China & World Economy

China & World Economy / 1–25, Vol. 29, No. 3, 2021

Does the Belt and Road Initiative Increase the Carbon Emission Intensity of Participating Countries?

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Abstract

The impact that the Belt and Road Initiative (BRI) has had on carbon emissions is a hotly debated issue. Using a panel dataset of 178 countries from 2002 to 2017, and applying the quantile difference-in-difference method in different industries, this study finds that, first, the BRI overall tends to reduce the carbon emission intensity of BRI countries. Second, the impact of BRI on reducing the carbon emission intensity is significant for BRI countries at higher (0.8 and 0.9) and lower (0.2 and 0.3) carbon emission intensity quantiles but it is insignificant for those at medium levels. Third, the BRI has significant impacts on reducing carbon emission intensity in the energy-intensive industries, and this effect is the highest at the quantile level of 0.9 for all three industries considered here: transportation, electric and heating, and manufacturing and construction. These results indicate that establishing BRI cooperation with China will improve the environment and enhance the sustainable development ability of BRI countries.

Key words: Belt and Road Initiative, carbon emission intensity, difference-in-difference, quantile regression

JEL codes: F02, O13, Q56

I. Introduction

With increasing globalization, resource and environmental issues have become the global challenges threatening human sustainable development, especially in developing countries. Under the framework of the Paris Agreement, developing countries face the dual challenges of economic development and environmental pressure. A country is considered to be using a low-carbon and sustainable development model only when its

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This research was financially supported by the National Social Science Foundation of China (No. 20CGJ019). The authors are grateful for professor Xunpeng Shi's helpful comments on revising this paper.

carbon emission intensity – measured as carbon emissions per unit of GDP – decreases. Transferring carbon-intensive industries to other countries is a way to achieve emission intensity reduction but it is not desirable. It is therefore interesting to know whether China, which has pledged to bring its emissions to a peak before 2030 and will achieve net zero emission by 2060, has shifted its emissions overseas.

The Belt and Road Initiative (BRI), which was launched by China in 2013, provided a good case study to investigate whether China has reduced its emission intensity by shifting its emissions to other countries. The BRI is the first initiative that has a global impact but it is led by a developing country, which provides a contrast with the dominant cooperation models between developed and developing countries. By the end of 2019, 137 countries and 30 international organizations had participated in the BRI,[1] accounting for approximately 23 percent of global GDP[2] and 28 percent of global carbon emissions.[3] Since the implementation of the BRI, China's outward foreign direct investment (OFDI) in BRI countries has increased rapidly. China's OFDI stock in the BRI countries surged from US$56.2 billion in 2012 to US$143.8 billion in 2017, increasing 155.9 percent (UNCTAD, 2013–2018). However, Chinese investment in the US and the EU has been declining since peaking in 2016 (Kirkegaard, 2020). In the same period, China's trade with BRI countries has also expanded from US$0.96 trillion to US$1.90 trillion, increasing 97.92 percent.[3] Such global cooperation among developing countries will likely have a different emission impact from the prevailing developed–developing or developed–developed cooperation nexus. Most BRI countries are developing countries in economic transition, and their carbon emission and pollution problems are more prominent than in other countries, so it will be more difficult to reduce carbon emission intensity and pursue sustainable development.

What impact has the BRI had on the carbon emission intensity of BRI participating countries? The answers to this question are inconclusive, and sometimes contradictory, in the literature. Some studies argued that the BRI might increase carbon emissions in addition to economic growth (e.g. Tracy et al., 2017; Zhang et al., 2017; Ascensão et al., 2018; Rauf et al., 2018; Teo et al., 2019), whereas others argue that the BRI would benefit the environment in BRI countries in some aspects due to cooperation with China, especially in reducing the carbon emissions of BRI countries by developing green energy (Han et al., 2018; Saud et al., 2019). The existing studies have produced mixed

[1]The latest BRI participating countries can be found at: https://www.yidaiyilu.gov.cn (online; cited September 2020).

[2]The data are available from: https://databank.worldbank.org/source/world-development-indicators (online; cited September 2020).

[3]The data are available from: https://www.iea.org/data-and-statistics (online; cited September 2020).

findings and, as a result, further studies on the impact of the BRI on carbon emission intensity are still necessary.

This study investigated empirically the impact of the BRI on carbon emission intensity in BRI countries in general and in different energy-intensive industries with different carbon emission intensity levels in particular. The results of this study will help to clarify potential environmental problems in the implementation of the BRI and provide important empirical evidence and policy implications for the further promotion of the green BRI. Participation in the BRI provides an effective quasi-natural experiment in assessing the impact of the BRI on carbon emission intensity.

This paper makes three contributions: (i) it assesses a major international concern that the BRI may cause more carbon emissions in other countries and it also explores the carbon emission changes in BRI countries, which may be conducive to the emission reduction solutions for China and BRI countries' policy makers; (ii) it applies the quantile difference-in-difference (DID) method to evaluate the heterogeneous impact of the BRI on the carbon emission intensity of BRI countries at different quantile levels of carbon emission intensity; and (iii) it uses data related to the energy-intensive industries to estimate the impact of the BRI on carbon emission intensity in different energy-intensive industries of BRI countries and proposes policy implications for different industries' development in the context of the green BRI.

The structure of the paper is as follows. Section II discusses the mechanism of the relationship between the BRI and carbon emission intensity and reviews the relevant literature. Section III sets up a regression model for carbon emission intensity based on the DID method. Section IV assesses empirically the impact of the BRI on the carbon emission intensity of BRI countries and discusses the heterogeneous impacts at different quantile levels in three energy-intensive industries. Section V concludes and provides some policy implications.

II. Impacts of the BRI on carbon intensity: Mechanism and literature

1. The relationship between the BRI and carbon intensity

Since the implementation of the BRI, China's cooperation with BRI countries has been growing rapidly. China has indicated that low carbon emissions and climate change will be considered fully in economic cooperation projects such as infrastructure construction and its operational management. Cooperation regarding the ecological environment and climate change will also be strengthened through investment, trade, and other cooperation models to build the green BRI jointly.

