Does the Belt and Road Initiative Affect the Energy Intensity of Countries along the Route?

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Abstract: We empirically evaluate the effect of China's Belt and Road Initiative (BRI) on the energy intensity of host countries along the route. Furthermore, we decompose this overall effect into direct effects via connectivity and indirect effects through development. We apply a relatively new synthetic control method based on interactive fixed effects to identify the causal effects of the BRI after controlling for the demand features of countries. Our main results include: (1) the overall effect of the BRI reduces the energy intensity of countries along the route by 0.0152 toes per thousand dollars, of which the direct effect is 0.0125 (82%); (2) the indirect effect in the current status is limited, mainly through the contradictory effects of economic growth and industrial structural change, which reduce the energy intensity by 0.0033 and increase it by 0.0007, respectively; and (3) countries along the route with a lower level of development, more abundant energy endowments, less stringent carbon regulations, and higher levels of energy technology experience a greater reduction in energy intensity after the BRI. Our results partially alleviate worries about the climate and energy impact of the BRI, but still raise concerns over its long-term impact through industrial and energy structural changes, and for some specific country groups.

Keywords: Belt and Road Initiative; energy intensity; direct and indirect effects; synthetic control method

1. Introduction

The Belt and Road Initiative (BRI) was proposed by China in September 2013 with the aim of promoting regional cooperation and economic integration. By June 2021, China had signed 206 cooperation documents for jointly building the BRI with 140 countries/regions and 32 international organizations, in which 64 countries along the route are commonly referred to as "BRI countries." The initiative focuses on connectivity, with policy coordination, facilities connectivity, unimpeded trade, financial integration, and people-to-people bonds ("The Five Connectivities") as its main content. In addition, the BRI encourages overseas investment in China in these particular countries (Chen and Lin, 2020; Du and Zhang, 2018; Shao, 2020). It is predicted that the initiative would possibly bring economic growth of the host countries by 3.35% (de Soyres et al., 2020).

Yet, there is growing concern over whether the initiative is "green." First, as China's BRI investments are concentrated in energy and transportation infrastructure, they might consume a large amount of cement and fossil energy, which eventually increases energy demand (Zhou et al., 2018) and carbon emissions (Ascensão et al., 2018; Zhang et al., 2017) in BRI countries. Second, China is one of the most important participants in transnational coal-fired power projects; accordingly, more than 70% of the world's coal-fired power plants rely on Chinese funds (Gallagher and Qi, 2018; Lin and Bega, 2021; Ren et al., 2017; Tao et al., 2020). Some worry that China's overseas energy investments might work against the global trend of energy transition. Third, some studies argue that the BRI exports excess capacity in China's high-polluting and high-energy consuming industries. As such, some host countries might become a "pollution haven" (Cai et al., 2018; Mahadevan and Sun, 2020; Zhou et al., 2018).

However, the above questions did not consider certain factors. One factor is the development status and demands of the BRI countries, most of which are emerging and developing economies. These countries simultaneously deal with a large development potential and energy consumption demand.[1] However, the lack of energy infrastructure and technology has become the main obstacle to sustained economic development. Thus, high-quality investments in this field are required. So, when evaluating the energy and environmental impact of the BRI, one should consider the economic development needs and the corresponding energy demands of these countries. This also implies that,

[1] For example, in 2017, their per capita GDP was only 68% of the world's average; in contrast, their growth rates in GDP, carbon emissions, and energy consumption were all higher than the global average (3.82%, 2.86%, and 1.73% compared with 3.30%, 1.83%, and 1.44%) according to the World Bank Statistics.

aside from its direct effects on countries' energy consumption through the enhancement of regional connectivity, there might be considerable indirect effects through host countries' developments that the BRI investment might bring.

Second, there has been increasing attention on China's green BRI policies and growing reserves in clean energy technologies. On the one hand, since the initiative was put forward, the Chinese government has issued a series of green Belt and Road policies[2]; accordingly, green has become a part of BRI's core contents. In fact, in 2021 China announced that it would stop financing new coal-fired power projects abroad.[3] On the other hand, China's technological reserves in clean energy have been considerably increasing in the past decade and even play a leading role in the fields of photovoltaic, wind, and nuclear power.[4] There is a need to evaluate whether the BRI is becoming green in terms of energy consumption in countries along the route.

In this study, we evaluated the impact of the BRI on the energy intensity of host countries. Specifically, we designed our empirical research to address the abovementioned development perspective and the policy evaluation issue, which are our main contributions compared with the existing literature.

First, to consider host countries' development needs, we decomposed the impact of the BRI into direct and indirect effects, which makes our evaluation more comprehensive than the existing ones. Current studies that focus on the projects (Liu et al., 2020; Yang et al., 2020) or industry level (Jiang et al., 2021; Wu et al., 2020, 2021a) are de facto assessing the direct effect of the BRI via regional connectivity. For example, infrastructure projects or manufacturing industry investments cause energy consumption or emissions. Moreover, studies at the country level have not distinguished between direct and indirect effects (Han et al., 2018; Li et al., 2021; Wu et al., 2020; Jiang et al., 2021; Wu et al., 2021a). On the contrast, we quantitatively evaluate the signs and sizes of the possible indirect effects the BRI might bring through economic development, structural change, and technological progress in BRI countries. Although numerous studies have predicted the potential impact of the BRI on regional economic indicators (Bird et al., 2020; de Soyres et al., 2020; Jackson and Shepotylo, 2021), there is seldom consideration of the corresponding influences on energy consumption features

[2] Such as *Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road*, *Guidance on Promoting Green Belt and Road*, and *The Belt and Road Ecological and Environmental Cooperation Plan*.

[3] See China's announcement at the *Qingdao Initiative for Belt and Road Green Energy Cooperation*.

