

Article

The Impact of the Belt and Road Initiative on Carbon Emission Intensity in Cities Along the Route in China

Jie Chen ^{1,*}, Jiexuan Li ¹, Yongjuan Liu ¹, Xiangdong Liang ¹ and Huibin Yao ²

¹ School of Economics and Management, Changsha University of Science and Technology, Changsha 410076, China; jiexuanli@csust.edu.cn (J.L.); 24207101695@csust.edu.cn (Y.L.); 005722@csust.edu.cn (X.L.)

² School of Economics, Hunan University of Finance and Economics, Changsha 410205, China; yaohuibin@hufe.edu.cn

* Correspondence: 006764@csust.edu.cn

Abstract

As China pursues its Dual Carbon Goals, understanding the environmental effects of the Belt and Road Initiative (BRI) is of critical importance. Employing panel data from 282 prefecture-level cities in China over the period 2003–2023, this study adopts a difference-in-differences (DID) approach to systematically assess the impact of the BRI on carbon emission intensity (CEI). The empirical results show that the BRI significantly reduces CEI in Chinese cities along its corridors, a finding that proves robust across multiple robustness checks and after addressing potential endogeneity concerns. Mechanism analysis reveals that the BRI reduces CEI by promoting industrial structure optimization, lowering energy intensity, and alleviating market fragmentation. Moderating effect tests indicate that government intervention strengthens the CEI reduction effect of the BRI. Heterogeneity analysis suggests that the CEI reduction effect is more pronounced in central-western cities, key environmental protection cities, old industrial base cities, and non-logistics hub cities.

Keywords: belt and road initiative (BRI); carbon emission intensity (CEI); difference-in-differences (DID)

1. Introduction

The overwhelming scientific consensus holds that human-generated carbon emissions are the primary driver of greenhouse gas accumulation, placing them at the center of efforts to address escalating climate change [1]. Consequently, a country's proactive response to climate change and effective control of its carbon emissions not only demonstrates its commitment to global responsibilities but also serves as an essential driver for transitioning to high-quality development. Recently, China has demonstrated strong determination in climate governance and achieved significant reductions in carbon emissions. The national strategy focuses on transitioning to green and low-carbon energy, accelerating emission reductions in critical industries, and enhancing ecological carbon sink capacity. However, challenges remain in further lowering the carbon emission intensity (CEI) [2]. Thus, a pressing issue for China is how to reduce CEI, accelerate emission reductions, and ultimately achieve carbon neutrality.

As a cornerstone of China's strategy to advance comprehensive opening-up and deepen global connectivity, the Belt and Road Initiative (BRI) has, since its launch in 2013, substantially boosted economic collaboration and infrastructure building between China and participating countries [3]. In this process, Chinese cities along the BRI routes



Academic Editor: Maria Rosa Trovato

Received: 12 January 2026

Revised: 20 February 2026

Accepted: 20 February 2026

Published: 4 March 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article

distributed under the terms and

conditions of the [Creative Commons](#)

[Attribution \(CC BY\)](#) license.

have emerged as vital hubs for exporting production capacity and logistics, while also gaining opportunities to reduce their CEI [4]. Figure 1 illustrates a pronounced green transition trend among Chinese BRI cities from 2003 to 2023. This trend is characterized by simultaneous growth in total carbon emissions and economic output alongside a continuous decline in CEI. Specifically, total CO₂ emissions in these cities rose from approximately 951 million tons to 2.459 billion tons, representing an increase of about 159%. Over the same period, aggregate GDP expanded from 4.69 trillion yuan to 44.68 trillion yuan. Despite the increase in absolute emissions, CEI declined steadily throughout. The most notable reduction occurred between 2013 and 2023, when average CEI fell from 0.97 to 0.55, marking a decrease of 43.3%. This phase of accelerated decarbonization closely aligns with the BRI's implementation timeline.

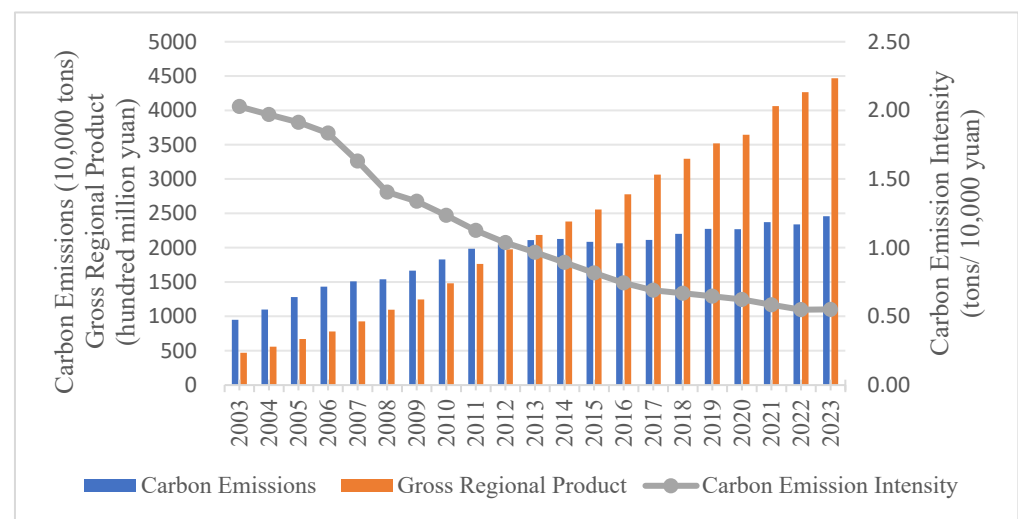


Figure 1. Carbon emission intensity in cities along the route in China, 2003–2023. (Source: EDGAR database, China City Statistical Yearbook).

