0.041)	0.027 (0.023)	- 0.030 (0.041)	0.090*** (0.023)	0.027 (0.029)	- 0.020 (0.030)
INST	0.057 (0.035)	0.156*** (0.029)	0.151*** (0.022)	0.001 (0.039)	0.066** (0.032)	0.290*** (0.021)	0.027 (0.035)	0.224*** (0.018)	0.130*** (0.030)	0.224*** (0.018)	0.019 (0.024)	0.078*** (0.022)
MVA	- 0.001	0.006**	0.011***	0.002	0.008***	0.005***	- 0.011***	0.006***	0.002	0.006***	- 0.009***	9.31e-05

Table 3 (continued)

	(0.004)	(0.003)	(0.001)	(0.005)	(0.003)	(0.001)	(0.004)	(0.003)	(0.001)	(0.003)	(0.002)
Constant	- 3.283*** (0.748)	90.55 (75.23)	15.03 (11.64)	0.744 (0.828)	59.06 (82.49)	1.938 (11.29)	- 3.112*** (0.734)	83.38 (74.82)	9.414 (8.433)	- 0.939* (0.516)	68.40 (52.64)

Robust standard errors are in parentheses

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively

highlighted that green transportation and distribution systems are required to alleviate destructive effects on humans, flora, and fauna. The poor performance of green logistic operations such as transport infrastructure surges fossil fuel consumption, which produced a colossal sum of CO₂, creating several environmental hazards. Leigh and Li (2015) argued that environmental hazards such as environmental degradation and global warming could be neutralized using biofuels and REC in SCM process.

Table 4 shows that renewable energy consumption (REC) is positively and significantly linked with green logistic operations, indicating that a 1% improvement in REC improves LPITTC, LPICQL, LPICPS, LPICCP, LPICCT, LPITINF, and GLPI by 0.136%, 0.110%, 0.091%, 0.091%, 0.123%, 0.050%, and 0.101%, respectively, at 1% level of significance. The results highlight that REC caused efficiency-based energy conservation that improves logistic operations. According to IEA (2019), global CO₂ from transportation only increased by 0.6% in 2018 as compared with 1.6% in 2016, which dedicates to the efficiency advancement and green logistic operations in global SCM. This also indicates that poor logistic operations are linked to a lower level of REC and vice versa. Abid et al. (2012) stressed that renewable energies and biofuels would preserve environmental beauty while at the same time helping to achieve rapid economic progress. The implementation of green energy policy is considered as a prime step to achieving green logistics operations. Without particular support of political leadership and eco-friendly regulations, the business community cannot enforce it in their logistical and business activities. Recognizing the environmental constraint, Datta et al. (2015) articulated that biofuel is a possible green energy source that has the potential to transform logistics operations in commercial activities. On the other hand, Khan et al. (2016) and Mafakheri and Nasiri (2014) derived that biofuel and green energy resources do not have a promising future without reasonable governmental support and eco-legislation for tax waivers and subsidies on these projects. Besides former arguments, Li (2014) highlighted that green and renewable energy resources can mitigate ecological deprivation; through the use of renewable energy and biofuels in logistics and transportation activities, firms can create an advantage, leading to greater customer satisfaction and a better reputation in global markets that boost cross-border trade. The results conclude that green logistic performance has a profound impact to achieve sustainable growth by simultaneously minimizing CO₂ with an alternative policy shift to REC.

Undeniably, the host country’s public and private institutional quality has significantly influence logistic performance, such as customs clearance, competence, and quality of logistics. The results from Table 4 confirm that institutions are significantly and positively contribute to green logistic operation: a 1% improvement in host country’s institutional quality increase LPITTC,

Table 4 Empirical results of Belt and Road host countries (full sample) from FGLS and Sys(S)-GMM estimators

Variables	LPTTTC		LPICQL		LPICPS		LPICCP		LPICCT		LPTINF		GLPI	
	FGLS	S-GMM	FGLS	S-GMM	FGLS	S-GMM	FGLS	S-GMM	FGLS	S-GMM	FGLS	S-GMM	FGLS	S-GMM
FDI	0.059*** (0.005)	0.050*** (0.010)	0.061*** (0.004)	0.042*** (0.007)	0.033*** (0.005)	0.032*** (0.007)	0.029*** (0.004)	0.031*** (0.009)	0.046*** (0.005)	0.043*** (0.007)	0.051*** (0.005)	0.044*** (0.008)	0.046*** (0.004)	0.034*** (0.007)
TO	0.047** (0.02)	0.035 (0.021)	0.013 (0.017)	0.003 (0.017)	0.104*** (0.019)	0.083*** (0.023)	0.060*** (0.017)	0.054 (0.033)	0.043** (0.018)	0.038* (0.019)	0.015 (0.018)	- 0.007 (0.021)	0.048*** (0.015)	0.023 (0.019)
GDP	0.140*** (0.043)	0.131** (0.049)	0.066* (0.038)	0.059 (0.059)	0.268*** (0.041)	0.204*** (0.042)	0.260*** (0.038)	0.214*** (0.053)	0.144*** (0.040)	0.113** (0.048)	0.220*** (0.040)	0.151*** (0.042)	0.183*** (0.032)	0.139*** (0.043)
CO ₂	- 0.001 (0.002)	- 0.002 (0.003)	- 0.008*** (0.002)	- 0.006** (0.003)	- 0.005** (0.002)	- 0.003 (0.002)	- 0.014*** (0.002)	- 0.013*** (0.003)	1.79e-05 (0.00269)	- 0.001 (0.003)	- 0.012*** (0.002)	- 0.010*** (0.004)	- 0.006*** (0.002)	- 0.005* (0.002)
REC	0.136*** (0.014)	0.121*** (0.021)	0.110*** (0.012)	0.089*** (0.017)	0.091*** (0.013)	0.088*** (0.017)	0.091*** (0.012)	0.099*** (0.023)	0.123*** (0.013)	0.113*** (0.022)	0.050*** (0.013)	0.052*** (0.017)	0.101*** (0.010)	0.096*** (0.016)
HS	0.149*** (0.033)	0.117*** (0.038)	0.205*** (0.029)	0.150*** (0.046)	- 0.045 (0.031)	- 0.027 (0.038)	0.0272 (0.029)	0.072 (0.045)	0.118*** (0.031)	0.120*** (0.037)	0.105*** (0.031)	0.123*** (0.038)	0.090*** (0.025)	0.091*** (0.033)
INST	0.200*** (0.022)	0.170*** (0.045)	0.251*** (0.020)	0.189*** (0.032)	0.179*** (0.021)	0.149*** (0.032)	0.287*** (0.020)	0.276*** (0.044)	0.151*** (0.021)	0.165*** (0.041)	0.290*** (0.021)	0.224*** (0.036)	0.224*** (0.017)	0.183*** (0.037)
MVA	0.004*** (0.002)	0.006 (0.003)	0.006*** (0.001)	0.011*** (0.003)	0.004*** (0.001)	0.005* (0.002)	0.006*** (0.001)	0.009*** (0.003)	0.011*** (0.001)	0.007*** (0.003)	0.005*** (0.001)	0.006** (0.002)	0.006*** (0.001)	0.009** (0.003)
Lag. dependent	-	0.189*** (0.012)	-	0.234*** (0.012)	-	0.155*** (0.011)	-	0.067*** (0.015)	-	0.077*** (0.011)	-	0.227*** (0.014)	-	0.199*** (0.015)
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Arellano bond test AR-1	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000
Arellano bond test AR-2	-	0.252	-	0.307	-	0.450	-	0.230	-	0.109	-	0.263	-	0.245
Hansen (p value)	-	0.219	-	0.184	-	0.210	-	0.238	-	0.238	-	0.279	-	0.290