[4] In the field of renewable energy, China's investment reached 83.4 billion dollars in 2019, ranking as first in the world. Specifically, China accounted for more than one-third of the global accumulated installed wind power capacity in 2018 according to the statistics of the Global Wind Energy Council (Leng et al., 2020).

through growth. The World Bank (2019) conducted a model simulation taking this perspective. But we provide the first empirical evaluation, accounting for both direct and indirect effects.

Second, to obtain more accurate policy evaluation results of the BRI, we adopted a relatively new counterfactual estimation method, which is the synthetic control method based on the interactive fixed effects of Gobillon and Magnac (2016). Compared with the existing evaluation that adopts the difference-in-differences (DID), such as Liu et al. (2020) and Wu et al. (2021a) or propensity score matching DID (PSM-DID) (Jiang et al., 2021), this approach can control for time-varying confounders indicating country-level features, thus better capturing the features of development status among host countries. In addition, it does not require a pretreatment parallel trend assumption between control and treatment groups as the DID does, which are often invalid with country-level data, and thus more suitable for policy evaluation at the country level.

The remainder of this paper begins with Section 2, which presents the literature review and the theoretical framework. Next, Section 3 describes the methodology and data used and then Section 4 presents our empirical results. Finally, Section 5 concludes the paper.

2. Literature Review and Theoretical Framework

We reviewed related literature from specific perspectives. As mentioned above, whether the BRI is green in terms of host countries' energy consumption features is controversial in existing studies. Furthermore, the effect can be divided into direct and indirect effects. In addition, we discuss the demand characteristics of BRI countries that may yield country-specific results. We then propose a theoretical framework based on this analysis.

2.1. Pollution Haven and Pollution Halo of the BRI

The BRI may bring either "pollution haven" or "pollution halo" effects on host countries' energy demand features. The former refers to the transfer of industries with heavy pollution and low energy efficiency to the host countries by foreign direct investment (FDI), leading to a decline in energy consumption performance or environmental quality (Copeland and Taylor, 1994). Correspondingly, the latter refers to the beneficial impact of FDI on the environment (Birdsall and Wheeler, 1993; Doytch and Narayan, 2016; Eskeland and Harrison, 2003).

Given this, some studies believe that the BRI is designed to transfer China's excess production capacity (Mahadevan and Sun, 2020). Accordingly, FDI from high-energy consuming industries may export pollution and fossil fuel demands to the host countries, making countries along the route a pollution haven (Cai et al., 2018; Walter and Ugelow, 1979; Zhang et al., 2017). The problem may be severe in China-participated transnational coal-fired power plants, which consume a large amount of fossil energy and significantly increase the carbon emissions of the host countries (Gallagher and Qi, 2018; Tao et al., 2020).

In contrast, some studies have shown that the BRI might also have a positive impact on energy consumption features along the route (Li et al., 2021). Since the BRI was proposed, China's FDI has become greener, and clean energy projects have increased significantly (Liu et al., 2020). This may reduce the pollution caused by energy consumption in BRI countries by improving energy efficiency and energy structure (Han et al., 2018), thereby creating the pollution halo effect. Jiang et al. (2021) found that the BRI could reduce the energy consumption and carbon emissions of host countries through trade, industry, and technology. Wu et al. (2021a) found that the BRI overall tends to reduce the carbon emission intensity of BRI countries; moreover, the impact is significant for countries with higher and lower carbon emission intensity quantiles.

2.2. The direct effect of the BRI on the energy intensity of countries along the route

The BRI may directly influence BRI countries' energy intensity through connectivity such as investments in transportation and energy infrastructures, facilitating inter-regional trade, and soft infrastructure construction such as policies, institutions, and cultural communications. These are officially summarized as "The Five Connectivities" of the BRI, which might influence the BRI countries' energy intensity in the following ways.

In the "The Five Connectivities", "hard" infrastructure and economic connectivity includes "facilities connectivity" and "unimpeded trade."

i. Facilities connectivity. The initiative launched a series of cross-border transportation and infrastructure projects that might increase energy demand (Zhou et al., 2018). Meanwhile, the BRI transportation network is estimated to significantly reduce transportation time and costs, which is more conducive to economic development (de Soyres et al., 2020). In addition, energy infrastructure facilities have the benefit of improving energy efficiency, which in turn affects energy intensity.

ii. Unimpeded trade. The BRI infrastructure can also promote cross-border trade (Baniya et al., 2020; Yang et al., 2020). The expansion of a country's exports could increase its carbon emissions and change its energy intensity (Cole, 2006). Exports could also strengthen a country's comparative advantage industries, thereby affecting energy intensity. Moreover, less developed countries could reduce their emissions, and correspondingly, the energy intensity, when increasing imports from China (Wu et al., 2021b).

"Soft" infrastructure connectivity includes "policy coordination," "financial integration" and "people-to-people bonds."

iii. Policy coordination. Effective policy coordination is a prerequisite for cooperation among the countries under the BRI. High-level international political cooperation with the BRI countries could increase political mutual trust and reduce political risks in BRI countries (Shao, 2020), thereby affecting energy intensity.

iv. Financial integration. The BRI clearly proposes that green finance is one of the key measures for building a green Belt and Road. By the end of 2018, China's financial institutions and enterprises had issued more than 700 billion yuan of green bonds at home and abroad to support environmental improvement and resource-saving activities in the BRI countries.[5]

v. People-to-people bonds. The BRI could help increase public spending on green energy technologies and education in the BRI countries, thus accelerating the growth of the green economy and consequently reducing energy intensity (Zhang et al., 2021).

2.3. The indirect effect of the BRI on the energy intensity of countries along the route

The BRI may further affect the BRI countries' energy intensity through stimulating their development by FDI or trade. It could be further decomposed into the scale, composition, and technology effects under the framework of openness (Antweiler et al., 2001; Grossman and Krueger, 1995). But such effects of the BRI are to be empirically assessed.