With the continued evolution of global climate governance, CEI has emerged as a critical research focus in environmental economics and sustainable development, with a steadily expanding body of literature. The Environmental Kuznets Curve (EKC), introduced by Grossman and Krueger (1995) [5], posits that with economic advancement, environmental degradation follows an initial upward trajectory which later reverses, resulting in the characteristic inverted U-shaped curve. This hypothesis thus establishes a foundational analytical framework, which guides and structures the subsequent investigation into the dynamic relationship between CEI and economic growth. Subsequent empirical studies have identified multiple factors influencing CEI, including industrial structure evolution [6], energy mix [7], technological innovation [8], and trade integration into global value chains [9]. A substantial and expanding literature is specifically dedicated to examining CEI trends in China. Research indicates that China has achieved a consistent decline in CEI since 2005, reflecting overall improvements in energy efficiency and industrial structure [10]. However, significant regional disparities in CEI persist across the country [11]. Eastern coastal regions have demonstrated faster reductions, largely driven by industrial upgrading and green innovation capabilities. In contrast, central and western regions continue to experience higher CEI levels, constrained by industrial relocation, resource endowment, and energy structure limitations [12]. Moreover, the spatial distribution of CEI across Chinese cities exhibits significant clustering effects. Cities with high CEI tend to cluster geographically, forming typical “high-high” agglomeration patterns [13].

Since the launch of the BRI, economic exchanges among participating countries have intensified. This has stimulated industrial transfer and driven rapid economic growth in these nations [14]. Against this backdrop, a growing literature examines the environmental effects of the Initiative in host countries, giving rise to a persistent global academic debate. The discourse is primarily structured around the competing frameworks of the “Pollution Haven Hypothesis” and the “Pollution Halo Hypothesis.” On the one hand, scholars aligned with the Pollution Haven Hypothesis contend that the BRI exacerbates environmental pollution in participating countries [15], an effect argued to be especially acute within energy-intensive industries like power generation and large-scale construction [16]. This is particularly concerning given that infrastructure projects along the BRI routes often involve heavy reliance on carbon-intensive materials such as cement and steel during construction, as well as on fossil-fuel-powered machinery, which can generate substantial embodied carbon emissions. On the other hand, proponents of the Pollution Halo Hypothesis posit that the BRI contributes to lower carbon emissions and enhanced environmental quality in host nations. They further argue that mechanisms such as green technology diffusion and policy coordination under the Initiative can enhance green total factor productivity, ultimately strengthening the capacity for a low-carbon transition in these economies [17].

Empirical research on the domestic environmental effects of the BRI has primarily focused on environmental issues confronting provinces and firms along its routes within China. Most studies utilize the difference-in-differences (DID) methodology, and their collective findings support the conclusion that the BRI fosters green and sustainable development in the affected regions and corporations [18]. At the provincial level, Liu & Xin (2019) [19] applied a fuzzy regression discontinuity design to provincial data. Their analysis demonstrates that the BRI significantly boosted both green total factor productivity and technological advancement in major participating provinces. Regarding firm-level impacts, Cao et al. (2022) [20] documented significant reductions in environmental pollution among Chinese firms. Similarly, drawing on data from Chinese A-share listed manufacturing firms, Cao et al. (2023) [21] showed that the BRI notably promotes corporate green transformation and upgrading.

Existing research on the domestic environmental effects of the BRI has primarily focused on environmental issues at the provincial and firm levels within China, such as pollution emissions and resource consumption, often employing empirical methods like difference-in-differences or spatial econometric models. However, systematic quantitative analysis of its impact on urban CEI remains insufficient, despite cities serving as key spatial units for policy implementation and carbon emissions. This suggests that while progress has been made at the provincial and firm levels within China, attention to the urban dimension remains limited. As a result, our understanding of the BRI’s carbon reduction effects and the underlying mechanisms at the city scale remains incomplete.

To address this gap, this study makes three key contributions to fill this void. First, it offers a systematic, city-level analysis of the BRI’s impact on CEI along its routes, thereby providing granular evidence that is currently absent in the literature. Second, drawing on sustainable transition theories, this study aims to identify and empirically examine how the BRI influences urban CEI. It does so by testing three specific pathways including the promotion of industrial structure optimization, the reduction of energy intensity, and the alleviation of market fragmentation, thereby clarifying the specific channels through which emission reductions occur. Third, recognizing the pivotal role of policy context, it incorporates government intervention as a moderator, revealing how varying degrees of state support or regulation condition the BRI’s environmental effects. This nuanced perspective deepens our understanding of the institutional factors that enable or constrain green transition within large-scale development initiatives.

The organization of this paper is as follows: Section 2 (Theoretical Analysis and Research Hypothesis); Section 3 (Methodology and Data); Section 4 (Results and Analysis); Section 5 (Heterogeneity Analysis); Section 6 (Discussion); and Section 7 (Conclusions and Policy Implications).

2. Theoretical Analysis and Research Hypothesis

2.1. Influence Direction of the BRI on CEI

While the BRI is not a traditional environmental regulation policy, its vision of a “Green Silk Road” and its mechanisms for promoting international cooperation and competition create policy incentives with a “quasi-regulatory effect”. These incentives facilitate economic integration and technological exchange among participating countries. Through this process, Chinese cities along the BRI routes gain enhanced access to international advanced clean and efficient energy technologies. Notable examples include the large-scale deployment of renewable energy sources like solar and wind, alongside energy-saving technologies in industrial sectors [22]. This technological transfer directly reduces energy consumption and carbon emissions in production processes. Furthermore, it generates technology spillover effects that stimulate green innovation among local firms, fostering the emergence of competitive green technologies and industries [23]. Additionally, the green development principles advocated by the BRI have established a clear policy orientation, which has prompted municipal governments along the routes to prioritize environmental governance. However, against the backdrop of divergent objectives between central and local governments, local authorities often face dual pressures between economic growth and environmental protection. Drawing on principal–agent theory, we argue that under promotion incentives centered on GDP growth, local officials may strategically relax environmental regulations when implementing BRI projects. This perspective sheds light on the underlying central–local conflicts of interest that shape the effectiveness of the BRI’s quasi-regulatory effect, and highlights the critical role of government moderation in determining environmental outcomes. Relevant government agencies have strengthened carbon emission control systems through stricter emission standards and market-based mechanisms such as emissions trading systems [24]. These measures compel enterprises to pursue green transformation and reduce their CEI. Ultimately, this dual-driver of technology and institutional reform enables these cities to diverge from the conventional “pollute first, clean up later” development model. They achieve a decoupling of carbon emissions from economic growth, creating mutual environmental and economic benefits. Accordingly, we hypothesize:

Hypothesis 1: *The BRI reduces CEI in Chinese cities along the routes.*

2.2. Mechanisms of the BRI’s Impact on CEI

Guided by classic theoretical frameworks such as the Environmental Kuznets Curve and the Pollution Halo Hypothesis, this study develops its research hypotheses to analyze how the BRI influences CEI in regions along its routes.