How does the BRI affect the carbon emission intensity of these countries? The BRI focuses on policy communication, infrastructure connectivity, unimpeded trade, financial integration, and people-to-people connectivity. In the promotion of the above "five links," political relations, infrastructure cooperation, financial support, trade flow, cultural exchanges, and other aspects related to the "five links" will affect the industrial structure adjustment, technology spillovers, and economic development in BRI countries, and thus probably have a significant impact on carbon intensity.

First, policy communication is an important guarantee for the BRI, which could promote low carbon development. Climate change is one of the focuses of policy communication between China and BRI countries (Zhang et al., 2017). Compared with developed countries, developing countries have a large amount of low-cost emission reduction potential (Zhang et al., 2009). However, the lack of financial support and effective technical means to reduce emissions make it difficult for developing countries to realize their emission reduction targets, thus increasing the need for related international cooperation (Han et al., 2018). On the one hand, due to the existence of externality, emissions reduction cannot become a single and conscious act of a country, while international cooperation including an effective constraint mechanism or compensation mechanism is an effective means to eliminate the externality of emission reduction. On the other hand, the cost of emission reduction varies greatly among different countries and regions because of different comparative advantages (Zhang et al., 2011), while international cooperation can use external forces effectively to minimize the cost of emission reduction.

Second, infrastructure connectivity, a priority area for the BRI, can lessen, relatively, the carbon intensity of BRI countries. The large-scale construction of infrastructure will not only promote economic development but also cause carbon emissions (Shi et al., 2012). Energy-efficient infrastructure construction will therefore play an important role in carbon emission intensity reduction. Under the BRI, China's rich infrastructure implementation technology and experience will help maintain the lower carbon emission level in the construction process thus further helping the economic development of BRI countries (Liu and Hao, 2018). Some renewable energy infrastructure ventures involving cooperation with China, such as hydropower stations, will also reduce the use of fossil fuels, and will promote low carbon emissions and the sustainable development of BRI countries (Shi and Yao, 2019).

Third, financing is an important support for BRI countries' carbon intensity reduction. Recent studies have examined the relationship between finance and carbon emissions. Tamazian et al. (2009) used data on loans of BRICS countries (Brazil, Russia, India, China, and South Africa) to link finance creatively with carbon emissions and pointed out that financial development and capital market opening could eliminate backward and high-polluting enterprises, which are important factors for carbon emission reduction. Gu and He (2012) confirmed that China's financial development had made significant contributions to reducing carbon emissions and improving the environment. Financial support from China based on RMB settlement, mainly through the Asian Infrastructure Investment Bank (AIIB) established in 2015, could help the BRI countries to reduce carbon intensity (Gao and Li, 2020).

Fourth, unimpeded trade is a key element of the BRI. As the world's biggest trader in 2019, China's bilateral trade with the BRI participating countries reached US$1.9 trillion, increasing by 10.8 percent and accounting for 41.5 percent of China's total foreign trade, especially for the exports with an increase of 16.7 percent (Ministry of Commerce, 2020). By the end of 2019, China had signed free trade agreements (FTA) with 16 BRI countries.[4] A large number of imports from China have replaced the related high-emission production in BRI countries, which may reduce carbon emissions to some extent (Han et al., 2018). China has turned to exporting high value-added products in recent years, such as communications equipment, computers, and high-speed rail technology, which bring technology spillovers and upgrading of industrial structure, thus tending to reduce carbon emissions intensity in BRI countries. The "green technologies" diffused by trade with China also have positive implications for reducing the carbon emissions intensity of BRI countries (Zhao et al., 2020).

Fifth, people-to-people connectivity, or cultural exchange, is an essential condition for the green BRI. Some studies show that culture could explain environmental differences among different countries (Park et al., 2007; Ringov and Zollo, 2007; Peng and Lin, 2009; Halkos and Tzeremes, 2013). Cultural distance also directly affects the cost of trade and investment between countries (Sala et al., 2008), thus influencing the environmental impacts of international cooperation (Lankhuizen and de Groot, 2016). The BRI covers Europe, Africa, and Asia, with four ancient civilizations and about one hundred languages coexisting along the route, so there are huge cultural differences among BRI countries. China has signed intergovernmental scientific and technological cooperation agreements with 49 BRI countries (The Leading Group Office of the BRI, 2019). China has established 1,023 pairs of sister cities with 61 BRI countries, accounting for 40.18 percent of the total number of Chinese sister cities (State Information Centre, 2018). China has also set up the "Silk Road" government

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[4]The latest FTA signing situation can be found at: http://fta.mofcom.gov.cn/english (online; cited September 2020).

scholarship to support more than 10,000 freshmen from BRI countries to study in China every year and signed agreements on mutual recognition of higher education qualifications and degrees with 24 BRI countries (State Information Centre, 2018). All of these can push technological progress and economic transformation, and thus the low-carbon development of BRI countries.

2. Literature review

With the implementation of the BRI, there has been a growing body of empirical studies investigating the impact of the BRI on carbon emissions. However, the findings in the literature are controversial and inconclusive. They fall into three groups.

(1) Negative impacts

First, some studies argue that the BRI might lead to negative impacts on the environment, especially for carbon emissions resulting from economic growth in BRI countries. For example, Rauf et al. (2018) found that in both the short term and the long term, the BRI had an increasing effect on the carbon emissions of BRI countries. By analyzing social, economic, and political factors, Teo et al. (2019) argued that the BRI could bring negative impacts on the environment and increase the carbon emissions of BRI countries. Second, some studies argued that the expansion of trade and investment under the BRI could increase the carbon emissions of BRI countries. For example, by calculating carbon emissions embodied in the imports and exports of BRI countries, Cai et al. (2018) found that 19 developing BRI countries had become pollution havens for developed countries, which means that the pollution-intensive industries tend to be based in countries with relatively low environmental standards. Based on the panel data of 65 BRI countries over the period of 1985–2017, Khan and Qiu (2020) found that FDI had led to an increase in carbon emissions in BRI countries across South Asia, Southeast Asia, East Asia, and Europe. Based on the Tapio decoupling model and the Kaya-log mean decomposition index model for the panel data from 57 BRI countries for the period of 1991–2016, Hu et al. (2020) found that energy exports under the BRI increased carbon emissions of BRI countries. Third, some studies argued that, with the expansion of economic activity, especially infrastructure development and natural resource exploitation, the BRI could not only pollute the environment in BRI countries but also cause environmental problems globally. They argued that the BRI might increase total global carbon emissions (Zhang et al., 2017), would create new environmental risks across the entire Eurasian continent, especially in countries with predominately poor records of environmental governance (Tracy et al., 2017), and might promote permanent environmental degradation globally (Ascensão et al., 2018).