The scale effect refers to the influence on the host country's environmental or energy performance (i.e., energy intensity) by stimulating economic growth, typically by FDI or trade (Andreoni and Levinson, 2001; Borensztein et al., 1998). An expansion of the economic scale would probably increase the country's energy consumption and energy intensity. Meanwhile, an increase in per capita gross domestic product (GDP) could reduce energy intensity from two aspects. For example, with

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[5] Data are from: https://www.financialnews.com.cn/zt/ydyl2019/201904/t20190427_158980.html

increased income and environmental awareness, people are more willing to adopt environmentally friendly consumption and lifestyles (Yue et al., 2011); moreover, FDI or trade may change the extensive development mode in the past through more efficient production equipment and production modes (Mold, 2003).

The composition effect is the influence of industrial or energy structure adjustments (Choi et al., 1995). If the proportion of energy-intensive sectors increases, the energy intensity increases (Huang et al., 2020; Mi et al., 2015). If FDI promotes the transformation of the host country's energy consumption structure from fossil energy to clean energy, it will help reduce energy consumption and energy intensity (Xu et al., 2021).

The technological effect is the influence of technology spillovers such as demonstration, competition, and learning. It is generally believed that it helps reduce energy intensity (Ma and Stern, 2008; Tan and Lin, 2018; Zarsky, 1999). However, some studies believe that it further promotes economic growth and generates new demand for energy, partially offsetting energy savings (Berkhout et al., 2000).

2.4. Development status and demand characteristics of BRI countries

The demand features of BRI countries also affect whether the initiative would bring pollution haven or pollution halo to them. This mainly includes the following aspects: i. Different levels of development imply different extents of facility and economic connectivity of the BRI countries and China under the initiative; ii. The energy abundance of BRI countries may affect the types of investment projects they attract; iii. More stringent environmental regulation of host countries may attract cleaner inward FDI, and thus more likely to generate the pollution halo effect (Antweiler et al., 2001); iv. higher technological level, especially reserves for clean technology, indicates a stronger absorptive capacity of international spillovers of such technologies. The above features of BRI countries could affect the sizes or even signs of the above direct and indirect effects.

2.5. Theoretical framework

Thus, we propose a theoretical framework based on the literature analysis (Figure 1). Not limiting to empirically evaluation whether the BRI could reduce host countries' energy intensity, we further decompose this overall effect into the direct effect via connectivity, and the indirect effect through scale, composition, and technology channels. Then, host countries' characteristics, such as development status, energy abundance, environmental regulation, and technological level, may further affect the sizes and signs of such effects.

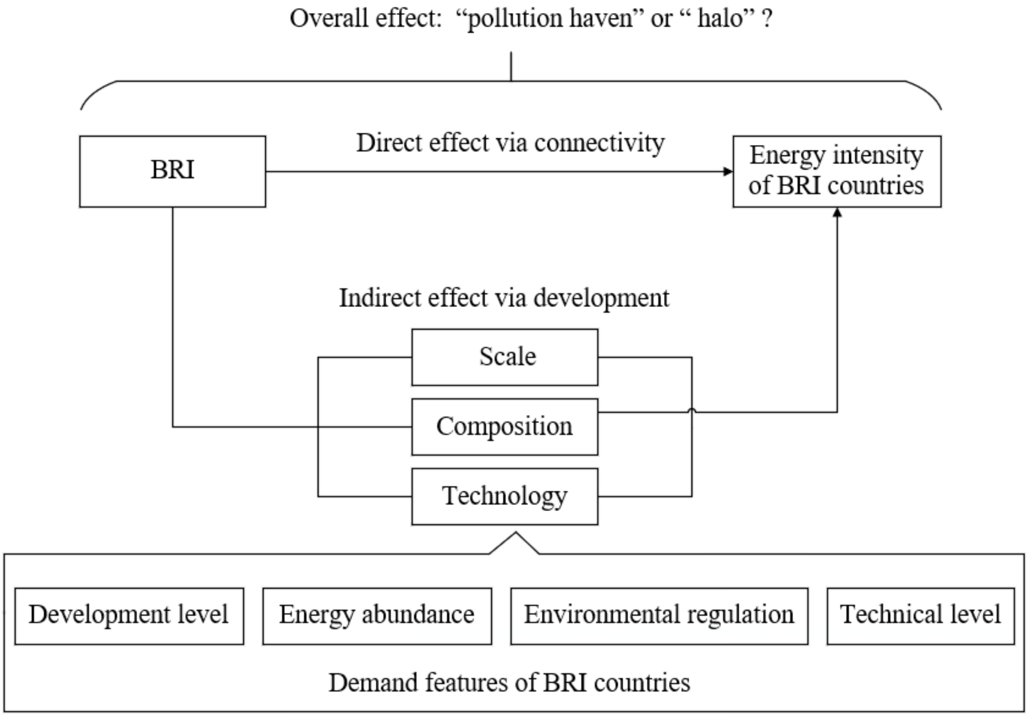

Figure 1 Theoretical Framework

3. Methodology and data

3.1. Methodology

We adopt the synthetic control method based on interactive fixed effects for policy evaluation to better control the differences in development status among countries. Then, the overall effect is decomposed into direct and indirect effects via scale, composition, and technology.

3.1.1. The synthetic control method based on interactive fixed effects

Policy effects are commonly empirically evaluated by constructing counterfactuals. Among such quasi-experimental methods, we apply a synthetic control method based on the interactive fixed effects proposed by Gobillon and Magnac (2016) based on Bai (2009). The synthetic control method is an improved nonparametric method based on DID (Abadie et al., 2015, 2010; Abadie and Gardeazabal, 2003). It constructs control units as a counterfactual for the treated units by reweighting the control units.