2.2.1. The Role of Promoting Industrial Structure Optimization

In terms of industrial structure optimization, the BRI creates important opportunities for such upgrading in Chinese cities along its routes by deepening economic cooperation and outward investment with partner countries. The initiative provides a vast overseas market for traditional competitive industries, facilitating the orderly transfer of production capacity abroad and freeing up essential factor resources in domestic cities. This process creates space for cultivating and developing high-tech industries and modern services,

thereby directly promoting industrial structure optimization [25]. Such structure transformation directly suppresses local CEI while generating significant spatial spillover effects to surrounding areas through technology diffusion and industrial linkages, promoting regional synergistic emission reduction [26]. These effects are particularly pronounced in energy-intensive sectors, as they are key sources of carbon emissions. Specifically, structure optimization in energy-intensive industries can directly and substantially reduce local CEI. Moreover, the green technologies, standards, and management models developed in these sectors can drive synchronous transformation in neighboring regions through supply chain requirements and demonstration effects, ultimately achieving systematic CEI reduction at a regional scale. Accordingly, we hypothesize:

Hypothesis 2.1: *The BRI helps reduce CEI in Chinese cities along its routes by promoting industrial structure optimization.*

2.2.2. The Role of Lowering Energy Intensity

The environmental outcomes of the BRI's quasi-regulatory effect are theoretically uncertain. On one hand, it may facilitate green technology transfer; on the other hand, it may exacerbate carbon lock-in or trigger pollution haven effects, depending on local institutional contexts and implementation modalities. Focusing specifically on energy intensity, the BRI creates favorable conditions for lowering energy intensity in Chinese cities along its routes through international patent transfers, joint R&D programs, and other cooperative mechanisms. These efforts facilitate the translation of clean energy and high-efficiency equipment innovations into practical productivity. The core logic is that the BRI serves as an open cooperation platform that promotes the dissemination and application of green innovation outcomes, thereby lowering energy intensity [27]. Crucially, reducing energy consumption intensity is key to lowering the CEI of cities along the BRI routes. According to the Kaya identity, a decrease in energy intensity is directly linked to a decline in CEI, provided the energy structure remains constant or improves. Essentially, lowering energy intensity enhances the efficiency of converting energy into economic value, resulting in less energy input and lower carbon intensity, which consequently drives down CEI [28]. Empirical evidence demonstrates a particularly strong influence on the green transformation of Chinese cities along the BRI routes [29]. Following the relocation of energy-intensive industries and the accelerated adoption of clean energy, these cities have witnessed a marked reduction in energy intensity, effectively alleviating local carbon emission pressures and reducing CEI. This provides a viable pathway for urban green transformation along the routes. Accordingly, we hypothesize:

Hypothesis 2.2: *The BRI helps reduce CEI in Chinese cities along its routes by lowering energy intensity.*

2.2.3. The Role of Alleviating Market Fragmentation

From the perspective of alleviating market fragmentation, the BRI promotes infrastructure connectivity. This effectively breaks down domestic market segmentation and lowers inter-regional transaction costs, thereby enabling a more efficient allocation of production factors across broader geographical areas and reshaping China's economic geography [30]. Simultaneously, China's engagement with international rules generates an institutional learning effect that drives the domestic regulatory system toward greater standardization and coordination, progressively addressing the institutional transaction costs associated with administrative fragmentation [31]. These combined institutional and structural changes systematically elevate the level of market integration in China. Building on this enhanced integration, market integration provides an efficient pathway for cities along the BRI routes to achieve high-quality development and reduce CEI, which is

manifested in two key aspects: reshaping industrial specialization to promote low-carbon production [32] and optimizing resource allocation to channel factors toward green innovation [33]. Thus, market integration not only reshapes regional economic spatial structures but also, by incentivizing green innovation and low-carbon specialization, offers an endogenous, sustainable, and systemic driver for the low-carbon transition of cities along the Belt and Road. Accordingly, we hypothesize:

Hypothesis 2.3: *The BRI helps reduce CEI in Chinese cities along its routes by alleviating market fragmentation.*

2.3. Moderating Effect of BRI on CEI

Government intervention exerts a significant positive moderating effect on the impact of the BRI on the carbon emission intensity of Chinese cities along its routes. In this study, government intervention is defined as the capacity of local governments to guide regional economic activities and enforce environmental regulations through the allocation of fiscal resources and the use of policy instruments. This moderating effect operates through a hybrid governance system that integrates both constraining and incentivizing mechanisms. Drawing on the Porter Hypothesis, such intervention employs unified environmental standards, enhanced carbon disclosure, and stringent supervision to transform environmental compliance pressure into a driver for corporate green innovation [34]. Concurrently, grounded in Endogenous Growth Theory, targeted resources including green finance and R&D subsidies effectively reduce the costs and risks of low-carbon technology development [35]. This process embeds green growth within the BRI's broader progress. Collectively, these mechanisms generate a dual-track dynamic that couples regulation-induced innovation with resource-enabled growth.

Moreover, the impact of government intervention is amplified through the lens of Institutional Theory [36]. In line with this theory, the government integrates carbon reduction targets into project evaluation and policy assessment systems, while constructing a comprehensive governance framework that combines information disclosure, green finance, and rigorous oversight. This systematically reshapes the developmental logic and behavioral patterns of local governments and enterprises.