Robust standard errors are in parentheses. Diagnostics test of System GMM estimator: Hansen’s test for overidentification indicates that the additional instruments associated with the system GMM estimator are valid. The test hypothesis of AR-1 is rejected, while AR-2 cannot be rejected, indicating toward the assumption that the residuals are serially uncorrelated at the second-order condition is fulfilled. The coefficients of lag. dependent variables are significantly positive, confirming that current values of logistic operations are substantially affected by their own lagged values. It also confirms the rationality of System GMM estimator

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively

LPICQL, LPICPS, LPICCT, LPITINF, and GLPI by 0.200%, 0.251%, 0.179%, 0.287%, 0.151%, 0.290%, and 0.242% respectively, at 1% level of significance. HS and MVA produce a positive correlation across all logistic performance indicators, suggesting that higher logistic performance is attributed to higher MVA and HS. The coefficient of HS is positive against the assumption, which might be the reason that major BRI developing countries have relatively lower health spending, lower average life due to lower socioeconomic status, relatively higher population growth, poverty, and food deprivation, thus increasing health problems caused by higher public health spending (Chan et al. 2019). However, several regions (see Appendix Table 7) show a negative correlation between HS and logistics quality. Burrell (2006) examined that emission activities in firms and industries have a detrimental effect on our society, particularly human health issues due arise from air pollution. Due to poor transport-related infrastructure, various pollution-related ailments are growing, which caused asthma, hypertension, eye infection, severe lower respirational contagions in children, and lung problem (Dekker et al. 2012; Khan et al. 2020).

Most of the BRI developing countries fall in the lower range of institutional quality as compared with developed countries. Due to political unrest, military control or dictatorship, terrorism, wars, weak government control, poor legislation, and terrestrial disputes in most of the BRI host countries jeopardize political stability, economic progress, and environmental legislation (Duan et al. 2018). Heldeweg et al. (2015) and Rodríguez et al. (2014) argued that social concerns can only be mitigated through long-term political stability and efficient institutional governance, which helps to not only improve countries economic prosperity but also improve eco-friendly regulations efficiency (Bush et al. 2015; Datta et al. 2015; Nawaz et al. 2019). Generally, the BRI host countries have weak logistics infrastructure and customs efficiency due to less effective equipment and unqualified staff (Arvis et al. 2018).

Also, most of the transactions processed manually, which is the core reason for delays in the end-to-end clearance process. Moreover, most of the BRI countries carry the culture of bribe and corruption, particularly developing south asian BRI countries like India, Pakistan, and Bangladesh. (Quazi 2014). In some instances, the customs authorities deliberately obstruct the

custom clearance process to grab the bribe money. Bölük and Mert (2015) argued that inefficient customs clearance processes, poor transport-related infrastructure, polluting logistics vehicles, and corruption reduced trade potential with European economies. It also damages a country’s image in the international market through the adoption of non-green practices and less stringent environmental laws in its global logistics operations. Zawaydeh (2017) revealed that logistics industries significantly promote the economic health of the host country. It is mainly attributed to higher energy and CO₂ that far beyond impacts ecological sustainability, human diseases, and global warming. Since the inception of BRI in 2013, the logistics performance of BRI host countries has significantly improved. Infrastructure-based Chinese outward FDI helps to build logistic transport and infrastructure across the BRI route (Du and Zhang 2018). Although the trend is positive, but still there is a need to improve basic institutional quality as well as quantity of logistics in terms of transport-related infrastructure to achieve sustainable development. Table 5 confirms the acceptance of all three hypotheses tested in this study, indicating that GLOs are positively linked with the economic, environmental and social development of BRI host countries.

These results confirm the theoretical foundations of triple bottom line (TBL). This theory provides a sustainability framework that examines social, environmental, and economic performances of firms. We have expanded this theory to draw the link between TBL factors and GLOs at the national level through macro-indicators across BRI host countries. The acceptance of TBL hypotheses opens a new avenue for the legislatures to formulate national strategies and derive sustainable growth. It can be served as a foundation to analyze firm-level factors at a national scale to integrate an overall impact of a country’s performance.

The BRI countries are following diverse socio-economic and demographic characteristics. Therefore, to internalize heterogeneous regional effects, it is also imperative to draw the relationship across different demographic regions, which not only helps us to compare the results with overall BRI findings but also provides interesting insights from diverse BRI sample. Appendix Table 7 reports the estimates from seven regions across the BRI host countries. The overall results support our primary findings; however, they reveal significant variation across the BRI sub-samples. These variations are

Table 5 Summary of hypotheses decision across Belt and Road host countries

Hypothesis	Description	Decision
H1	GLOs are positively correlated with macro-economic indicators	Accepted
H2	GLOs are positively correlated with greater environmental sustainability	Accepted
H3	GLOs are positively correlated with social indicators	Accepted

Source: Authors estimation

attributed to the different socio-economic and institutional characteristics of BRI host countries.

Conclusion

The BRI is considered a new “global grand strategy” that develops connectivity between China’s less-developed western region with other less developed countries in central Asia through multiple logistic infrastructure and transport projects (Cai 2017). The BRI developing countries exhibited significant logistic infrastructure gaps, which not only restricts their trade and economic progress but also creates several social and environmental challenges (Wiederer 2018). Therefore, this study investigates the relationship between green logistics operations, economic, environmental, and social indicators of countries along with the Belt and Road Initiative (BRI). From the perspective of modern supply chain management, the stance that global logistics should have in encouraging economic, environmental, and social activities is quite contentious. This discussion is further complicated by including other essential factors in logistic operations such as institutional quality, human health, ecological deprivation, and social issues. Therefore, this study examines the correlation between green logistics operations, economic, environmental, and social indicators using FGLS and Sys-GMM estimators.