We chose this method for three reasons. First, compared with the DID, it not only controls for the time and individual fixed effects, but also for the time-varying confounders that may affect pretreatment trends. Therefore, it does not require for the pretreatment parallel trends as the DID does, and can reduce the estimation bias. Second, although a matching between treatment and control units may alleviate the problem, the method we use can yield accurate results, as it constructs a counterfactual scenario based on both the control and treatment samples in the pretreatment periods. Third, the method we use is more suitable for our data compared with other synthetic control techniques for multiple treatment units. One is the matrix completion method proposed by Athey et al. (2021). Although it has attractive computational properties with a large sample size, the range of our data is limited, and the number of time-varying confounders is small. In such cases, the Gobillon and Magnac method we used are more suitable according to the Monte Carlo simulation (Liu et al., 2020). The other is the generalized synthetic control method proposed by Xu (2017). It requires long pretreatment periods, otherwise leading to bias estimation, while our data do not meet this condition. In such a case, the expectation–maximization (EM) algorithm in our method is more efficient in constructing the counterfactual based on limited samples.

3.1.2. Model setups and estimation

Suppose y_{it} is the energy intensity of country i in year t. $D_i \in \{0,1\}$ is the country dummy variable, $D_i = 1$ for countries along the Belt and Road (the treatment group) which is indexed by $i = 1, \cdots, N_1$; whereas $D_i = 0$ for countries not along the route (the control group) which is indexed by $i = N_1 + 1, \cdots, N$. Suppose the BRI is implemented in T_D, and we set $I_t \in \{0,1\}$ as the time dummy for whether the BRI has been implemented. Set $BRI_{it} = I_t D_i$, $BRI_{it} = 1$ refers to countries along the route after the implementation of the BRI. Then, y_{it} is given by the following linear factor model:

$$y_{it} = \alpha_{it} BRI_{it} + x_{it}\beta + f_t'\lambda_i + \mu_i + \eta_t + \varepsilon_{it}, \qquad (1)$$

In which α_{it} is the treatment effect on country i in year t; x_{it} is a k vector of control variables, and β is a k vector of unknown parameters; $f_t = (f_{1t} \cdots f_{lt})'$ denotes a vector of unobserved common factors, $\lambda_i = (\lambda_{i1} \cdots \lambda_{il})'$ is a vector of unknown factor loadings, and $f_t'\lambda_i$ represents unobservable time-varying confounders among countries; μ_i and η_t are country and year fixed effects, respectively; and ε_{it} represents the random disturbance term.

Let $y_{it}(1)$ and $y_{it}(0)$ denote the potential outcomes of country i $(i < N_1)$ in year t $(t > T_D)$ when $BRI_{it} = 1$ and$BRI_{it} = 0$, respectively. The individual treatment effect of countries along the route is $y_{it}(1) - y_{it}(0)$. The average treatment effect on the treated (ATT) in year t can be expressed as

$$ATT_t = (1/N_1)\sum_{i \in N_1}[y_{it}(1) - y_{it}(0)] \qquad t > T_D. \tag{2}$$

As the outcome $y_{it}(1)$ is given by the real data, the key for estimation is to obtain the estimated $\hat{y}_{it}(0)$, which is synthesized by the control and treatment group data. Consequently, the process is divided into three steps.

Step 1. The EM algorithm is used to obtain the estimated coefficient $\hat{\beta}$ of the observable control variable, and $\widehat{f_t'}$, the unobservable common factor in Equation (1), using the samples of the control group in the whole period and the treatment group in the pretreatment period.

Step 2. Estimate the factor loadings $\widehat{\lambda_i}$ of the treatment group by using the ordinary least square regression and the data of the treatment group in pretreatment periods.

Step 3. Calculate the treated counterfactuals by substituting $\hat{\beta}$, $\widehat{f_t'}$ and $\widehat{\lambda_i}$ into Equation (1), using the treatment group sample.

$$\hat{y}_{it}(0) = x_{it}\hat{\beta} + \widehat{f_t'}\widehat{\lambda_i} + \mu_i + \eta_t. \tag{3}$$

Finally, we obtain the estimated Average Treatment Effect on the Treated (ATT) according to Equation (2).

3.1.3. Decomposition of the direct and indirect effects

Now, we focus on how to decompose the overall effect of the BRI on energy intensity into the abovementioned direct and indirect effects. Here, we separate the intermediate variables of the indirect effect—such as scale, composition, and technology indicators—from the control variables, as Z_{it}, and rewrite Equation (1):

$$y_{it} = \alpha_1 BRI_{it} + \sigma Z_{it} + x_{it}\beta + f_t'\lambda_i + \mu_i + \eta_t + \varepsilon_{it} \tag{4}$$

The challenge of the decomposition in our study is that the intermediate variables of the indirect effect, such as the scale, composition, and technology indicators, are not only affected by the BRI, but also important determinants (control variables) of the energy intensity of host countries according to a considerable number of existing studies (Antweiler et al., 2001; Huang, 1993).

Therefore, it leads to a dilemma for us to estimate the overall effect of the BRI on energy intensity, which is of our interest. On the one hand, when we control for Zs in Equation (4), the very important "indirect effects" of the BRI on energy intensity through the scale, composition, and technology effects, have been captured by Zs. As a result, α_1, the coefficient of the BRI_{it} in Equation (4), only reflects the "direct" effect of the BRI. On the other hand, if we drop Zs in Equation (4), although the coefficient of the BRI_{it} includes the indirect effects mentioned above, it may suffer from the bias of omitted variables, as Zs are important controls for energy intensity.

The way we solve the problem is to construct a set of intermediate indicators where the effect of the BRI on them has been removed. Then, we include these adjusted sets of indicators in Equation (4) as control variables.