In conclusion, moderate government intervention not only corrects market failures in low-carbon investment and ensures policy coherence but also, through a multi-theoretical governance approach, steers the BRI from a traditional infrastructure-oriented model toward a green development paradigm. Such systematic intervention enables the simultaneous advancement of economic growth and carbon reduction objectives, thereby institutionalizing the BRI's role in consistently lowering the carbon emission intensity of cities along its corridors. Accordingly, we hypothesize:

Hypothesis 3: *The BRI contributes to lowering CEI in Chinese cities along the routes through the positive moderating role of government intervention.*

Figure 2 shows the study's theoretical framework, which incorporates the established assumptions.

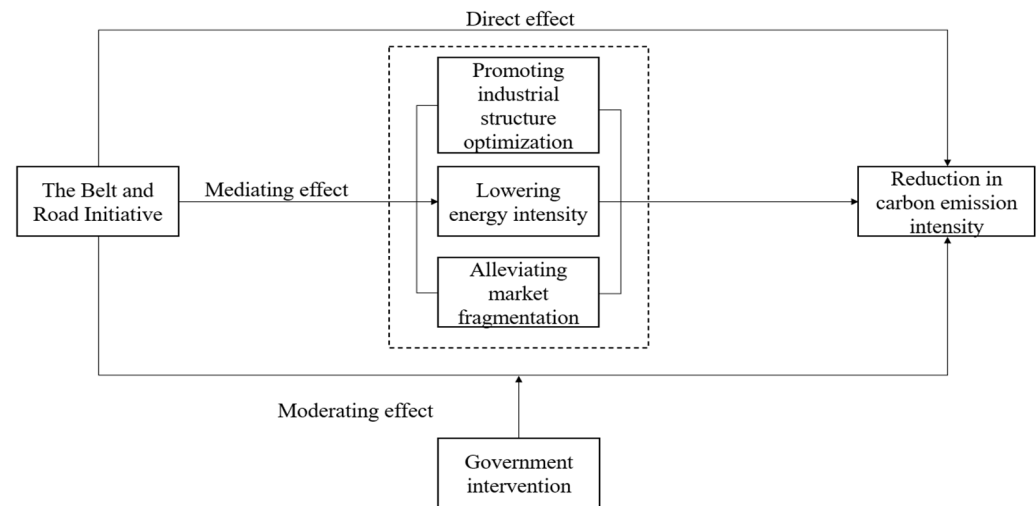


Figure 2. Theoretical framework.

3. Methodology and Data

3.1. Empirical Methodology

Based on the policy document *Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road* and the approach of Lu et al. (2021) [37], we designate 37 key BRI cities as the treatment group. These include 8 cities in the north-west and northeast, 7 inland cities, 3 in the southwest, and 19 along the eastern coast. Cities outside the BRI network serve as the control group. The DID model is specified in Equations (1) and (2):

$$CEI_{it} = \alpha_0 + \alpha_1 \times DID_{it} + \sum_{k=1}^n \alpha_k \times X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

$$DID_{it} = Time_t \times Treated_i \quad (2)$$

where i represents cities and t indexes time periods; CEI_{it} represents the carbon emission intensity; α_1 captures the average treatment effect of the BRI on CEI in route cities; X_{it} represents a vector of control variables. λ_i and μ_t respectively denotes city fixed effects and year fixed effects; and ε_{it} is the idiosyncratic error term.

The preceding theoretical analysis suggests that $Medium_{it}$ as a mediating channel through which the BRI influences CEI in route cities. To empirically examine this transmission mechanism, a stepwise mediation approach is implemented, as specified in Equations (3)–(5).

$$Medium_{it} = \beta_0 + \beta_1 DID_{it} + \sum_{k=1}^n \beta_k X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (3)$$

$$CEI_{it} = \gamma_0 + \gamma_1 Medium_{it} + \sum_{k=1}^n \gamma_k X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (4)$$

$$CEI_{it} = \eta_0 + \eta_1 DID_{it} + \eta_2 Medium_{it} + \sum_{K=1}^n \eta_K X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (5)$$

In the above model, the mediator variable includes industrial structure optimization, energy intensity, and market segmentation.

As government intervention potentially moderates the relationship between the BRI and CEI, an interaction term between the DID and government intervention is incorporated. Thus, the subsequent model is more precisely defined in Equation (6) as:

$$CEI_{it} = \theta_0 + \theta_1 DID_{it} + \theta_2 Gov_{it} + \theta_3 DID \times Gov_{it} + \sum_{k=1}^n \theta_k X_{it} + \lambda_i + \mu_t + \varepsilon_{it} \quad (6)$$

Among them, government intervention (Gov) serves as a moderating variable.

3.2. Variables and Data

3.2.1. Explained Variable: The CEI in Cities Along the Route in China (CEI)

The dependent variable is carbon emission intensity in Chinese cities along the Belt and Road routes, calculated as total city-level carbon emissions divided by gross regional product [38]. This widely adopted indicator captures carbon output per unit of economic activity and thus serves as a key metric for assessing low-carbon transition efficiency and green development performance at the regional scale.

3.2.2. Core Explanatory Variable: The BRI $\times$ Post Interaction Term (DID)

Following Chingiz et al. (2025) [39], this study defines 2013 as the starting year of policy implementation. Cities are assigned to the treatment group if they are designated as core or important nodes along the BRI routes. The DID term is constructed through the following steps. First, we create a group dummy variable, which is assigned a value of 1 if a city is located along the BRI routes, and 0 otherwise. Second, we define a time dummy variable, which takes the value of 1 for the years from 2013 onward and 0 for previous years. The core explanatory variable is the interaction term between these two dummy variables, which represents the DID estimator. This term captures the average treatment effect of the BRI on the treated group.