(2) Positive impacts

First, some studies argue that the BRI would benefit the environment, especially by reducing carbon emissions in BRI countries, due to cooperation with China. For example, Han et al. (2018) revealed that the BRI had improved the environmental performance of BRI countries through regional cooperation and trade integration. Gu and Zhou (2020) found that China's investment in wind and solar energy projects had effectively reduced carbon emissions of the host countries. Liu et al. (2020) found that the BRI has a strong policy effect on Chinese green and low-carbon outward foreign direct investment (OFDI) in developing BRI countries. Second, some studies argued that the expansion of trade and investment under the BRI could reduce carbon emissions and improve the environmental quality of BRI countries. For example, using panel data from 29 BRI countries over the period of 1995–2014, Li et al. (2018) found that the investment rate and openness play an important role in pushing the decrease in the carbon intensity growth rate, revealing that the BRI could promote reducing the global carbon emissions. Based on panel data from 59 BRI countries over the period of 1980–2016, Saud et al. (2019) found that an increase in FDI and trade openness in BRI countries reduced carbon emissions per capita, thus improving the environmental quality in BRI countries. Third, a few studies argued that the green BRI is likely to benefit the environment, especially by reducing carbon emission intensity in BRI countries. For example, Qi et al. (2019) argued that China had been making a great effort to construct a green BRI, which would improve general energy efficiency and reduce the carbon emission intensity of BRI countries.

(3) Different impacts

A few empirical studies argued that there may be different environmental impacts in different patterns of BRI collaborations or in different BRI countries. In terms of different patterns of BRI collaborations, for example, by establishing the green development capability (GDC) index to measure the green development level, and using the spatial Durbin model for empirical testing based on 41 BRI countries for the period of 2007–2016 on different cooperative patterns between China and BRI countries, Huang and Li (2020) found that economic development cooperation, environmental governance cooperation, and sustainable cooperation were conducive to enhancing the GDC of BRI countries, while cooperation involving resource utilization based on fossil energy trading had an adverse effect. In terms of different BRI countries, for example, based on the panel data of 65 BRI countries from 2000 to 2016 and using quantile two-stages least square (2SLS) regression, Muhammad et al. (2020) found that FDI increased carbon emissions in all BRI countries, exports reduced carbon emissions in low- and high-income BRI countries but increased carbon emissions in middle-income BRI countries, and imports increased carbon emissions in low-income BRI countries but decreased carbon emissions in middle- and high-income BRI countries.

The BRI may therefore have a significant impact on carbon emissions but the direction is uncertain and needs to be tested empirically. Most of the studies focus on the amount of carbon emissions, while few studies focus on the carbon emission intensity, which is a better measure to evaluate the comprehensive impact of the BRI on carbon emissions, economic growth, and sustainable development. To fill the gap, this study uses a panel dataset containing 178 countries for the period from 2002 to 2017 and applies the DID method to investigate the impact of BRI on carbon emission intensity of BRI countries in general and the heterogeneous impacts of BRI on carbon emission intensity in energy-intensive industries of BRI countries in particular.

III. Practices, variables, and the difference-in-difference model

1. China's practices and policies in implementing the BRI

China hopes to bring green, low-carbon and sustainable development to more than 4 billion people in BRI countries including China by building a green Belt and Road. In fact, some green cooperation projects under the BRI have been implemented.

First, China is leading the world in building clean power plants. China has four of the world's top 10 wind-turbine makers, six of the world's top 10 solar panel makers,[5] and sells more electric cars than the rest of the world combined. For example, as the first large-scale hydropower construction project invested by China Three Gorges South Asia Investment Company under the BRI, the Pakistan Karot hydropower project provides over 3.1 billion kilowatt-hours of clean energy to Pakistan every year, which effectively alleviates Pakistan's electricity shortage, and greatly promotes the industrial upgrading of local power supporting industries. Another case is the Adama wind power project in Ethiopia financed by the Hydro China Corporation and the China Overseas Construction Group. The project can provide about 476 million kilowatt-hours of electricity every year, which meets more than 20 percent of the electricity demand of Ethiopia's capital city and enhances Ethiopia's technical strength in developing wind energy resources.

Second, China requires the companies that invest in BRI countries to take their environmental and social responsibilities seriously. China has also actively promoted

[5]The four Chinese wind-turbine makers are Xinjiang Goldwind Science & Technology, Jiangsu Envision Energy Group, Guangdong MingYang Smart Energy, and Beijing Sinovel Wind Group. The six Chinese solar panel makers are Hebei JA Solar Technology, Sichuan Tongwei Solar Group, Jiangsu Trina Solar Group, Shanghai Jinko Solar Group, Xi'an LONGi Solar Technology, and Guangdong Aiko Solar Technology.

green industrial development in BRI countries. For example, the China–Egypt Teda Suez Economic and Trade Cooperation Zone takes green and environmental protection as one of the entry thresholds and gives priority to the introduction of low-carbon and environment-friendly enterprises. Wind and solar energy street lights have been installed on all the main roads of the Teda industrial park, making it the first park in Egypt to use green energy street lights on a large scale. In Vietnam, the Chinese Esquel Industrial Park has reduced chemical, water, and energy use by 25 to 50 percent compared with other comparable production bases through its green supply chain model, and at the same time maintained constant production capacity, quality, and efficiency.