The findings show that Chinese outward foreign direct investment significantly improves the quality of all logistic operations of the BRI host countries. The lower quality of green logistic performance indicators in terms of trade and transport-related infrastructure, customs clearance efficiency, competency of logistics services, and competitively priced shipments lead toward higher carbon emissions due to higher fossil fuel consumption in SCM process, not only creating environmental pollution but also agonies people health. The application of renewable energy resources and green practices significantly improves the quality of all logistics operations, which in turn mitigates social and ecological concerns while improving the economic growth of the host countries. Further, the efficiency of customs clearance process, cost, time and delivery efficiency of consignments, and greater information sharing among supply chain partners is positively correlated with trade openness. It suggests that a higher green logistic performance stimulates trade and business activities and boost economic growth.

The quality of institutions significantly improves all green logistic performance indicators. On the other hand, manufacturing value-added and public health spending are positively correlated with higher logistic performance indicators; however, their results show significant variations across diverse regional samples (see Appendix Table 7). Higher green logistic performances in terms of shipment cost, tracking and delivery, transport-infrastructure, and customs

clearance are negatively correlated with health spending of south Asia, central Asia, east Asia, and CIS countries, respectively. Interestingly, health spending is negatively linked to all green logistic performance indicators in central and eastern Europe, suggesting a higher sustainable and green logistics improves the health conditions of local inhabitants, resultantly reducing per capita public health expenditures. Concludingly, a higher quality of green logistic operations is positively correlated with economic health indicators (FDI, GDP, and TO), environmental sustainability (lower CO₂ and higher REC), and social indicators (institutions and health). The overall results imply that strong institutions improve the economic and social development of host countries. At the same time, environmental pollution can be mitigated by adopting REC and green logistics in SCM process.

Policy recommendations

The findings of the study can help to draft green logistics policies and regulations that would be helpful to promote green practices at a national scale. The BRI minimizes logistics infrastructure gap, in turn stimulating FDI growth, GDP, trade, employment, and green logistics performance. Therefore, it can be used as a tool of poverty alleviation and environmental sustainability across the Belt and Road region. Without sequester logistic infrastructure, a country’s sustainable growth is impeded. Thus, BRI host countries need to devise policies that increase Chinese infrastructure-based FDI, which can also produce several technology spillovers for recipient countries. Moreover, energy consumption is at the heart of the logistic operations. Therefore, innovation-led energy conservation (renewable energy) in logistic operations can decrease carbon emissions, control climate change, and protect flora and fauna. An environmentally friendly and green logistics network can create a competitive edge in global competition, and better reputation in global markets boost cross-border trade and economy and facilitate greater socio-environmental sustainability. Finally, a strong institutional foundation is a pre-requisite to align all these objectives. Without reasonable institutional capacity, neither a country implements green practices in logistic operations nor achieve socio-economic milestones. Therefore, besides physical logistic infrastructure, the BRI host countries need to build a strong institutional governance framework to achieve sustainable development.

Limitations and future direction

However, this study attempts to draw the link between logistic operations with social, economic, and environmental factors. However, this study is limited to national indicators across Belt and Road host countries using China-specific investment in the region. Due to specific scope, this study examines international logistics operations, and future research should be

directed to study domestic logistics operations and their impact on socio-economic factors at the disaggregated/country level.

Authors' contribution Hui An: supervision: conceptualizing, and drafting of the original draft.

Asif Razzaq: conceptualizing, methodology, empirical estimations, writing, and drafting of the original draft

Ahsan Nawaz: Review and editing

Sohail M. Noman: Data collection

Syed Abdul Rehman Khan: Review and editing

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Declarations

Ethical approval Not applicable

Consent to participate Not applicable

Consent to publish Not applicable

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Appendix

Table 6 Descriptive statistics of Belt and Road regional samples

Region		LPITTC	LPICQL	LPICPS	LPICCP	LPICCT	LPITINF	GLPI	FDI	TO	GDP	CO ₂	REC	HS	INST	MVA
South Asia	Mean	2.65	2.58	2.69	2.41	3.06	2.39	2.64	14.27	3.98	7.43	1.08	3.42	4.26	3.63	11.91
	SD	0.30	0.37	0.33	0.31	0.33	0.36	0.30	2.01	0.52	0.85	0.79	1.21	1.23	0.47	5.82
	Min	1.95	1.71	1.86	1.83	2.21	1.70	2.04	9.76	3.23	6.26	0.10	0.70	2.63	2.76	1.92
	Max	3.52	3.39	3.36	3.17	3.74	3.34	3.42	17.42	5.22	8.99	3.07	4.53	7.27	4.44	19.44
Southeast Asia	Mean	2.99	2.82	3.04	2.74	3.37	2.80	2.96	16.14	4.48	8.47	5.48	2.59	5.13	3.90	16.71
	SD	0.56	0.59	0.62	0.58	0.50	0.66	0.54	1.97	1.20	1.23	5.99	1.37	1.21	0.90	7.46
	Min	1.57	1.60	1.50	1.63	2.08	1.67	1.71	10.68	-1.79	6.59	0.18	0.10	1.95	2.56	0.14
	Max	4.25	4.21	5.19	4.18	4.53	4.28	4.19	19.88	6.08	10.97	24.63	4.46	7.93	6.19	31.07
East Asia	Mean	3.92	3.87	3.65	3.68	4.14	3.96	3.86	18.50	4.66	10.41	9.12	1.19	7.86	5.04	16.34
	SD	0.16	0.17	0.18	0.23	0.14	0.22	0.17	2.64	1.04	0.29	2.38	0.54	0.52	0.68	11.08
	Min	3.56	3.59	3.33	3.22	3.86	3.44	3.52	15.43	3.20	9.92	5.79	0.56	7.02	3.70	0.98
	Max	4.13	4.12	4.18	3.99	4.34	4.25	4.12	23.01	6.09	10.80	13.59	2.24	8.56	5.78	28.48
Central Asia	Mean	2.44	2.35	2.47	2.21	2.88	2.26	2.44	14.38	4.31	7.58	5.11	2.34	4.57	3.51	11.91
	SD	0.30	0.21	0.30	0.24	0.34	0.23	0.22	1.38	0.42	1.00	5.77	1.27	0.70	0.44	2.33
	Min	1.67	1.90	2.00	1.80	2.04	1.86	1.93	12.40	3.39	6.51	0.31	0.81	3.36	2.65	7.62
	Max	2.96	2.75	3.29	2.75	3.72	2.76	2.83	17.00	4.98	9.32	16.80	4.14	5.94	4.41	18.27
MENA countries	Mean	2.94	2.87	2.89	2.67	3.38	2.83	2.93	14.16	4.33	9.09	11.51	1.35	6.01	4.23	13.57
	SD	0.49	0.46	0.40	0.47	0.46	0.54	0.43	2.30	0.47	1.28	11.71	1.41	1.18	0.93	10.37
	Min	1.86	1.91	1.93	1.63	2.07	1.45	2.04	8.63	3.03	6.50	0.25	0.10	3.76	1.68	1.63
	Max	3.96	3.92	3.89	3.84	4.38	4.07	3.96	17.82	5.26	11.15	51.93	4.50	8.02	5.95	65.01
Central and eastern Europe	Mean	3.07	2.99	3.08	2.84	3.56	2.84	3.07	12.09	4.71	9.37	6.41	3.08	6.67	3.78	15.29
	SD	0.39	0.32	0.28	0.34	0.35	0.37	0.31	1.98	0.28	0.52	3.43	0.44	0.55	0.44	4.81
	Min	1.67	2.00	2.28	2.00	2.13	1.98	2.08	8.59	4.07	8.16	1.32	1.98	5.31	2.89	4.61
	Max	3.84	3.72	3.75	3.58	4.52	3.57	3.68	15.56	5.13	10.20	18.60	3.76	7.68	5.03	24.87
Western Europe	Mean	3.79	3.68	3.48	3.50	4.06	3.76	3.70	15.17	4.49	10.54	7.72	2.38	8.14	4.57	11.73
	SD	0.43	0.51	0.35	0.46	0.35	0.51	0.42	2.44	0.43	0.25	1.86	0.39	0.42	0.86	4.56
	Min	2.54	2.69	2.69	2.38	3.25	2.87	2.83	9.52	3.82	10.01	4.57	1.49	7.30	3.28	3.89
	Max	4.27	4.31	4.05	4.12	4.48	4.44	4.23	19.14	5.11	10.92	11.02	3.07	8.64	6.00	20.85
CIS countries	Mean	2.49	2.43	2.58	2.37	2.97	2.41	2.54	12.66	4.53	8.37	3.97	2.20	5.55	3.63	11.87
	SD	0.41	0.22	0.22	0.37	0.41	0.35	0.17	1.68	0.23	0.30	1.99	0.81	0.40	0.45	6.27
	Min	0.93	2.00	2.00	1.58	1.25	1.15	2.14	9.49	4.02	7.95	1.34	1.17	3.90	2.66	3.99
	Max	3.20	2.85	3.05	3.87	3.51	3.30	2.98	15.37	5.06	8.83	6.91	3.72	6.12	4.65	26.42