3.2.3. Mediating Variables

To measure key mechanisms, the following variables are constructed. First, industrial structure optimization (Stru) is measured by the tertiary-to-secondary sector value-added ratio [40]. Second, energy intensity (Ei) is defined as the ratio of total energy consumption to regional GDP [41]. Finally, market fragmentation (Fg) is proxied inversely by wholesale and retail sales over GDP, where lower values indicate greater market segmentation [42].

3.2.4. Moderating Variable

Government intervention (Gov) is constructed to quantify the governance role of local governments in green development under the BRI. Drawing on the classic approach in public economics and institutional analysis for measuring government size, we use the ratio of total local fiscal expenditure to local GDP as the measure [43]. This ratio not only reflects the fiscal capacity of local governments to mobilize and allocate resources, but also directly captures the depth of their involvement in and regulation of regional economic activity. It thus serves as a key proxy for institutional driving forces.

3.2.5. Control Variables

To control for potential confounding factors, several variables are included. Population density (Poden) is defined as the number of people per unit of land area, measured in persons per square kilometer, and is transformed using the natural logarithm to address skewness. Openness (Open) is captured by the ratio of actually utilized foreign capital to regional GDP, with foreign capital originally reported in U.S. dollars converted to RMB using the annual average exchange rate. Education expenditure (Edu) represents the share

of fiscal spending allocated to education, calculated as the ratio of educational expenditure to total government budgetary expenditure. Science and technology support (Scien) is given by the ratio of government R&D expenditure to total government budgetary expenditure. Human capital (Hum) is approximated by the share of the number of higher education students in the total population. Mobile phone penetration (Cell) is defined as mobile phones per capita. Financial development (Finc) is proxied by the credit-to-GDP ratio, defined as total loans extended by financial institutions relative to regional GDP.

3.2.6. Data Sources

Data are drawn primarily from the EDGAR database, along with several Chinese statistical yearbooks: *the China Statistical Yearbook*, *China City Statistical Yearbook*, *China Statistical Yearbook on Science and Technology*, *China Energy Statistical Yearbook*, *China Industrial Statistical Yearbook*, and *China Environmental Statistical Yearbook*. Based on panel data from 282 prefecture-level cities in China over the period 2003–2023, missing values were imputed using linear interpolation. To ensure data quality, cities with missing energy consumption data for three or more consecutive years were excluded from the sample. In addition, annual fluctuations exceeding $\pm 50\%$ were individually cross-checked against the original statistical yearbooks to rule out potential changes in statistical reporting standards or data entry errors. Descriptive statistics for all variables are presented in Table 1.

Table 1. Descriptive statistics of main variables.

Variable	Observations	Mean	Standard Deviation	Min	Max
CEI	5922	2.514	2.499	0.074	28.120
DID	5922	0.069	0.253	0.000	1.000
Stru	5922	0.997	0.568	0.094	4.387
Ei	5922	0.261	0.376	0.015	5.196
Fg	5922	0.393	0.410	0.000	1.720
Gov	5922	0.173	0.094	0.031	0.716
Poden	5922	5.734	0.928	1.547	8.176
Open	5922	0.026	0.029	0.000	0.156
Edu	5922	0.181	0.046	0.015	0.292
Scien	5922	0.024	0.016	0.005	0.071
Hum	5922	0.025	0.014	0.006	0.143
Cell	5922	0.878	0.779	0.020	1.671
Finc	5922	0.978	0.635	0.081	4.827

4. Results and Analysis

4.1. Baseline Regression Results

This study utilizes a difference-in-differences model to assess the effect of the BRI on CEI in Chinese cities along the route. Table 2 reports the estimation results. With the full set of controls, we focus on column (4). The DID coefficient is -0.5068 and remains statistically significant at the 1% level after controlling for relevant variables, city fixed effects, and year fixed effects. This indicates that the BRI has significantly reduced CEI in participating cities, supporting Hypothesis 1. Given the substantial scale of economic activity across BRI cities, this reduction carries meaningful economic implications and contributes to China's Dual Carbon Goals. Our findings are corroborated by recent research on the environmental

effects of the BRI. Using evidence from East African countries, Dusengemungu et al. (2023) [44] argued that BRI cooperation generates substantial environmental benefits and promotes green and sustainable development in partner nations. Focusing on Chinese cities, Zhang et al. (2023) [45] further confirmed that the BRI effectively lowers carbon emission intensity along the route. The consistency between our results and evidence from both domestic and international contexts underscores the BRI's role as a dual-purpose platform for economic cooperation and environmental governance.

Table 2. Impacts of the BRI on CEI.

Variable	(1)	(2)	(3)	(4)
	CEI	CEI	CEI	CEI
DID	−1.6785 *** (0.1716)	−0.7691 *** (0.0889)	−0.9075 *** (0.1643)	−0.5068 *** (0.1934)
Poden		−0.3042 *** (0.0710)		−3.9875 *** (0.1731)
Open		−0.5692 *** (0.0727)		−0.4208 *** (0.0787)
Edu		−1.5874 ** (0.6832)		−0.4126 ** (0.2037)
Scien		−0.1471 *** (0.0497)		−0.5201 *** (0.0404)
Hum		0.4176 ** (0.1736)		1.7148 ** (0.6777)
Cell		−0.5085 *** (0.0942)		−0.2084 ** (0.0966)
Finc		0.5184 *** (0.0946)		0.1661 * (0.0949)
Cons	2.6294 *** (0.1248)	4.6392 *** (0.8553)	2.5764 *** (0.1235)	4.9039 *** (0.8586)
Year FE	NO	NO	YES	YES
City FE	NO	NO	YES	YES
N	5922	5922	5922	5922
R ²	0.029	0.139	0.171	0.225