First, we add an auxiliary regression of Zs to BRI. It reflects the BRI-induced scale, composition, and technology effects.

$$Z_{it} = \delta_1 BRI_{it} + x_{it}\beta + f_t'\lambda_i + \mu_i + \eta_t + \varepsilon_{it}. \tag{5}$$

Then, we deduce the part of Z_{it} that was affected by the BRI from its original value by applying the estimated coefficient of δ_1:

$$\widetilde{Z_{it}} = Z_{it} - \widehat{\delta_1} BRI_{it}. \tag{6}$$

Third, we include the $\widetilde{Z_{it}}$ into the regression function of energy intensity as control variables, and rewrite Equation (4) as:

$$y_{it} = \gamma_1 BRI_{it} + \sigma\widetilde{Z_{it}} + x_{it}\beta + f_t'\lambda_i + \mu_i + \eta_t + \varepsilon_{it}. \tag{7}$$

As now the $\widetilde{Z_{it}}$ does not contain the effect of the BRI on Z_{it}, the coefficient of BRI_{it} in Equation (7), the γ_1, is the overall effect of the BRI on energy intensity, which includes the direct and indirect effects.

The coefficients that indicate the overall, direct, and indirect effects in Equations (4) through (7) are summarized in Figure 2. First, γ_1 in Equation (7) reflects the overall effect of the BRI on the energy intensity. Then, when we introduce Z_{it} into Equation (4), the indirect effects should be absorbed by the coefficients of Z_{it}, leaving the α_1 in Equation (4) as the direct effect. As for the indirect effect, it could be either measured as the difference between γ_1 and α_1, or the product of $\widehat{\delta_1}$ and σ, where $\widehat{\delta_1}$ and σ represent the impact of the BRI on Z_{it} and the impact of Z_{it} on energy intensity, respectively.[6]

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[6] Easily obtained if you substitute Equation (6) into (7) and compare it with Equation (4).

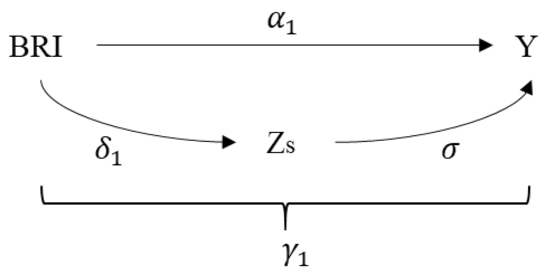

Figure 2 The Parameters That Indicate the Direct, Indirect, and Overall Effects

3.2. Data

We used country-level panel data containing 125 countries/regions from 2003 to 2017, which included 53 countries/regions along the Belt and Road route. The BRI was put forward in September of 2013; so, considering the lagging effect, we set 2014 as the time point for policy shock (Liu and Xin, 2019).

The dependent variable y is the energy intensity, which is the ratio of the country's final energy consumption to its GDP. The policy variable is the dummy BRI_{it}, which indicates whether it is a country along the route after the BRI.

The control variables include population (pop), represented by the logarithmic value of a country's total population; trade dependence (trade), indicated by the proportion of imports and exports of goods and services in GDP; industrial level (inelectricity), measured by the electricity demand of a country's industrial sector; energy resource endowment (energy), represented by the self-sufficiency rate of coal energy; and coal price, measured as the logarithm of the Newcastle/Port Kembla spot FOB price in Australia.

Intermediate indicators include the development level (pgdp), expressed as the logarithmic value of per capita GDP; industrial structure (service), indicated by the proportion of value added of the tertiary industry out of the GDP; energy structure (fossil), measured by the proportion of fossil energy in primary energy; technology level (technology), expressed as the logarithm of a country's energy-related patents.

Data on the economic indicators are from the World Bank, energy data are from the International Energy Agency (IEA), and the technology indicators are from the Organization for Economic Co-operation and Development (OECD) patent database. The descriptive statistics of these variables for all samples, the control group, and the treatment group are shown in Table 1.

4. Empirical results

4.1. The overall, direct, and indirect effects of the BRI on energy intensity

4.1.1. The direct and overall effect of the BRI on energy intensity

As shown in Table 2, the direct effect of the BRI on energy intensity estimated by Equation (4) is -0.0125, with a significance level of 1%. This implies that the direct effect of the BRI can reduce the energy intensity of countries along the route via connectivity by 0.0125 toes per thousand dollars. Meanwhile, the overall effect of the BRI on energy intensity estimated by Equation (7) is -0.0152, with a significance level of 1%. This means that the BRI can reduce the BRI countries' energy intensity via both direct and indirect effects through development by 0.0152 toe per thousand dollars. For comparison, we also introduce a regression in Column 3, which contains no control variables. The scale of the estimated coefficient is considerably smaller than that of the above two models, showing that missing control variables would cause a large estimation bias.

Table 1 Descriptive Statistics

Variable	Obs	Mean	Std.Dev	Min	Max
		Panel A：all samples			
y	1875	0.2099	0.1880	0.0280	1.8420
pop	1875	16.3656	1.5102	12.5760	21.0149
trade	1875	0.9521	1.2897	0.0017	33.8785
inelectricity	1875	8.9282	1.9435	3.7817	13.7271
energy	1875	0.7665	2.7791	0.0000	40.1100
price	1875	4.4362	0.4152	2.9149	7.2262
pgdp	1875	8.8662	1.4340	5.6680	13.6783
service	1875	53.2632	11.2833	19.1718	79.3320
fossil	1875	70.1077	26.7136	5.0000	100.0000
technology	1875	1.0855	1.8237	0.0000	8.6425
		Panel B：Treatment group sample			
y	795	0.2495	0.1776	0.0460	1.6690
pop	795	16.4305	1.5542	12.7751	21.0149
trade	795	0.9657	0.5446	0.0017	4.3733
inelectricity	795	9.0152	1.7215	3.7817	13.0520
energy	795	0.6222	1.0751	0.0000	9.3200
price	795	4.4645	0.3802	3.0693	5.6597
pgdp	795	8.6342	1.2391	6.0997	11.3195
service	795	49.1143	10.3079	19.1718	75.1803
fossil	795	79.5610	21.9101	9.000	100.0000