Third, China has advanced environmental cooperation projects in BRI countries. For example, to protect forest resources and reduce carbon emissions and pollution, the Myanmar forest protection project based on clean energy technology application helps the Than Bayar Khon village residents of Myanmar to use wood-saving stoves, solar lights, solar water pumps, and other clean energy equipment, successfully creating a sustainable green community.

Fourth, China has been expanding the export of green products and services to BRI countries and incorporated environmental protection requirements into free trade agreements. For example, the introduction of China-made electric buses provides a new solution to reduce urban exhaust emissions and energy consumption. It is the first time in Latin American countries that the pure electric bus was used.

Fifth, China has given full play to the role of finance to support low-carbon and sustainable project construction in BRI countries, such as the AIIB, the Silk Road Fund, the China–ASEAN Investment Cooperation Fund, and the China–Africa Capacity Cooperation Fund. For example, the solar mill project, funded by the China Development Bank in Zambia, has produced a large amount of corn flour and rice with clean energy to ease the country's tight food supply and, at the same time, 1,583 solar mills were installed in the districts where electricity was not available. Another case is the Wanbao Agricultural Park in Mozambique, which is China's largest rice-planting project in Africa and funded by the China–Africa Development Fund. The rice-planting project used clean energy technologies and advanced irrigation and water conservancy facilities to build a large-scale grain-planting and processing industrial base.

2. Research method and variables

The simplest method for estimating the effects of a policy is to compare the difference before and after the policy's implementation in the treatment group (the region or individual affected by the policy). This involves subtracting the sample mean before the policy implementation from the sample mean after the policy implementation in the treatment group. However, as the macroeconomic environment also changes over time (time effects), differences before and after policy implementation are probably not the same as the policy effects (treatment effects). To solve these problems, we need to use a control group that is not included in the policy region as a counterfactual reference, then take the difference before and after the policy implementation of the control group as the time effects of the treatment group. We subtract the difference before and after the policy implementation in the control group from the difference before and after the policy implementation in the treatment group to obtain a more reliable estimate of the policy effect (Ashenfelter, 1978).

This paper therefore uses the DID method to investigate the impact of BRI on carbon emission intensity in BRI countries. The policy implementation is measured as the signing of the BRI memorandum of understanding (MOU). Other countries that are not in the BRI area are set as the control group. The DID method can avoid the endogeneity problem existing in the policy implementation as the independent variable; that is, it can control the unobtainable individual heterogeneity and the influence of the unobtainable factors changing with time effectively, and can avoid reciprocal causation between the dependent variable and independent variables.

Carbon emission intensity is defined as the ratio of carbon emissions to GDP, which is in line with previous studies (Roberts and Grimes, 1997; Greening et al., 2001; Davis et al., 2003). According to previous empirical studies, we control for the following variables, which are expected to affect carbon emission intensity.

First, urbanization has an important impact on carbon emissions. We use the proportion of the urban population in the total population (*UR*) to control for the urbanization level. According to the environment Kuznets curve, when the urbanization level is low, urbanization increases the carbon emission intensity. After reaching a turning point, it decreases the carbon emission intensity (Grossman and Krueger, 1991). As most of the countries in the sample are developing countries, which have a relatively low urbanization level, we expect the urbanization level to have an increasing effect on carbon emission intensity.

Second, industrial upgrading, especially upgrading to tertiary industry, may have a very important impact on decreasing carbon emission intensity. We use the ratio of service sector value added over the GDP (*SER*) to control for the industrial structure. It is expected that the higher the share of the tertiary sector in the GDP, the lower the carbon emission intensity.

Third, the level of economic development is an important factor for carbon emission intensity. We use per capita GDP (*PGDP*) of a country measured in US dollars in 2010 constant prices to control for the level of economic development. According to the environmental Kuznets curve, when the economic development level is low, economic development increases carbon emission intensity, and after reaching a turning point, it decreases carbon emission intensity. Most of the countries in the sample are developing countries with a relatively low economic development level, so we expect per capita GDP to have an increasing effect on carbon emission intensity.

Fourth, the structure of energy consumption, especially the use of renewable energy, may have a very important impact on decreasing carbon emission intensity. We use the share of renewable energy consumption over total final energy consumption (*ENS*) to control for the structure of energy consumption. It is expected that the higher the share of renewable energy consumption in the total final energy consumption, the lower the carbon emission intensity will be.

Fifth, trade openness may have a significant impact on carbon emission intensity, but the direction is uncertain. We use the ratio of total imports and exports of goods and services to GDP (*TRADE/GDP*) to control for trade openness. Imports can substitute for domestic production and related carbon emissions, while exports may result in increase in carbon emissions because of increased production, so we have no position on the impact of trade openness on carbon emission intensity.

Sixth, we control for the total FDI stock. We use the share of FDI stock over GDP (*FDI/GDP*) to control for the total FDI stock. The impact of FDI on carbon intensity depends largely on the type of industry in which it is invested. If the industry is high pollution and low value added, such as the chemical and steel industries, it will increase the carbon intensity. If it is a low carbon and high value-added industry, such as technology and financial services, it will reduce carbon intensity. The impact of FDI on carbon intensity therefore depends on the industries and we have no position on the impact of FDI on carbon emission intensity as a whole in BRI countries.

Finally, human capital is an important driving factor to develop clean energy and improve energy efficiency because it will lead to technological progress and environmental awareness. However, the increase in human capital also leads to economic development and the expansion of production, with a consequent increase in carbon emissions. The impact of human capital enhancement on carbon intensity therefore depends on its impacts on GDP and carbon emissions. We use the share of the population in tertiary education over the gross school-age population between 18 and 22 (*EDU*) to control for the human capital. We take no position on the impact of human capital on carbon intensity as a whole in BRI countries.