Note: Parentheses contain city-clustered robust standard errors; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Turning to the control variables, several noteworthy patterns emerge. Population density (Poden) is significantly negatively associated with CEI, indicating that higher population density enhances public transit efficiency and resource sharing, thereby lowering per capita energy consumption [46]. Likewise, the coefficient of openness (Open) is also significantly negative, suggesting that greater openness promotes the adoption of energy-saving technologies and industrial structure upgrades, ultimately leading to lower unit output emissions [47]. The negative coefficient on education expenditure (Edu) implies that such educational investment strengthens the innovation capacity of the workforce, supplying the human capital essential for clean production [48]. Similarly, the coefficient for scientific expenditure (Scien) is negatively associated with CEI, as R&D expenditure promotes green innovation and energy structure optimization [49]. Human capital (Hum) displays a positive coefficient, potentially reflecting that higher human capital facilitates energy-intensive industrial upgrading in the short term [50]. Mobile phone penetration (Cell) is negatively correlated with carbon intensity, primarily through information diffu-

sion, remote work adoption, and smart city applications that reduce energy demand [51]. Financial development (Fin) shows a positive relationship with carbon intensity, possibly because financial deepening stimulates investment and industrial expansion, thereby raising aggregate energy consumption [52].

4.2. Robustness Tests

4.2.1. Parallel Trend Test

When evaluating the environmental impact of BRI, the DID model relies on the parallel trends assumption, which necessitates that treatment and control groups exhibit comparable trajectories before the policy implementation. To test this assumption, this study examines the dynamic effects of the BRI on CEI within a five-year window around its implementation. As shown in Figure 3, the pre-treatment period coefficients are statistically insignificant for all years prior to 2013, thereby supporting the parallel trends assumption. After 2013, however, the estimated coefficients become significantly negative, with their magnitudes increasing over time. This pattern suggests that the emission-reduction effect of the BRI is not instantaneous but rather materializes gradually and strengthens as the initiative deepens. The widening gap between treated and control cities in the post-treatment period further implies cumulative policy gains, highlighting the sustained role of the BRI in fostering low-carbon urban development along its routes.

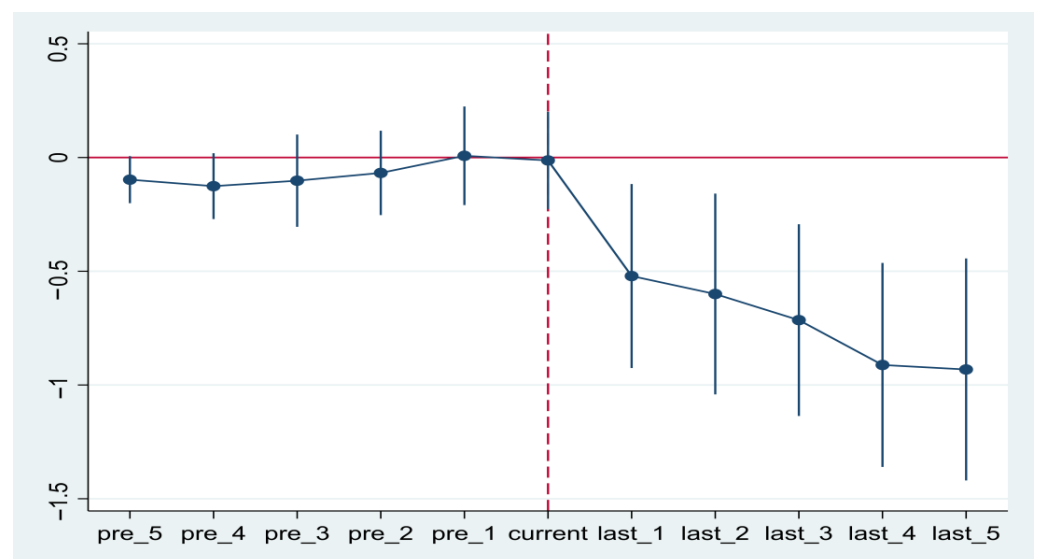


Figure 3. Results of the parallel trend test.

4.2.2. Placebo Test

To rule out the influence of omitted variables or random disturbances, this study conducts a placebo test following Ferrara et al. (2012) [53]. Specifically, we randomly assigned placebo treatment status and hypothetical implementation years to cities unaffected by the BRI, re-estimating the baseline model for each iteration. As shown in Figure 4, the distribution of placebo coefficients is tightly centered around zero and exhibits no systematic bias, indicating that random shocks do not confound our baseline estimates. The concentration of placebo estimates near zero, combined with the absence of any significant outliers, confirms that the observed emission reductions are attributable to the BRI itself rather than to coincidental factors or model misspecification. These findings reinforce the causal interpretation of our main results.

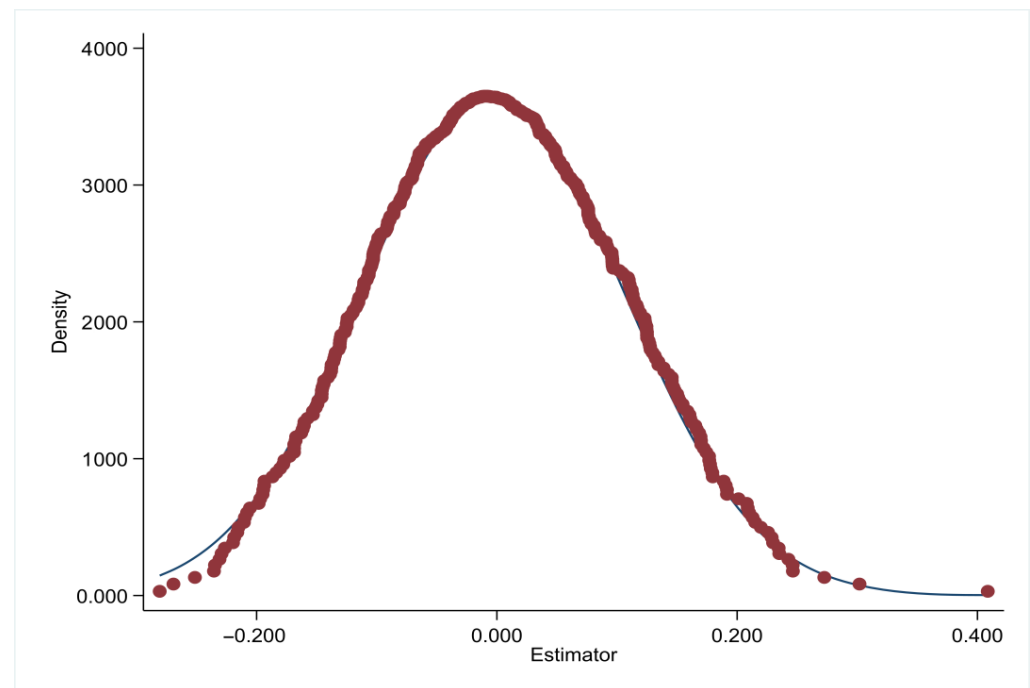


Figure 4. Results of the placebo test.