technology	795	1.1788	1.7934	0.0000	7.6234
Panel C：Control group sample					
y	1080	0.1808	0.1902	0.0280	1.8420
pop	1080	16.3178	1.4759	12.5760	19.5993
trade	1080	0.8388	0.6071	0.1910	4.4262
inelectricity	1080	8.8642	2.0903	4.3176	13.7271
energy	1080	0.8727	3.5407	0.0000	40.11
price	1080	4.4153	0.4382	2.9149	7.2262
pgdp	1080	9.0371	1.5406	5.6680	13.6783
service	1080	56.7173	10.9958	25.6326	79.3320
fossil	1080	63.1352	27.7633	5.0000	100.0000
technology	1080	1.0168	1.8436	0.0000	8.6425

From the estimation results, we can calculate the size of the indirect effect through development, which is -0.0027, the difference between the overall and direct effects. It can be seen that in the current status, the direct effect of the BRI accounts for the largest proportion in reducing the BRI countries' energy intensity, which is 82.2% out of the overall effect, while the indirect effect only accounts for 17.8%. There are two possible reasons for this finding. First, as the sample period covers only a limited number of years after the proposal of the BRI, the development effect has not yet been fully realized. Second, the indirect effect is a combination of the results of the scale, composition, and technology effects that might have opposite signs and scales that offset each other, which we will decompose in detail in the next subsection.

Table 2 The Overall and Direct Effects of the BRI on Energy Intensity of BRI Countries

Model	**Direct effect (1)**	**Overall effect (2)**	**Without control variables (3)**
BRI	-0.0125***	-0.0152***	-0.0054**
	(0.0030)	(0.0030)	(0.0024)
95% confidence interval	(-0.0183, -0.0067)	(-0.0210, -0.0093)	(-0.0101, -0.0006)
Control variables	Yes	Yes	No
Country fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Unobserved factors	2	2	2
Observations	1875	1875	1875

Note: Standard errors are shown in parentheses; *, **, and *** denote $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

4.1.2. The indirect effect of the BRI on energy intensity

We further decompose the indirect effect via the specific scale, composition, and technology effects using Equations (5) through (7) for each intermediate indicator. The BRI-induced scale, composition, and technology effects estimated with Equation (5) are in Column 1-4, Table 3, and the results of Equation (7) with the calculated indirect effects are reported in Column 5-8. We find that the main channels of the indirect effect are through economic growth and industrial structure adjustment.

Table 3 The Indirect Impact of the BRI on the Energy Intensity of Countries along the Route

Model		**BRI induced scale, composition, and technology effect**				**Decomposition of the indirect effects**			
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Variables		pgdp	service	fossil	technology	y	y	y	y
BRI		0.0554*** (0.0039)	1.1410*** (0.1399)	0.5173*** (0.1003)	0.0188 (0.0454)	-0.0158*** (0.0029)	-0.0118*** (0.0030)	-0.0126*** (0.0029)	-0.0125*** (0.0030)
95% confidence interval		(0.0478, 0.0629)	(0.8668, 1.4152)	(0.3208, 0.7139)	(-0.0702, 0.1078)	(-0.0214, -0.0102)	(-0.0177, -0.0059)	(-0.0182, -0.0070)	(-0.0183, -0.0067)
Adjusted intermediates indicators $\widetilde{Z_{it}}$	$\widetilde{pgdp}$					-0.0594***			
	$\widetilde{service}$						0.0006***		
	$\widetilde{fossil}$							-0.0002	
	$\widetilde{technology}$								-0.0003
Indirect effect: $BRI \times \widetilde{Z_{it}}$						-0.0554*0.0594 =-0.0033	1.1410*0.0006= 0.0007	0	0
Control variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unobserved factors		2	4	4	1	2	2	2	2
Observations		1875	1875	1875	1875	1875	1875	1875	1875

Note: Standard errors are shown in parentheses; *, **, and *** denote $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

For the scale effect, the BRI has a significant positive impact on the per capita GDP of countries along the route (0.0554). Each unit of the BRI-induced increase in per capita GDP could result in a significant decrease in energy intensity (-0.0594). Thus, the indirect effect through this channel is -0.0033 toes per thousand dollars. This implies that the BRI could be helpful in enhancing the living standards of BRI countries and thus decrease their energy intensity through the environmental Kuznets curve by cleaner production and consumption.

For the composition effect, we consider the channels of both the industrial and energy structures. The BRI increases the proportion of tertiary industries in the countries along the route (1.14%). Each unit of the BRI-induced structural change caused a very small but significant increase in energy intensity (0.0006). Thus, the indirect effect through the industrial structure is 0.0007. As BRI investment in the tertiary industry is largely concentrated in the transportation infrastructure, it might increase energy consumption and energy intensity in the short term.

The BRI increases the proportion of fossil energy in primary energy sources in countries along the route (0.52%), but the subsequent effect on energy intensity is small and insignificant. Therefore, the indirect effect of the energy structure adjustment is insignificant. This implies that in the current stage, the BRI investment still favors fossil fuel in the BRI countries, while this energy structure effect has a very limited impact on their energy intensity.

The impact of the BRI on the number of energy patents and the subsequent influences on energy intensity in countries along the route are both insignificant. This is possibly due to lags in technology spillovers of investments and policies.