3. Regression models

Participation in the BRI is put forward as a quasi-natural experiment to investigate its effect on the carbon emission intensity of BRI countries. Based on the discussion in the previous section, BRI countries are selected as the treatment group, other countries and regions are selected as the control group, and the following DID models are constructed:

$$CARINT_{it} = \beta_1 BRI_i \times MOU_{it} + \gamma_1 X_{it} + \alpha_i + \psi_t + \varepsilon_{it1}, \tag{1}$$

$$TRAINT_{it} = \beta_2 BRI_i \times MOU_{it} + \gamma_2 X_{it} + \alpha_i + \psi_t + \varepsilon_{it2}, \tag{2}$$

$$EAHINT_{it} = \beta_3 BRI_i \times MOU_{it} + \gamma_3 X_{it} + \alpha_i + \psi_t + \varepsilon_{it3}, \tag{3}$$

$$MACINT_{it} = \beta_4 BRI_i \times MOU_{it} + \gamma_4 X_{it} + \alpha_i + \psi_t + \varepsilon_{it4}. \tag{4}$$

Equations (1)–(4) are the DID estimation models that take time- and country-fixed effects into account. In the equations, i stands for the country from 1 to 178, and t stands for the year from 2002 to 2017. The dependent variable $CARINT_{it}$ is the total carbon emission intensity, which is measured as the ratio of carbon emissions to GDP. $TRAINT_{it}$ is the transportation carbon emission intensity, which is measured as the ratio of transportation carbon emissions to GDP. $EAHINT_{it}$ is the electric and heat carbon emission intensity, which is measured as the ratio of electric and heat carbon emissions to GDP. $MACINT_{it}$ is the manufacturing and construction carbon emission intensity, which is measured as the ratio of manufacturing and construction carbon emissions to GDP. It should be noted that this paper uses the GDP to calculate different industrial carbon emission intensities because the authors were unable to obtain the value-added of subdivided industries in most of the sample countries.

MOU_{it} is the dummy variable for processing the time effect of BRI. For MOU_{it}, the signing year of the BRI MOU between country i and China and the years after that are set as 1, and the previous years are set as 0. BRI_i is the dummy variable for processing the treatment group, indicating whether the country has joined the BRI. If a country has joined the BRI, this variable is 1, otherwise, it is 0. $BRI_i \times MOU_{it}$ is the interaction term between BRI_i and MOU_{it}, which is the core variable in the estimation by the DID method. X_{it} is a series of control variables for economic characteristics that may cause changes in carbon emission intensity, including urbanization level, industrial structure, per capita GDP, the structure of energy consumption, trade openness, FDI, and human capital. ψ_t is the year-fixed effect, α_i *is* the country-fixed effect, and ε_{it} is the random disturbance term.

We focus on the coefficients β_1, β_2, β_3, and β_4 of the variable $BRI_i \times MOU_{it}$ in these four equations, the economic implications of which can be explained by the impact of participating in the BRI on total carbon emission intensity, transportation carbon emission intensity, electric and heat carbon emission intensity, and manufacturing and construction carbon emission intensity, respectively. If the coefficients β_1, β_2, β_3, and β_4 are positive and statistically significant, the BRI tends to increase the carbon emission intensity of the BRI countries. On the other hand, if they are negative and statistically significant, the BRI tends to reduce carbon emission intensity of BRI countries.

This paper uses panel data containing 178 countries from 2002 to 2017; it covers 63 BRI countries that signed the BRI MOU before 2017 (the treatment group) and 115 other countries (the control group).[6] The data related to the years for signing the BRI MOU come from the Belt and Road Portal of Chinese government.[7] The data on carbon emissions come from the International Energy Agency (IEA) statistics.[8] The data on carbon emissions in the energy-intensive industries come from *CO_2 Emissions from Fuel Combustion*, which is a report series published every year (IEA, 2003–2018). The data on FDI stock come from the *World Investment Report* (UNCTAD, 2003–2018). All the other data come from the World Bank statistics.[9]

IV. Empirical results and analyses

1. The impact of BRI on carbon emission intensity of BRI countries

We use Equation (1) to estimate the impact of BRI on the carbon emission intensity of BRI countries. In the regression, we control for the year-fixed effect and the country-fixed effect of the 178 sample countries. Standard errors are clustered at the country level. The regression results are reported in column (1) of Table 1. Compared with other countries in the control group, the carbon emission intensity of BRI countries in the treatment group may have some inherent changing trend, rather than the effects caused by the BRI. Many BRI countries are developing economies and emerging economies, so along with economic development their production methods and lifestyles are changing from high-carbon to low-carbon. Ignoring the underlying changing carbon emission intensity trend in BRI countries may produce a biased estimation of the impact of BRI on the carbon emission intensity of BRI countries due to missing variables. We therefore set a continuous variable t representing the time trend and added the interaction term between the BRI and time trend in the regression, which is reported in column (2) of Table 1. This interaction term controls for the potential changing trend of carbon emission intensity in BRI countries. As shown in Table 1, although there is little difference, the absolute value of the coefficient of $BRI \times MOU$ in column (2) is slightly larger and more statistically significant, indicating that the results of column (2) are more robust.

[6]See Appendix for the list of 63 countries in the treatment group and 115 countries in the control group. Palestine and Bhutan are excluded from the sample due to a lack of carbon emission data.

[7]See https://www.yidaiyilu.gov.cn/gbjg/gbgk/77073.htm (online; cited September 2020).

[8]See https://www.iea.org/data-and-statistics (online; cited September 2020).

[9]See https://databank.worldbank.org/source/world-development-indicators (online; cited September 2020).

Table 1. Regression results of carbon emission intensity of BRI countries

Dependent variable	Carbon emission intensity	
	(1)	(2)
BRI× MOU	–8.833** (0.035)	–9.425*** (0.002)
EDU	–1.134*** (0.000)	–1.121*** (0.000)
FDI/GDP	–0.002*** (0.000)	–0.001*** (0.000)
ENS	–0.304* (0.084)	–0.352** (0.013)
PGDP	0.003*** (0.000)	0.002*** (0.000)
TRADE/GDP	0.668*** (0.000)	0.635*** (0.000)
UR	1.826*** (0.000)	2.124*** (0.000)
SER	–3.361*** (0.000)	–3.546*** (0.000)
R^2	0.24	0.24
Year-fixed effect	Yes	Yes
Country-fixed effect	Yes	Yes
BRI × Time trend		Yes
Observations	1,567	1,567

Source: Authors' estimation.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. *p*-values are in brackets. See subsection III.2 for the definition of each variable.