Source: Authors estimations

Table 7 Empirical results of Belt and Road regional samples

Panels	Variables	LPITTC		LPICQL		LPICPS		LPICCP		LPICCT		LPITINF		GLPI	
		FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS
South Asia	FDI	0.0613*** (0.0187)	0.0613*** (0.0223)	0.00593 (0.0164)	0.00593 (0.0196)	0.0855*** (0.0193)	0.0855*** (0.0232)	-0.0182 (0.0233)	-0.0182 (0.0279)	0.152*** (0.0275)	0.152*** (0.0329)	0.0682*** (0.0226)	0.0682*** (0.0271)	0.0597*** (0.0167)	0.0597*** (0.0201)
	TO	0.560*** (0.129)	0.560*** (0.155)	-0.0476 (0.114)	-0.0476 (0.136)	0.217 (0.161)	0.217 (0.161)	-0.299* (0.162)	-0.299* (0.162)	1.087*** (0.191)	1.087*** (0.228)	0.297* (0.157)	0.297* (0.198)	0.299** (0.116)	0.299** (0.139)
	GDP	-0.0193 (0.179)	-0.0193 (0.215)	-0.490*** (0.157)	-0.490*** (0.188)	0.00119 (0.186)	0.00119 (0.224)	-0.162 (0.224)	-0.162 (0.224)	-0.288 (0.268)	-0.288 (0.316)	-0.658*** (0.217)	-0.658*** (0.260)	-0.262 (0.161)	-0.262 (0.193)
	CO ₂	-0.00719 (0.0569)	-0.00719 (0.0682)	-0.154*** (0.0499)	-0.154*** (0.0598)	-0.332*** (0.0590)	-0.332*** (0.0707)	-0.0385 (0.0712)	-0.0385 (0.0712)	-0.125 (0.0839)	-0.125 (0.100)	-0.159** (0.0690)	-0.159** (0.0827)	-0.141** (0.0511)	-0.141** (0.0612)
	REC	0.213** (0.0873)	0.213** (0.105)	0.277*** (0.0766)	0.277*** (0.0917)	-0.0533 (0.0905)	-0.0533 (0.108)	0.371*** (0.109)	0.371*** (0.131)	-0.0280 (0.129)	-0.0280 (0.154)	0.298*** (0.106)	0.298*** (0.127)	0.173** (0.0784)	0.173** (0.0939)
Southeast Asia	HS	-0.305** (0.144)	-0.305** (0.173)	0.0585 (0.126)	0.0585 (0.151)	-0.345** (0.149)	-0.345** (0.179)	0.0276 (0.180)	0.0276 (0.216)	-0.208 (0.212)	-0.208 (0.254)	0.193 (0.175)	0.193 (0.209)	-0.102 (0.129)	-0.102 (0.155)
	INST	0.316*** (0.0876)	0.316*** (0.105)	0.531*** (0.0768)	0.531*** (0.0920)	0.440*** (0.0907)	0.440*** (0.109)	0.252* (0.109)	0.252* (0.131)	0.145 (0.129)	0.145 (0.154)	0.236** (0.106)	0.236** (0.127)	0.323*** (0.0786)	0.323*** (0.0942)
	MVA	0.0124 (0.00956)	0.0124 (0.0112)	0.0333*** (0.00821)	0.0333*** (0.00983)	0.0106 (0.0970)	0.0106 (0.116)	0.0131 (0.117)	0.0131 (0.140)	0.0300** (0.0138)	0.0300** (0.0165)	0.0385*** (0.0113)	0.0385*** (0.0136)	0.0227*** (0.00840)	0.0227*** (0.0101)
	FDI	0.0711*** (0.0148)	0.0711*** (0.0318)	0.041*** (0.0151)	0.041*** (0.0301)	0.171*** (0.0229)	0.171*** (0.0454)	0.072*** (0.0151)	0.072*** (0.0331)	0.00157 (0.0163)	0.00157 (0.0355)	0.0347** (0.0173)	0.0347** (0.0369)	0.0525*** (0.0132)	0.0525*** (0.0290)
	TO	0.0704*** (0.0226)	0.0704*** (0.0260)	-0.0188 (0.0230)	-0.0188 (0.0279)	0.876** (0.0350)	0.876** (0.0397)	0.0205 (0.0230)	0.0205 (0.0216)	0.0364 (0.0250)	0.0364 (0.0282)	0.0437* (0.0264)	0.0437* (0.0274)	0.0394* (0.0202)	0.0394* (0.0201)
East Asia	GDP	0.303*** (0.0965)	0.303*** (0.149)	-0.0610 (0.0981)	-0.0610 (0.138)	0.400*** (0.149)	0.400*** (0.218)	0.131 (0.0982)	0.131 (0.152)	0.110 (0.106)	0.110 (0.165)	0.211* (0.112)	0.211* (0.169)	0.183** (0.0861)	0.183** (0.133)
	CO ₂	-0.0268*** (0.00811)	-0.0268*** (0.0115)	-0.0632*** (0.00825)	-0.0632*** (0.00969)	0.00232 (0.0125)	0.00232 (0.0173)	-0.0238*** (0.00826)	-0.0238*** (0.00999)	-0.0370*** (0.00894)	-0.0370*** (0.0125)	-0.0105 (0.00944)	-0.0105 (0.0123)	-0.00239 (0.00724)	-0.00239 (0.00918)