4.2. Robustness tests

We used two alternative methods to test the robustness of the overall and direct effects. One is the DID; the other conducts a PSM-DID, which matches observations in the treatment group with observations in the control group with the most similar attributes.

The results using these two methods are similar to our benchmark results, with an overall effect of -0.0208 or -0.0184, and a large direct effect of -0.0193 or -0.0175, which is 92.8% or 95.1% of the overall effect. This feature is consistent with the main results.

Nevertheless, the results of the two methods are relatively larger in terms of absolute values than our benchmark results using synthetic control. This might be due to bias in the estimation with the two methods. As mentioned above, the DID method requires the parallel trend assumption, which is hardly met with macro data. Yet, although the PSM-DID could alleviate the problem and reduce the selection bias,[7] it is still less efficient than the synthetic control method we used in dealing with large differences in the development status and characteristics of sample countries.

Table 4 Robustness Test Results

Model	**DID**		**PSM-DID**	
	Direct effect	**Overall effect**	**Direct effect**	**Overall effect**
BRI	-0.0193*** (0.0053)	-0.0208*** (0.0053)	-0.0175*** (0. 0052)	-0.0184*** (0.0052)
95% confidence interval	(-0.0298, -0.0088)	(-0.0311, -0.0104)	(-0.0277, -0.0073)	(-0.0285, -0.0083)
Control variables	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes

[7] See its balance test result in the Appendix Table A.

Year fixed effects	Yes	Yes	Yes	Yes
R2	0.3351	0.3351	0.3568	0.3568
Observations	1682	1682	1228	1228

Note: Standard errors are shown in parentheses; *, **, and *** denote $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

4.3. Heterogeneity analysis

The signs and the relative sizes of the direct and indirect effects are heterogeneous with different characteristics of the BRI countries, such as their development levels, energy abundance, environmental regulations, and environmental technology levels. Accordingly, we conducted the subsample regressions in this section. The sample is divided according to the median value of indicators of the per capita GDP, energy self-sufficiency rate, the environmental regulation level from the "Travel and Tourism Competitiveness" report[8] (Cheng and Qi, 2021; Chung, 2014; Dong et al., 2021), and the numbers of environmental patents. The regression results are summarized in Figure 3 and the details are reported in Appendix Table B.

I. Development level.

The overall effect of the BRI on energy intensity is considerably higher in countries with a relatively lower level of development (-0.0192) than in the higher development group (-0.0049). More specifically, for countries with relatively higher levels of development, the direct effect is insignificant, leaving the indirect effect to play the entire role. Notably, for countries with a lower level of development, it is the direct effect that accounts for a larger proportion than the indirect effect (-0.0153 vs. -0.0039). There are some possible explanations, beginning with countries with lower levels of development may benefit more from the connectivity of the BRI, as they have defective transportation infrastructure and energy systems. On the contrary, countries with higher levels of development may enjoy more development effects of the BRI as they have a mature infrastructure and economic system.

II. Energy abundance.

The overall effect of the BRI on energy intensity is much higher in countries with relatively abundant energy endowments (-0.0230) than in less abundant countries (-0.0045). In particular, countries with abundant energy have relatively larger direct effects (-0.0151) than indirect effects (-0.0079), while countries with less abundant energy enjoy only a much smaller direct effect (-0.0045)

[8] The "Travel and Tourism Competitiveness" report was released by the World Economic Forum. This survey interviewed more than 10,000 business executives, and judged the country's environmental regulation level according to their scores on the strictness of the country's environmental regulations (1-7). Accordingly, 1 means lenient compared with most countries, and 7 means it is the most stringent regulation in the world.

and no significant indirect effect. This is probably because the former country group has a more sufficient energy supply that would in turn attract more investments and cooperation from the BRI, while the latter group mainly benefits from direct effects such as the construction of energy infrastructures.

III. Environmental regulation level.

Countries with higher levels of environmental regulation have much smaller overall effects (-0.0109) than those with lower levels of regulation (-0.0207). In the former country group, the indirect effect (-0.0061) is slightly larger than the direct effect (-0.0048), while in the latter country group, it is the direct effect (-0.0165), which takes a considerably larger proportion than the indirect effect (-0.0042). This implies that the BRI has not led to a pollution haven even when host countries have less stringent environmental regulations. In such countries, the initiative could help achieve economic growth with a smaller increase in energy consumption.

IV. Environmental technology level.

Countries with higher levels of environmental technology have an overall effect of -0.0159, in which direct and indirect effects are -0.0130 and -0.0029, respectively, while countries with lower levels of environmental technology have an insignificant effect. Countries in the former group have a larger stock of environmentally friendly technologies; thus, they are more inclined to introduce energy-saving projects and can better absorb such technology spillovers from foreign investment and openness.

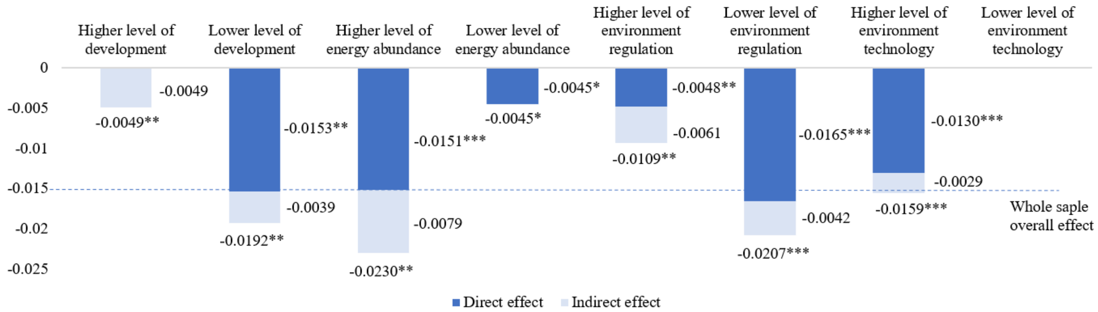

Figure 3 Heterogeneity Analysis Results

5. Conclusions

We empirically evaluated the impact of the BRI on the energy intensity of countries along the route, and further decomposed this overall effect into a direct effect via connectivity, and the indirect effect through development, such as the scale, composition, and technology channels. Under the counterfactual framework, we used the synthetic control method based on interactive fixed effects to obtain a better policy evaluation, using the data of 125 countries from 2003 to 2017. Our main conclusions are as follows.