As Table 1 shows, the coefficient of the interaction term (*BRI* × *MOU*) is significantly negative at the 1 percent level. This implies that the BRI has a decreasing effect on carbon emission intensity of BRI countries. The regression result therefore indicates that, on average, participating in the BRI tends to reduce carbon emission intensity of BRI countries. The reason is that, as we discussed in Section II, the general principles of green energy, green production, green living, and green finance embodied in the BRI will contribute to environmental protection and carbon emission reduction in BRI countries.

For the control variables, the coefficients of the variables of the human capital (*EDU*), the structure of energy consumption (*ENS*), and the industrial structure (*SER*) are negative and statistically significant, implying that the increase in the human capital level, the ratio of the renewable energy in total energy consumption, and the share of service sector in GDP will reduce carbon emission intensity. In contrast, the coefficients of the variables of the level of economic development (*PGDP*) and the urbanization level (*UR*) are positive and statistically significant, implying that the increase in economic development and urbanization level will increase carbon emission intensity.

These results are consistent with theoretical explanations and our expectations as discussed in Section III.

The coefficient of the variable of FDI stock over GDP (*FDI/GDP*) is negative and statistically significant, implying that an increase in the level of FDI stock over GDP tends to reduce carbon emission intensity. The possible explanation is that the effect of FDI on carbon emission reduction through technology spillovers and industrial upgrading is higher than the effect of FDI on carbon emission increase by consuming fossil energies and production expansion.

The coefficient of the variable of trade openness (*TRADE/GDP*) is positive and statistically significant. This implies that an increase in the level of trade openness will increase carbon emission intensity. The possible reasons for this are that, first, the effect of trade openness on carbon emission reduction through substituting domestic production from imports is lower than the effect of trade openness on carbon emission increase through production expansion for exports. Second, similar to the effect of the level of economic development (*PGDP*) on carbon emission intensity, trade expansion will lead to an income increase, which will lead to a higher level of consumption, thus increasing carbon emission intensity.

In Table 2, we divide carbon emission intensity into nine sub-points from low to high. Due to limited space, the regression results for the other control variables are not reported in the table. The regression results indicate that the BRI has significant effects on carbon emission intensity reduction at the high (0.8 and 0.9) and low (0.2 and 0.3) quantiles but has no significant effects on the carbon emission intensity at other quantile levels of BRI countries. In addition, the coefficient at the highest (0.9) quantile is much higher than those at the other quantiles. This implies that the role of the BRI on carbon emission intensity reduction is much larger for those BRI countries with high carbon emission intensities. The possible reason is that the BRI cooperation is more focused on energy- and resource-rich BRI countries, as well as some less developed BRI countries, which usually have high carbon emission intensities.

Table 2. Regression results by quantile difference-in-difference method

Quantile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
BRI × MOU	0.216 (0.869)	–9.571*** (0.000)	–9.315** (0.046)	–2.186 (0.709)	4.086 (0.758)	–11.227 (0.404)	–13.676 (0.455)	–12.097* (0.093)	–28.540*** (0.000)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.04	0.26	0.25	0.06	0.07	0.11	0.14	0.28	0.31

Source: Authors' estimation.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. *p*-values are in brackets. See subsection III.2 for the definition of variables.

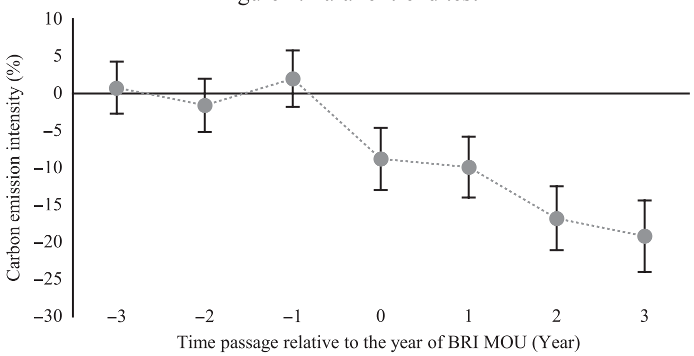
2. Data validity analysis and robustness checks

On the one hand, sample selective bias may lead to invalid data for the DID method. On the other hand, the difference before and after the implementation of policies may not be the treatment effect. In this situation, the DID results are not robust. Multiple tests are therefore needed to judge whether the results meet the conditions of data validity and robustness for using the DID method.

First, based on the mean value test, we can investigate whether there is a significant difference in carbon emission intensity between the treatment group and the control group after policy implementation. The null hypothesis of the mean test is that there is no significant difference. The test results show that the *p*-value equals zero from the policy implementation year, which indicates that there is a significant difference in carbon emission intensity between the two groups after participation in the BRI.

Second, we conduct a further parallel trend check before participation in the BRI. The DID model does not require the mean values to be the same but hypothesizes that the variation trends of the two groups must be the same before the implementation of the policy. To support this assumption, we set up a year dummy variable representing different years and the interaction term *BRI* × *Year* represents the possible different variation trends of carbon emission intensity in the treatment group compared with the control group. Figure 1 shows that the variation trend of the treatment group does not have significant differences in all the three years before participation in the BRI as the coefficient of *BRI* × *Year* is close to 0. Furthermore, from the year of participation in the BRI, the impact of the BRI on carbon emission intensity is significantly negative and gradually decreases with the passing of time. In the three years after participation in the BRI, the coefficient of *BRI* × *Year* decreases (increases in absolute value) from –8.8 in the year of participation in the BRI to –19.2 three years after participation in the BRI.

Figure 1. Parallel trend test



Source: Authors' estimation.

Notes: BRI, Belt and Road Initiative; MOU, memorandum of understanding.