	REC	0.302*** (0.0575)	0.302*** (0.102)	-0.0455 (0.0584)	-0.0455 (0.0948)	0.402*** (0.0888)	0.402*** (0.149)	0.127** (0.0585)	0.127** (0.105)	0.0979 (0.0633)	0.0979 (0.113)	0.211*** (0.0669)	0.211*** (0.117)	0.181*** (0.0513)	0.181*** (0.0914)
	HS	0.210*** (0.0616)	0.210*** (0.0894)	0.354*** (0.0626)	0.354*** (0.0764)	0.160* (0.0952)	0.160* (0.134)	0.136*** (0.0627)	0.136*** (0.0793)	0.206** (0.0679)	0.206** (0.0978)	0.189*** (0.0717)	0.189*** (0.0967)	0.208*** (0.0550)	0.208*** (0.0725)
	INST	0.310*** (0.0366)	0.310*** (0.0662)	0.299*** (0.0372)	0.299*** (0.0595)	0.284*** (0.0566)	0.284*** (0.0966)	0.482*** (0.0373)	0.482*** (0.0632)	0.232*** (0.0474)	0.232*** (0.0743)	0.402*** (0.0426)	0.402*** (0.0743)	0.332*** (0.0327)	0.332*** (0.0569)
Central Asia	MVA	-0.00288 (0.00563)	-0.00288 (0.00848)	0.0249*** (0.00573)	0.0249*** (0.00729)	-0.0147* (0.00870)	-0.0147* (0.0127)	0.00617 (0.00573)	0.00617 (0.00760)	0.0179*** (0.00621)	0.0179*** (0.00929)	0.00928 (0.00656)	0.00928 (0.00922)	0.00698 (0.00503)	0.00698 (0.00693)
	FDI	-0.0358*** (0.00808)	-0.0358*** (0.00908)	-0.0280*** (0.00825)	-0.0280*** (0.0144)	-0.0498*** (0.0157)	-0.0498*** (0.0262)	-0.0208 (0.0132)	-0.0208 (0.0215)	0.00125 (0.00927)	0.00125 (0.0184)	0.0562*** (0.0115)	0.0562*** (0.0198)	-0.0164* (0.00887)	-0.0164* (0.0159)
	TO	0.473*** (0.0692)	0.473*** (0.152)	0.452*** (0.0707)	0.452*** (0.151)	0.0715 (0.134)	0.0715 (0.353)	-0.00404 (0.113)	-0.00404 (0.309)	0.484*** (0.0794)	0.484*** (0.180)	0.513** (0.0981)	0.513** (0.214)	0.328*** (0.193)	0.328*** (0.193)
	GDP	0.655*** (0.0441)	0.655*** (0.140)	0.498*** (0.0450)	0.498*** (0.0825)	0.572*** (0.0855)	0.572*** (0.290)	0.479*** (0.0722)	0.479*** (0.247)	0.874*** (0.0506)	0.874*** (0.120)	0.974*** (0.0625)	0.974*** (0.144)	0.667*** (0.0484)	0.667*** (0.137)
	CO ₂	0.00595 (0.0398)	0.00595 (0.125)	0.00608 (0.0406)	0.00608 (0.119)	0.197** (0.0771)	0.197** (0.254)	-0.0527*** (0.0115)	-0.0527*** (0.0281)	-0.0406*** (0.00683)	-0.0406*** (0.0135)	-0.0652*** (0.00844)	-0.0652*** (0.0171)	-0.0397*** (0.00653)	-0.0397*** (0.0154)
Central Asia	REC	0.432*** (0.0713)	0.432*** (0.141)	0.311*** (0.0729)	0.311*** (0.149)	-0.347** (0.138)	-0.347** (0.346)	0.197** (0.117)	0.197** (0.291)	0.372*** (0.0819)	0.372*** (0.188)	0.0512 (0.101)	0.0512 (0.228)	0.119*** (0.0783)	0.119*** (0.187)
	HS	-0.104 (0.00892)	-0.104 (0.0152)	0.0581*** (0.00911)	0.0581*** (0.0167)	0.129*** (0.0173)	0.129*** (0.0392)	0.103*** (0.0146)	0.103*** (0.0146)	0.110*** (0.0102)	0.110*** (0.0231)	0.151*** (0.0126)	0.151*** (0.0284)	0.0961*** (0.00979)	0.0961*** (0.0214)
	INST	-0.00438 (0.00381)	-0.00438 (0.0116)	-0.00464 (0.00389)	-0.00464 (0.00572)	0.00379 (0.00624)	0.00379 (0.0208)	0.0106 (0.0187)	0.0106 (0.0187)	-0.00173 (0.00437)	-0.00173 (0.00882)	0.0108** (0.00540)	0.0108** (0.0133)	0.00169 (0.00418)	0.00169 (0.00958)
	MVA	-0.141* (0.074)	-0.141* (0.094)	0.0919*** (0.006)	0.0919*** (0.008)	0.0606 (0.0977)	0.0606 (0.125)	0.0512 (0.103)	0.0512 (0.116)	-0.109 (0.0834)	-0.109 (0.120)	0.126* (0.0705)	0.126* (0.0725)	0.0133 (0.0595)	0.0133 (0.0706)
	TO	0.435*** (0.0629)	0.435*** (0.0629)	0.0629 (0.130)	0.0629 (0.130)	0.130 (0.127)	0.130 (0.127)	0.127 (0.127)	0.127 (0.127)	0.120 (0.120)	0.120 (0.120)	0.223** (0.0705)	0.223** (0.0725)	0.176* (0.0595)	0.176* (0.0706)

Table 7 (continued)