4.2.3. Excluding Interference from Other Policies

Several concurrent policies could confound the estimated effect of the BRI. For instance, China launched the New Energy Demonstration City (NEDC) initiative in 2014 under its 12th Five-Year Plan for renewable energy. The pilot Carbon Emissions Trading Scheme (ETS) was also implemented during this period to facilitate regional low-carbon transitions. Meanwhile, three waves of the Low-Carbon City Pilot (LCCP) policy were introduced between 2010 and 2017 to advance market-based decarbonization. To isolate the distinct effect of the BRI from these overlapping initiatives, this study includes policy dummy variables for each intervention. As shown in Table 3, columns (1) to (3) control for the NEDC, pilot ETS, and LCCP policies, respectively, while column (4) incorporates all three simultaneously. The DID coefficient remains significantly negative across all specifications, confirming that the BRI consistently reduces CEI in participating cities. These results reaffirm the robustness of the baseline findings.

Table 3. Results of excluding interference from other policies.

Variable	(1)	(2)	(3)	(4)
	NEDC	Pilot ETS	LCCP	Three Policies
DID	−0.5074 *** (0.1955)	−0.4932 ** (0.1958)	−0.4941 *** (0.1914)	−0.4889 ** (0.1963)
Treated × NEDC	−0.0128 (0.1794)			−0.0168 (0.1826)
Treated × ETS		−0.0977 (0.2079)		−0.0553 (0.1960)
Treated × LCCP			−0.0923 (0.1702)	−0.0794 (0.1664)
Cons	4.9046 *** (0.8602)	4.8904 *** (0.8620)	4.9241 *** (0.8641)	4.9146 *** (0.8740)

Table 3. *Cont.*

Variable	(1)	(2)	(3)	(4)
	NEDC	Pilot ETS	LCCP	Three Policies
Control	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES
N	5922	5922	5922	5922
R ²	0.225	0.225	0.225	0.225

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2.4. Additional Robustness Tests

First, the PSM-DID method is employed. To effectively mitigate selection bias while controlling for external disturbances, this study combines propensity score matching with DID estimation. Specifically, propensity scores are first calculated using a Logit model and employed to match cities between the intervention and control groups. Regression estimation is then conducted on the matched sample. Second, lagged treatment is introduced. Considering the potential time-lag effect of the BRI on environmental outcomes, a one-period lag is applied to both the core explanatory variable and the control variables. Third, the sample window is restricted to 2007–2019 to avoid interference from structural changes over an extended time horizon. Fourth, observations from 2020 onward are excluded to avoid abnormal fluctuations in economic and social variables during exceptional periods. The results are presented in Table 4. The findings indicate that the core conclusions remain consistent across the multiple robustness tests, thereby reinforcing the credibility of the initial estimates.

Table 4. Results of additional robustness tests.

Variable	(1)	(2)	(3)	(4)
	PSM-DID	A One-Period Lag	Shorten the Time Window	Observations from After 2020
DID	−0.3071 *** (0.1163)	−0.5064 *** (0.1890)	−0.6144 *** (0.2000)	−0.5389 ** (0.2116)
Cons	5.0275 *** (0.5899)	4.6833 *** (0.8205)	3.9571 *** (0.7723)	5.0637 *** (0.9363)
Control	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
City FE	YES	YES	YES	YES
N	4776	5640	3666	5076
R ²	0.354	0.217	0.147	0.207

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.3. Endogeneity Treatment

To mitigate endogeneity, this study employs the instrumental variable approach proposed by Tsoutsoura (2015) [54] within a quasi-natural experiment framework. Specifically, building on Yu et al. (2021) [55], the analysis uses cities located along the ancient Silk Road as an instrument for BRI participation. This selection is justified on two grounds: first, the strong historical and spatial alignment between the ancient Silk Road and the modern BRI ensures the relevance of the instrument; second, the historical nature of the ancient

route satisfies the exogeneity restriction, as it is unlikely to directly influence contemporary carbon emission intensity.

Subsequently, a two-stage least squares estimation is implemented, with results presented in Table 5. In column (1), the interaction ($IV \times Time$) yields a statistically significant and positive effect, thereby indicating that cities with a historical Silk Road heritage were more likely to become core nodes under the BRI. Furthermore, diagnostic tests confirm instrument validity, with the Kleibergen–Paap rk LM statistic significant at the 1% level and the corresponding Wald F statistic well above the threshold of 10, confirming instrument relevance and ruling out weak identification. Column (2) reports a significantly negative coefficient on the DID term, implying that after accounting for endogeneity, the BRI continues to exert a substantial mitigating effect on CEI in treated cities.

Table 5. Results of endogeneity treatment.

Variable	(1)	(2)
	Phase I Regression DID	Phase II Regression CEI
$IV \times Time$	0.1858 *** (0.0670)	
DID		−2.0002 *** (0.6348)
Kleibergen–Paap rk Wald F		140.933
Kleibergen–Paap rk LM		134.736 [0.000]
Control	YES	YES
Year FE	YES	YES
City FE	YES	YES
N	5922	5922

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.4. Mediation Effect Test

To further investigate the mechanisms underlying the BRI's environmental impact, this study explores three potential channels: industrial structure optimization (Stru), energy intensity (Ei), and market fragmentation (Fg). To conduct robust mediation analysis, the Sobel test and Bootstrap mediation tests are employed to account for the non-normality of the sampling distribution.