Third, we conduct the placebo test by setting the policy event (participation in the BRI) in a period prior to 2013 to test whether there is still a significantly negative effect on the carbon emission intensity of BRI countries. As mentioned in the previous analysis, the premise of the DID method is that there is no significantly different trend in carbon emission intensity before participation in the BRI. If the estimated coefficient of the core variable (*BRI* × *MOU*) is significant in a period before 2013, it means that there are some potential unobserved factors other than the BRI that could affect the carbon emission intensity of BRI countries. To ensure the robustness of empirical results, the years are set as 2005, 2006, 2007, 2008, 2009, 2010, 2011, and 2012. The estimated results are reported in Table 3. It shows that the estimated coefficients of variable *BRI* × *MOU* are all insignificant, which proves that the DID estimation results are robust.

Table 3. Placebo test for robustness check, 2005–2012

Policy year	2005	2006	2007	2008	2009	2010	2011	2012
BRI × *MOU*	10.353 (0.221)	–3.425 (0.334)	–1.537 (0.232)	3.773 (0.531)	–5.552 (0.346)	–3.784 (0.256)	–2.689 (0.534)	–6.468 (0.387)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.12	0.13	0.15	0.13	0.14	0.11	0.10	0.11

Source: Authors' estimation.

Notes: *p*-values are in brackets. See subsection III.2 for the definition of variables.

Based on the above tests we can conclude that there is no selective bias in our sample and the policy effects of BRI on carbon emissions of BRI countries are not interfered with by other policies. The DID results are therefore robust.

3. Heterogeneous impact of the BRI on industrial carbon emission intensity

The impact of BRI cooperation on carbon emissions in different industries may be heterogeneous. For example, cooperation projects in transportation will create carbon emissions but cooperation projects in hydropower development will reduce carbon emissions. Different industries also have different levels of carbon emissions; for example, the electric and heating industry accounts for more than half of the total carbon emissions of BRI countries. In this subsection, we examine the impacts of participation in the BRI on carbon emission intensity in three energy-intensive industries (transportation, electric and heating, and manufacturing and construction) in BRI countries based on the DID method and the quantile DID method.

Table 4 reports the DID regression results in the three industries. The variable *BRI* × *MOU* is negative and statistically significant at the 10 percent level estimated by Equation (2) (transportation), the 5 percent level estimated by Equation (3) (electric and heating), and the 1 percent level estimated by Equation (4) (manufacturing and construction), indicating that participation in the BRI has reduced the carbon emission intensity in all the three industries. The regression results have therefore provided strong empirical evidence that the BRI has produced a significant impact on carbon emission intensity reduction of the energy-intensive industries of BRI countries. This suggests that conducting BRI cooperation with China will improve energy efficiency, reduce carbon emission intensity, and promote sustainable development of BRI countries.

Table 4. Regression results in three industries

Dependent variable	Carbon emission intensity		
	Equation (2) Transportation	Equation (3) Electric and heating	Equation (4) Manufacturing and construction
BRI × MOU	–12.057* (0.079)	–59.368** (0.018)	–15.561*** (0.002)
EDU	–0.243*** (0.001)	–0.444*** (0.004)	–0.094** (0.015)
FDI/GDP	–0.001*** (0.000)	–0.001*** (0.000)	–0.002*** (0.000)
ENS	0.201 (0.132)	–0.431*** (0.000)	–0.230*** (0.000)
PGDP	0.001*** (0.000)	0.003** (0.020)	0.001*** (0.000)
TRADE/GDP	0.210*** (0.000)	0.412*** (0.000)	0.041*** (0.006)
UR	0.489*** (0.000)	0.820*** (0.000)	0.293*** (0.000)
SER	–0.397** (0.013)	–1.175*** (0.000)	–0.703*** (0.000)
R^2	0.22	0.27	0.26
Year-fixed effect	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes
BRI × Time trend	Yes	Yes	Yes
Observations	1,567	1,567	1,567

Source: Authors' estimation.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. *p*-values are in brackets. See subsection III.2 for the definition of variables.

For the control variables, the impact of the share of renewable energy consumption over total final energy consumption (*ENS*) on carbon emission intensity is negative and statistically significant at the 1 percent level estimated by Equation (3) (electric and heating) and Equation (4) (manufacturing and construction), but it is positive and insignificant by Equation (2) (transportation), indicating that the structure of energy consumption has no significant impact on the carbon emission intensity of the transportation industry. A possible explanation is that the transportation sector, whose major fuel is fossil energy, has little involvement in renewable energy. The regression results of other control variables are the same as reported in Table 1 and are consistent with our theories and expectations.

In Table 5, the carbon emission intensity of the three energy-intensive industries is divided into nine sub-points from low to high, respectively. Based on the quantile DID method, we find that the impact of the BRI on carbon emission intensity varies at different carbon emission quantile levels in the three energy-intensive industries of BRI countries. First, the reduction effects of BRI on carbon emission intensity in the three equations are all significant at the higher and lower quantile levels and insignificant at the medium quantile levels, which is similar to the results for the total carbon emission intensity in Equation (1) reported in Table 2. Second, the reduction effects of BRI on carbon emission intensity gradually increase, reaching the highest at the quantile level (0.9) in all three equations. This indicates that the BRI has the largest effect on carbon emission intensity reduction in the high-carbon emission industries. Third, in contrast with Equations (2) and (3), the reduction effects of the BRI on carbon emission intensity in Equation (4) (the manufacturing and construction industry) occur more widely, covering the high quantiles from 0.6 to 0.9. This is because of the concentration of the green BRI cooperation with China in the manufacturing and construction sectors of high carbon emission intensity BRI countries.

Table 5. Regression results by quantile difference-in-difference method

Equation (2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
BRI × MOU	–0.016 (0.945)	–3.492*** (0.000)	–8.998*** (0.004)	–1.232 (0.350)	–0.726 (0.768)	–4.232 (0.366)	–6.663 (0.411)	–11.112* (0.088)	–14.956** (0.015)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.04	0.10	0.15	0.05	0.05	0.07	0.13	0.20	0.30
Equation (3)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
BRI × MOU	–0.663*** (0.008)	–2.467*** (0.000)	–2.883** (0.021)	–1.674 (0.354)	–1.341 (0.667)	–4.470 (0.365)	–2.072 (0.873)	–15.558** (0.048)	–89.82*** (0.000)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.18	0.23	0.24	0.05	0.06	0.07	0.09	0.13	0.24
Equation (4)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
BRI × MOU	–0.508** (0.021)	–1.773 (0.146)	–0.997 (0.187)	–1.365 (0.125)	–1.652 (0.275)	–4.476** (0.018)	–5.059** (0.011)	–8.623*** (0.000)	–30.25*** (0.000)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.19	0.04	0.06	0.09	0.06	0.18	0.12	0.26	0.27

Source: Authors' estimation.