Panels	Variables		LPITTC		LPICQL		LPICPS		LPICCP		LPICCT		LPITINF		GLPI			
	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS		
MENAs states	GDP	(0.120) 1.108*** (0.371)	(0.146) 1.108*** (0.408)	(0.0977) 0.420 (0.303)	(0.102) 0.420 (0.378)	(0.157) 0.773 (0.488)	(0.173) 0.773 (0.613)	(0.166) 0.337 (0.515)	(0.239) 0.337 (0.669)	(0.134) 1.504*** (0.416)	(0.140) 1.504*** (0.543)	(0.113) 0.141 (0.352)	(0.141) 0.141 (0.555)	(0.0957) 0.729** (0.297)	(0.114) 0.729** (0.379)	(0.114) 0.729** (0.379)	(0.114) 0.729** (0.379)	
	CO ₂	(0.0412) -0.106*** (0.160)**	(0.0453) -0.106*** (0.160)**	(0.0336) -0.0579* (0.0235)	(0.0393) -0.0579* (0.0235)	(0.0541) -0.0581 (0.141*)	(0.0645) -0.0581 (0.141*)	(0.0570) 0.00686 (0.0736)	(0.0736) 0.00686 (0.0736)	(0.0736) 0.00686 (0.0736)	(0.0462) -0.108** (0.0462)	(0.0579) -0.108** (0.0579)	(0.0390) -0.0390 (0.0604)	(0.0604) -0.0390 (0.0604)	(0.0329) -0.0600* (0.0130)	(0.0403) -0.0609 (0.0130)	(0.0403) -0.0609 (0.0130)	(0.0403) -0.0609 (0.0130)
	REC	(0.0641) -0.378** (0.207)	(0.0865) -0.378** (0.197)	(0.0524) -0.0199 (0.169)	(0.0643) -0.0199 (0.189)	(0.0843) -0.243 (0.273)	(0.101) -0.243 (0.328)	(0.0889) -0.258 (0.287)	(0.110) -0.258 (0.320)	(0.110) -0.258 (0.320)	(0.0719) -0.856*** (0.233)	(0.0789) -0.856*** (0.233)	(0.0608) 0.0879 (0.197)	(0.0608) 0.0879 (0.262)	(0.0513) -0.288* (0.166)	(0.0528) -0.288* (0.184)	(0.0528) -0.288* (0.184)	(0.0528) -0.288* (0.184)
	INST	(0.143) -0.265* (0.117)	(0.242) -0.265* (0.188)	(0.0461)** -0.260** (0.117)	(0.0461)** -0.260** (0.117)	(0.383** -0.383** (0.188)	(0.383** -0.383** (0.188)	(0.423** -0.423** (0.199)	(0.423** -0.423** (0.199)	(0.423** -0.423** (0.199)	(0.534*** -0.534*** (0.161)	(0.215) -0.534*** (0.139)	(0.277** -0.277** (0.136)	(0.277** -0.277** (0.136)	(0.115) -0.361*** (0.115)	(0.115) -0.361*** (0.115)	(0.115) -0.361*** (0.115)	(0.115) -0.361*** (0.115)
	MVA	(0.0158) -0.0594*** (0.0167)	(0.0300) -0.0594*** (0.0167)	(0.0129) -0.0461*** (0.00624)	(0.0129) -0.0461*** (0.00624)	(0.0208) -0.0319 (0.0355***)	(0.0278) -0.0319 (0.0355***)	(0.0258) -0.0263 (0.00370)	(0.0258) -0.0263 (0.00370)	(0.0258) -0.0263 (0.00370)	(0.0247) -0.0298* (0.0110)	(0.0247) -0.0298* (0.0110)	(0.0150) -0.0713*** (0.0121)	(0.0150) -0.0713*** (0.0121)	(0.0126) -0.0426*** (0.0126)	(0.0197) -0.0426*** (0.0126)	(0.0197) -0.0426*** (0.0126)	(0.0197) -0.0426*** (0.0126)
Central and eastern Europe	FDI	(0.0127) 0.125*	(0.0134) 0.125*	(0.00624) 0.0447	(0.0117) 0.0447	(0.0113) 0.383***	(0.0116) 0.383***	(0.0136) 0.262***	(0.0142) 0.262***	(0.0122) 0.0517	(0.0132) 0.0517	(0.0121) 0.171**	(0.0121) 0.171**	(0.0484) 0.180***	(0.0484) 0.180***	(0.0484) 0.180***	(0.0484) 0.180***	
	TO	(0.0751) 0.381***	(0.0792) 0.381***	(0.0734) 0.369***	(0.0767) 0.369***	(0.0668) 0.0461	(0.0702) 0.0461	(0.0805) 0.441***	(0.0849) 0.441***	(0.0722) 0.430***	(0.0718) 0.430***	(0.0722) 0.617***	(0.0722) 0.617***	(0.0580) 0.369***	(0.0580) 0.369***	(0.0580) 0.369***	(0.0580) 0.369***	
	GDP	(0.0857) -0.0138***	(0.0840) -0.0138***	(0.0838) -0.0244***	(0.0808) -0.0244***	(0.0762) -0.00196	(0.0754) -0.00196	(0.0919) -0.0228***	(0.0919) -0.0228***	(0.0824) -0.0151***	(0.0779) -0.0151***	(0.0824) -0.0304***	(0.0740) -0.0304***	(0.0662) -0.0176***	(0.0662) -0.0176***	(0.0662) -0.0176***	(0.0662) -0.0176***	
	CO ₂	(0.00458) 0.129***	(0.00408) 0.129***	(0.00448) 0.0523**	(0.00426) 0.0523**	(0.00407) 0.127***	(0.00388) 0.127***	(0.00491) 0.0741**	(0.00477) 0.0741**	(0.00440) 0.121***	(0.00417) 0.121***	(0.00440) 0.0380	(0.00395) 0.0380	(0.00354) 0.0916***	(0.00354) 0.0916***	(0.00354) 0.0916***	(0.00354) 0.0916***	
	REC	(0.0269) -0.109	(0.0298) -0.109	(0.0262) -0.0594	(0.0254) -0.0594	(0.0239) 0.0617	(0.0224) 0.0617	(0.0288) 0.120	(0.0277) 0.120	(0.0277) 0.120	(0.0258) -0.130*	(0.0279) -0.130*	(0.0258) -0.259***	(0.0246) -0.259***	(0.0207) -0.0970	(0.0208) -0.0970	(0.0208) -0.0970	(0.0208) -0.0970