First, the overall effect of the BRI reduces the energy intensity of BRI countries by 0.0152 toes per thousand dollars, of which the direct effect via connectivity reduces it by 0.0125 (82.2% out of the total). This is much larger than the indirect effect through development.

Second, the indirect effect through development in the current status is limited (-0.0027). This is mainly due to the contradictory effects of promoting economic growth and the tertiary industry. Through the former, the BRI could reduce energy intensity by 0.0033, while through the latter, it increased it by 0.0007. Channels through energy structure adjustment and technology spillover are not significant.

Third, country-level characteristics generate heterogeneous results. The overall and direct effects of the BRI on reducing energy intensity are stronger in countries with lower levels of development, more abundant energy endowments, less stringent environmental regulations, and higher levels of environmental technology.

Generally, our empirical results show that in terms of reducing energy intensity, the BRI could play a positive role, which may partially alleviate the concerns over the climate and environmental impact of the initiative. Currently, the direct effect via connectivity contributes to a larger proportion, while the indirect effect is limited. As the development effect of the BRI is fully revealed, the indirect effect may play a more important role in the future. Nevertheless, there are still concerns regarding the BRI's long-term impact. For example, the channel through industrial structure adjustment is still unfavorable in reducing the energy intensity, and the energy structure change induced by the BRI still favors the use of fossil fuels. This calls for more policy support in the field of building a green Belt and Road. In addition, some country-specific effects deserve further consideration. For example, in countries with less abundant energy endowments and lower levels of environmental technology, the overall effect of the BRI on energy intensity is small, while these countries may be more vulnerable to climate and environmental problems and require investments to foster their clean and sustained development.

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Appendix

Appendix Table A

Appendix Table A Balance Test Result of the PSM

Variables	Sample	Mean		Bias		T value	P value
		Treated	Control	%	% reduced		
trade	Unmatched	1.0089	0.7585	51.9	84.6	10.79	0.000
	Matched	0.9740	1.0126	-8.0		-1.23	0.219
energy	Unmatched	0.6060	0.7724	-7.0	-0.8	-1.33	0.183
	Matched	0.6211	0.4533	7.0		1.61	0.107
price	Unmatched	4.4577	4.4039	13.2	88.5	2.64	0.008
	Matched	4.4487	4.4426	1.5		0.30	0.768
technology	Unmatched	1.0963	0.8967	11.4	35.6	2.33	0.020
	Matched	1.0560	0.9275	7.3		1.35	0.176
pgdp	Unmatched	8.7321	8.9713	-17.4	29.1	-3.46	0.001
	Matched	8.7359	8.5664	12.3		2.67	0.008
service	Unmatched	50.7260	56.9250	-61.4	80.6	-12.40	0.000
	Matched	51.3660	52.5670	-11.9		-2.13	0.033
fossil	Unmatched	78.6200	60.7780	73.5	94.3	14.63	0.000
	Matched	77.5760	76.5510	4.2		0.85	0.397

Appendix Table B

Appendix Table B Heterogeneity Analysis Results

	Overall effect	Direct effect	Indirect effect	Overall effect	Direct effect	Indirect effect
Panel A	Higher level of development			Lower level of development		
BRI	-0.0049** (0.0023)	-0.0004 (0.0023)	-0.0045	-0.0192*** (0.0057)	-0.0153** (0.0057)	-0.0039
95% Confidence Interval	(-0.0095, -0.0003)	(-0.0050, 0.0042)		(-0.0303, -0.0080)	(-0.0264, 0.0041)	
Unobserved factors	1	1		5	2	
Observations	930	930	930	945	945	945
Variables	Higher level of energy abundance			Lower level of energy abundance		
BRI	-0.0230** (0.0056)	-0.0151*** (0.0056)	-0.0079	-0.0045* (0.0031)	-0.0045* (0.0027)	0
95% Confidence Interval	(-0.0958, -0.0740)	(-0.0343, -0.0125)		(-0.0123, -0.0001)	(-0.0099, -0.0005)	
Unobserved factors	2	2	1	3	1	
Observations	975	975	975	900	900	900
Variables	Higher environmental regulations			Lower environmental regulations		
BRI	-0.0109** (0.0021)	-0.0048** (0.0021)	-0.0061	-0.0207*** (0.0031)	-0.0165*** (0.0054)	-0.0042
95% Confidence Interval	(-0.0150, -0.0068)	(-0.0123, -0.0001)			(-0.0271, -0.0060)	
Unobserved factors	1	1		3	2	
Observations	930	930	930	945	945	945
Variables	Higher level of environmental technology			Lower level of environmental technology		
BRI	-0.0159*** (0.0015)	-0.0130*** (0.0017)	-0.0029	-0.0110 (0.0085)	-0.0098 (0.0086)	0
95% Confidence Interval	(-0.0188, -0.0129)	(-0.0161, -0.0099)		(-0.0277, 0.0057)	(-0.0268, 0.0071)	
Unobserved factors	1	1		1	1	
Observations	990	990	990	885	885	885
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors are shown in parentheses; *, **, and *** denote $p < 0.1$, $p< 0.05$, and $p < 0.01$, respectively.