Notes: ***, **, and * represent significance at the 1, 5, and 10 percent levels, respectively. *p*-values are in brackets. See subsection III.2 for the definition of variables.

V. Conclusion and policy implications

This study investigated empirically the impact of the BRI on the carbon emission intensity of BRI countries and the heterogeneous impacts of BRI on carbon emission intensity in three energy-intensive industries of BRI countries based on the DID method and quantile DID method. The study provided the following main findings.

First, the study found that participation in the BRI on average has had a significant effect on reducing the carbon emission intensity of BRI countries. The estimation results are robust based on a number of statistical tests, including the mean test, the parallel trend test, and the placebo test.

Second, the impact of BRI on carbon emission intensity varies at different quantile levels of carbon emission intensity of BRI countries. The estimation results from the quantile DID method reveal that the BRI has a significant impact on reducing carbon emission intensity for BRI countries at higher (0.8 and 0.9) and lower (0.2 and 0.3) carbon emission intensity quantile levels but has no significant impact on carbon emission intensity for BRI countries at other carbon emission intensity quantile levels. This implies that the BRI countries with high and low carbon emission intensity benefit more in reducing carbon emission intensity from participation in the BRI.

Third, the BRI has a significant impact on reducing carbon emission intensity in energy-intensive industries in BRI countries. The carbon emission intensity reduction effects of the BRI are more significant and are greatest at the high quantile levels of carbon emission intensity for all the three energy-intensive industries in the BRI countries.

The above findings indicate that participation in BRI cooperation with China under the general principle of green energy, green production, green living, and green finance will contribute to environmental protection and carbon emission reduction, and benefit the sustainable development of BRI countries.

The findings of this study provide some policy implications. First, the general principle of green energy, green production, green living, and green finance of BRI should be upheld and further strengthened in all BRI cooperation projects, especially projects with large impacts on the environment and carbon emissions, to achieve the goal of building the "green BRI." Second, the BRI should prioritize some environmentally friendly cooperation projects to produce clean and renewable energy, like hydropower, solar power, and wind power. China has the technology and rich experience in these areas and can provide assistance to BRI countries. These projects will have a significant impact both on carbon emission reduction and on the economic growth of BRI countries. Third, as the BRI has a positive environmental impact on some energy-intensive industries in BRI countries, the BRI countries have the potential to advance their sustainable development by introducing energy-saving and emission reduction technologies from China, such as electric cars and high-speed train technologies in the transportation industry. Fourth, in the construction sector, in addition to continuing to expand investment from China in infrastructure, the BRI countries can strengthen cooperation in some other areas, like building construction and urban renewal, to further use China's technology and experience to reduce carbon emissions in the construction process. Finally, in the manufacturing sector, through trade with China and investment from China, technology spillovers and funds can be used to drive industrial upgrading, improve production efficiency, thus reducing carbon emission intensity of BRI countries.

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Appendix

List of 178 countries including 63 in the treatment group and 115 in the control group

Treatment group	Afghanistan	Albania	Armenia	Azerbaijan	Bahrain	Bangladesh	Belarus
	Bosnia and Herzegovina	Brunei	Bulgaria	Cambodia	Croatia	Cyprus	Czech Republic
	Egypt	Estonia	Georgia	Greece	Hungary	India	Indonesia
	Iran	Iraq	Israel	Jordan	Kazakhstan	Kuwait	Kyrgyzstan
	Laos	Latvia	Lebanon	Lithuania	Macedonia	Malaysia	Maldives
	Moldova	Mongolia	Montenegro	Myanmar	Nepal	Oman	Pakistan
	Philippines	Poland	Qatar	Romania	Russia	Saudi Arabia	Serbia
	Singapore	Slovakia	Slovenia	Sri Lanka	Syria	Tajikistan	Thailand
	Turkey	Turkmenistan	Ukraine	United Arab Emirates	Uzbekistan	Vietnam	Yemen

Control group	Algeria	America	Angola	Antigua and Barbuda	Argentina	Australia	Austria
	Barbados	Belgium	Benin	Bolivia	Botswana	Brazil	Britain
	Burundi	Cabo Verde	Cameroon	Canada	Chad	Chile	Colombia
	Comoros	Cook Islands	Costa Rica	Côte d'Ivoire	Cuba	Curacao	Denmark
	Democratic People's Republic of Korea	Democratic Republic of the Congo	Djibouti	Dominica	Dominican Republic	Ecuador	El Salvador
	Equatorial Guinea	Eritrea	Ethiopia	Federated States of Micronesia	Fiji	Finland	France
	Gabon	Gambia	Germany	Ghana	Gibraltar	Grenada	Guatemala
	Guinea	Guyana	Haiti	Honduras	Iceland	Ireland	Italy
	Jamaica	Japan	Kenya	Kiribati	Kosovo	Lesotho	Liberia
	Libya	Luxembourg	Madagascar	Mali	Malta	Mauritania	Mauritius
	Mexico	Morocco	Mozambique	Namibia	Nauru	Netherlands	New Zealand
	Nicaragua	Niger	Nigeria	Niue	Norway	Papua New Guinea	Paraguay
	Panama	Peru	Republic of Congo	Portugal	Rwanda	Samoa	Senegal
	Seychelles	Sierra Leone	Solomon Islands	Somalia	South Africa	South Korea	South Sudan
	Spain	Sudan	Suriname	Sweden	Switzerland	Tanzania	Timor-Leste
	Togo	Tonga	Trinidad and Tobago	Tunisia	Uganda	Uruguay	Vanuatu
	Venezuela	Zambia	Zimbabwe				

(Edited by Zhinan Zhang)