Western Europe	INST	(0.0799) 0.256***	(0.0717) 0.256***	(0.0781) 0.248***	(0.0707) 0.248***	(0.0710) 0.177***	(0.0756) 0.177***	(0.0856) 0.194***	(0.0820) 0.194***	(0.0820) 0.194***	(0.0775) 0.257***	(0.0768) 0.264***	(0.0677) 0.264***	(0.0677) 0.264***	(0.0577) 0.230***	(0.0577) 0.230***	(0.0577) 0.230***	(0.0577) 0.230***
	MVA	(0.0513) -0.0160***	(0.0600) -0.0160***	(0.0501) -0.0116***	(0.0573) -0.0116***	(0.0456) -0.00369*	(0.0424) -0.00369*	(0.0550) -0.00209	(0.0550) -0.00209	(0.0456) -0.00209	(0.0457) -0.00294	(0.0493) -0.00779***	(0.0475) -0.00779***	(0.0493) -0.00679***	(0.0411) -0.00679***	(0.0411) -0.00679***	(0.0411) -0.00679***	(0.0411) -0.00679***
	FDI	(0.00251) -0.0290*	(0.00338) -0.0290*	(0.00245) 0.0116	(0.00244) 0.0116	(0.00223) -0.0107	(0.00275) -0.0107	(0.00269) -0.00286	(0.00249) -0.00286	(0.00241) 0.00332	(0.00353) 0.00332	(0.00241) 0.00723	(0.00212) 0.00723	(0.00194) -0.00369	(0.00194) -0.00369	(0.00186) -0.00369	(0.00186) -0.00369	(0.00186) -0.00369
	TO	(0.0168) 0.0328	(0.0191) 0.0328	(0.0112) -0.0103	(0.0121) -0.0103	(0.0155) -0.0855	(0.0167) -0.0855	(0.0134) -0.0557	(0.0124) -0.0557	(0.0124) -0.0557	(0.0199) -0.143	(0.0183) -0.143	(0.0153) 0.173**	(0.0154) 0.173**	(0.0119) -0.0216	(0.0113) -0.0216	(0.0113) -0.0216	(0.0113) -0.0216
	GDP	(0.0873) 0.885***	(0.0964) 0.885***	(0.0582) 0.588***	(0.0504) 0.588***	(0.0804) 0.543***	(0.0739) 0.543***	(0.0696) 0.646***	(0.0682) 0.646***	(0.0682) 0.646***	(0.103) 0.603***	(0.101) 0.603***	(0.0794) 0.462***	(0.0884) 0.462***	(0.0618) 0.621***	(0.0655) 0.621***	(0.0655) 0.621***	(0.0655) 0.621***
Central and eastern Europe	CO ₂	(0.113) -0.405***	(0.0968) -0.405***	(0.0751) -0.284***	(0.0733) -0.284***	(0.104) -0.261***	(0.103) -0.261***	(0.0899) -0.272***	(0.0899) -0.272***	(0.134) -0.379***	(0.129) -0.379***	(0.103) -0.226***	(0.102) -0.226***	(0.0798) -0.304***	(0.0752) -0.304***	(0.0752) -0.304***	(0.0752) -0.304***	
	REC	(0.0776) -0.00798	(0.0773) -0.00798	(0.0517) 0.00798**	(0.0535) 0.00798**	(0.0714) 0.00226	(0.0744) 0.00226	(0.0619) 0.0171***	(0.0514) 0.0171***	(0.0919) 0.00653	(0.0917) 0.00653	(0.0706) -0.00145	(0.0654) -0.00145	(0.0549) 0.00442	(0.0496) 0.00442	(0.0496) 0.00442	(0.0496) 0.00442	
	INST	(0.0525) 0.0102	(0.0454) 0.0102	(0.0350) -0.00492	(0.0329) -0.00492	(0.0483) 0.00943	(0.0403) 0.00943	(0.0419) -0.00978**	(0.0445) -0.00978**	(0.0445) -0.00978**	(0.0622) 0.00538	(0.0619) -0.00538	(0.0477) -0.00607	(0.0493) -0.00607	(0.0371) -0.000708	(0.0361) -0.000708	(0.0361) -0.000708	(0.0361) -0.000708
	MVA	(0.00647) -0.0173	(0.00605) -0.0173	(0.00431) 0.0654***	(0.00454) 0.0654***	(0.00596) 0.00446	(0.00627) 0.00446	(0.00516) 0.0669***	(0.00516) 0.0669***	(0.00516) 0.0669***	(0.00766) 0.0284***	(0.00766) 0.0284***	(0.00589) 0.0367***	(0.00525) 0.0367***	(0.00458) 0.0297***	(0.00409) 0.0297***	(0.00409) 0.0297***	(0.00409) 0.0297***
	FDI	(0.0175) -0.0256	(0.0198) -0.0256	(0.0148) 0.333***	(0.0165) 0.333***	(0.0164) 0.128	(0.0227) 0.128	(0.0126) 0.289***	(0.0126) 0.289***	(0.0126) 0.289***	(0.0127) 0.282***	(0.0129) 0.282***	(0.0125) 0.00482	(0.0125) 0.00482	(0.0110) 0.170**	(0.0116) 0.170**	(0.0116) 0.170**	(0.0116) 0.170**
Western Europe	TO	(0.111) -0.0197	(0.142) -0.0197	(0.0942) -0.313	(0.0996) -0.313	(0.104) 0.950**	(0.137) 0.950**	(0.0806) 0.815***	(0.0702) 0.815***	(0.0806) 0.815***	(0.0727) -0.347	(0.0799) 0.221	(0.0839) 0.221	(0.0703) 0.256	(0.0734) 0.256	(0.0734) 0.256	(0.0734) 0.256	
	GDP	(0.429) -0.426	(0.426) -0.426	(0.363) -0.363	(0.360) -0.360	(0.402) -0.402	(0.518) -0.518	(0.289) -0.289	(0.289) -0.289	(0.310) -0.310	(0.311) -0.311	(0.308) -0.308	(0.285) -0.285	(0.271) -0.271	(0.285) -0.285	(0.285) -0.285	(0.285) -0.285	(0.285) -0.285

Table 7 (continued)

Panels	Variables		LPITTC		LPICQL		LPICPS		LPICCP		LPICCT		LPITINF		GLPI	
	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS	FGLS	P-OLS
CO ₂	-0.0336*	-0.0336*	0.00418	0.00418	0.00225	0.00225	-0.00857	-0.00857	0.00214	0.00214	0.00214	0.00214	-0.0265	-0.0265	-0.00816	-0.00816
	(0.0236)	(0.0199)	(0.0200)	(0.0214)	(0.0221)	(0.0227)	(0.0171)	(0.0200)	(0.0171)	(0.0171)	(0.0171)	(0.0171)	(0.0169)	(0.0198)	(0.0149)	(0.0157)
REC	-0.254	-0.254	0.0427	0.0427	0.258	0.258	0.205*	0.205*	0.204	0.204	0.204	0.204	-0.184	-0.184	0.0634	0.0634
	(0.206)	(0.193)	(0.174)	(0.168)	(0.192)	(0.203)	(0.149)	(0.116)	(0.149)	(0.149)	(0.149)	(0.149)	(0.147)	(0.128)	(0.130)	(0.113)
HS	0.761***	0.761**	0.964***	0.964***	0.140	0.140	-0.0852	-0.0852	0.810***	0.810***	0.810***	0.810***	0.395**	0.395**	0.483***	0.483***
	(0.255)	(0.291)	(0.216)	(0.228)	(0.239)	(0.326)	(0.185)	(0.187)	(0.185)	(0.185)	(0.185)	(0.185)	(0.183)	(0.168)	(0.161)	(0.183)
INST	0.0210	0.0210	-0.0785	-0.0785	0.0148	0.0148	0.134***	0.134***	-0.0194	-0.0194	-0.0194	-0.0194	0.128***	0.128***	0.0315	0.0315
	(0.0584)	(0.0694)	(0.0494)	(0.0512)	(0.0547)	(0.0649)	(0.0422)	(0.0403)	(0.0423)	(0.0423)	(0.0423)	(0.0423)	(0.0419)	(0.0480)	(0.0368)	(0.0390)
MVA	0.0389***	0.0389***	0.0296***	0.0296***	0.00969	0.00969	0.0209***	0.0209***	0.0140*	0.0140*	0.0140*	0.0140*	0.0417***	0.0417***	0.0246***	0.0246***
	(0.0111)	(0.0104)	(0.00936)	(0.0106)	(0.0104)	(0.0113)	(0.00801)	(0.00792)	(0.00803)	(0.00811)	(0.00811)	(0.00811)	(0.00794)	(0.00892)	(0.00698)	(0.00734)
FDI	-0.0340	-0.0340	-0.00481	-0.00481	-0.00172	-0.00172	-0.0379	-0.0379	0.0615	0.0615	0.0615	0.0615	-0.0902**	-0.0902**	-0.0164	-0.0164
	(0.0511)	(0.0535)	(0.0214)	(0.0240)	(0.0366)	(0.0446)	(0.0551)	(0.0582)	(0.0572)	(0.0572)	(0.0572)	(0.0572)	(0.0440)	(0.0515)	(0.0180)	(0.0219)
TO	0.925**	0.925**	0.172	0.172	0.655**	0.655**	0.335	0.335	0.106	0.106	0.106	0.106	0.178	0.178	0.402***	0.402***
	(0.393)	(0.369)	(0.165)	(0.167)	(0.282)	(0.351)	(0.424)	(0.440)	(0.440)	(0.440)	(0.440)	(0.440)	(0.338)	(0.373)	(0.138)	(0.143)
GDP	-0.720***	-0.720***	-0.442***	-0.442***	-0.0759	-0.0759	0.0976	0.0976	-0.771***	-0.771***	-0.771***	-0.771***	0.0346	0.0346	-0.310***	-0.310***
	(0.184)	(0.237)	(0.0771)	(0.0997)	(0.132)	(0.140)	(0.198)	(0.169)	(0.206)	(0.206)	(0.206)	(0.206)	(0.158)	(0.157)	(0.0648)	(0.0818)
CO ₂	0.0521	0.0521	-0.00241	-0.00241	-0.000299	-0.000299	0.0308	0.0308	-0.0545	-0.0545	-0.0545	-0.0545	0.150*	0.150*	0.0261	0.0261
	(0.0833)	(0.0965)	(0.0349)	(0.0438)	(0.0597)	(0.0756)	(0.0898)	(0.0976)	(0.0932)	(0.0932)	(0.0932)	(0.0932)	(0.0717)	(0.0825)	(0.0293)	(0.0368)
REC	0.133	0.133	-0.00156	-0.00156	-0.0332	-0.0332	-0.0550	-0.0550	-0.0826	-0.0826	-0.0826	-0.0826	0.0546	0.0546	0.00327	0.00327
	(0.159)	(0.177)	(0.0666)	(0.0819)	(0.114)	(0.145)	(0.171)	(0.202)	(0.178)	(0.178)	(0.178)	(0.178)	(0.137)	(0.170)	(0.0559)	(0.0680)
HS	0.423***	0.423**	0.0176	0.0176	-0.0533	-0.0533	-0.437***	-0.437***	0.396*	0.396*	0.396*	0.396*	-0.234**	-0.234**	0.0220	0.0220
	(0.129)	(0.193)	(0.0539)	(0.0729)	(0.0922)	(0.118)	(0.139)	(0.145)	(0.144)	(0.144)	(0.144)	(0.144)	(0.111)	(0.111)	(0.0453)	(0.0564)
INST	0.383***	0.383**	0.125**	0.125**	0.0981	0.0981	0.464***	0.464***	-0.459***	-0.459***	-0.459***	-0.459***	0.440***	0.440***	-0.0399	-0.0399
	(0.138)	(0.184)	(0.0578)	(0.0584)	(0.0989)	(0.107)	(0.149)	(0.135)	(0.154)	(0.154)	(0.154)	(0.154)	(0.119)	(0.116)	(0.0486)	(0.0554)
MVA	-0.0283*	-0.0283*	0.00895	0.00895	-0.0260**	-0.0260**	0.00321	0.00321	0.00833	0.00833	0.00833	0.00833	-0.00290	-0.00290	-0.00670	-0.00670
	(0.0151)	(0.0141)	(0.00634)	(0.00727)	(0.0108)	(0.0134)	(0.0163)	(0.0148)	(0.0169)	(0.0169)	(0.0169)	(0.0169)	(0.0130)	(0.0143)	(0.00552)	(0.00572)

Source: Authors estimations

Table 8 List of Belt and Road host countries (65)

South Asia (6)	Southeast Asia (12)	East Asia (3)	Central Asia (4)	MENA countries (16)	Central and eastern Europe (12)	Western Europe (7)	CIS countries (5)
Bangladesh	Brunei Darussalam	Hong Kong	Kazakhstan	Bahrain	Albania	Belgium	Armenia
India	Cambodia	Japan	Kyrgyz Republic	Egypt, Arab Rep.	Bosnia and Herzegovina	Cyprus	Azerbaijan
Maldives	Indonesia	Korea, Rep.	Tajikistan	Iran, Islamic Rep.	Bulgaria	France	Belarus
Nepal	Malaysia		Uzbekistan	Iraq	Croatia	Germany	Georgia
Pakistan	Mongolia			Israel	Czech Republic	Greece	Ukraine
Sri Lanka	Myanmar			Jordan	Estonia	Italy	
	Philippines			Kenya	Hungary	Netherlands	
	Russian Federation			Kuwait	Latvia		
	Singapore			Lebanon	Lithuania		
	Thailand			Nigeria	Poland		
	Timor-Leste			Oman	Romania		
	Vietnam			Qatar	Slovenia		
				Saudi Arabia			
				Turkey			
				United Arab Emirates			
				Yemen, Rep.			

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