Columns (1) to (3) in Table 6 report the mediation effects of industrial structure optimization. The estimates indicate a statistically positive coefficient for the DID term in column (1), contrasted by a significantly negative one for the industrial structure optimization (Stru) variable in column (2). In column (3), both coefficients remain significantly negative. This evidence lends support to Hypothesis 2.1, which posits that, in correlational terms, the BRI is linked to reduced urban CEI through industrial optimization. This finding corroborates the mechanism identified in prior studies. Zhang et al. (2023) [45] found that the BRI reduces carbon emissions in cities along the BRI corridor through industrial structure optimization effects. Similarly, Zhou et al. (2023) [56] confirmed that the initiative improves domestic environmental quality via the same channel.

Table 6. Results of mediation effect test.

Variable	(1) Stru	(2) CEI	(3) CEI	(4) Ei	(5) CEI	(6) CEI	(7) Fg	(8) CEI	(9) CEI
DID	0.2037 ** (0.1001)		−0.3198 * (0.1878)	−0.0892 * (0.0479)		−0.3843 ** (0.1932)	0.2696 *** (0.1043)		−0.4894 ** (0.2014)
Stru		−0.9358 *** (0.1996)	−0.9182 *** (0.1975)						
Ei					1.4977 *** (0.2604)	1.4910 *** (0.2594)			
Fg								−0.1268 ** (0.0612)	−0.1646 ** (0.0716)
Cons	0.9964 *** (0.1914)	5.9229 *** (0.9549)	5.8188 *** (0.9579)	1.7651 *** (0.1808)	2.4119 *** (0.9233)	2.3218 ** (0.9188)	−0.3012 *** (0.1093)	4.9952 *** (0.8664)	4.8844 *** (0.8627)
Control	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	5922	5922	5922	5922	5922	5922	5922	5922	5922
R ²	0.369	0.247	0.247	0.395	0.297	0.296	0.442	0.225	0.223

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Columns (4) to (6) of Table 6 demonstrate the mediating role of energy intensity. The significantly negative coefficient on the DID term in column (4), alongside the significantly positive coefficient on Ei in column (5), establishes the preliminary relationships. In column (6), the estimates for the DID term and Ei continue to be significantly negative and positive, respectively. This pattern of results supports the conclusion that there is a correlational pathway through which the BRI is associated with lower CEI in cities along the routes, consistent with lower energy intensity, thereby providing correlational evidence for Hypothesis 2.2. The role of energy efficiency gains identified here aligns with Dong et al. (2017) [57], who highlighted the initiative's role in fostering a cleaner domestic energy structure. Furthermore, Zhang et al. (2025) [58] offer additional evidence, attributing emission reductions to enhanced energy efficiency driven by green infrastructure and technology spillovers along the BRI routes.

The analysis reveals a positive and significant DID estimator in column (7) and a significantly negative coefficient for market segmentation (Fg) in column (8). In column (9), both variables show significantly negative coefficients. These results collectively indicate a correlational pathway wherein the BRI is associated with reduced CEI, potentially through promoting market integration, thus providing correlational support for Hypothesis 2.3. This conclusion reinforces Wang et al. (2024) [59], who argued that the initiative promotes cross-regional factor mobility, which in turn generates economies of scale and optimizes resource allocation. These effects collectively enhance economic efficiency and market integration, ultimately leading to a reduction in CEI.

While the BRI contributes positively to lowering carbon intensity, meeting the 2030 peak and 2060 neutrality targets will require coordinated efforts across multiple policy domains, including energy restructuring, industrial modernization, and regional cooperation.

4.5. Moderating Effect Analysis

To examine whether government intervention moderates the relationship between the BRI and CEI, we conducted a moderation analysis with results presented in Table 7. Columns (1) reports the baseline effect of the BRI on CEI. Column (2) shows the combined effects of the BRI, government intervention, and their interaction term. The significantly negative coefficient on the interaction term indicates that government intervention strengthens the negative effect of the BRI on CEI, thereby supporting Hypothesis 3.

Table 7. Results of moderating effect analysis.

Variable	(1)	(2)
	CEI	CEI
DID	−0.5068 *** (0.1934)	−0.7385 *** (0.2243)
DID × Gov		−3.8376 * (2.0878)
Gov		−1.5764 (1.2145)
Cons	4.9039 *** (0.8586)	5.2197 *** (0.8431)
Control	YES	YES
Year FE	YES	YES
City FE	YES	YES
N	5922	YES
R ²	0.225	0.244

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

According to Sohag et al. (2024) [60], the effectiveness of environmental policies is fundamentally contingent on governmental governance capacity. Strong government intervention thus constitutes a key mechanism for enhancing the carbon emission reduction impact of the BRI, primarily through improved policy enforcement and systemic coordination. In practice, effective governance not only translates macro-level green development strategies into measurable local actions but also integrates diverse objectives such as infrastructure investment, industrial cooperation, and environmental protection. This integrated approach helps overcome the constraints of market spontaneity and policy fragmentation. Therefore, a government with strong intervention and coordination capabilities is crucial for unlocking the full green potential of BRI development, which in turn significantly amplifies its mitigating effect on CEI along the routes.

5. Heterogeneity Analysis

As shown in Figures 5 and 6, the CEI of Chinese cities along the Belt and Road routes exhibited an overall declining trend from 2003 to 2023. However, the extent of reduction and the evolutionary pathways varied noticeably across different regions. This spatial variation implies that the carbon mitigation effect of the BRI may be shaped by region-specific factors, particularly differences in local policy contexts, including the stringency of environmental regulations, the strength of fiscal incentives for green investment, and the degree of policy coordination with central government mandates. To further explore this heterogeneity, we divided the full sample into regional subgroups and conducted a formal heterogeneity analysis.

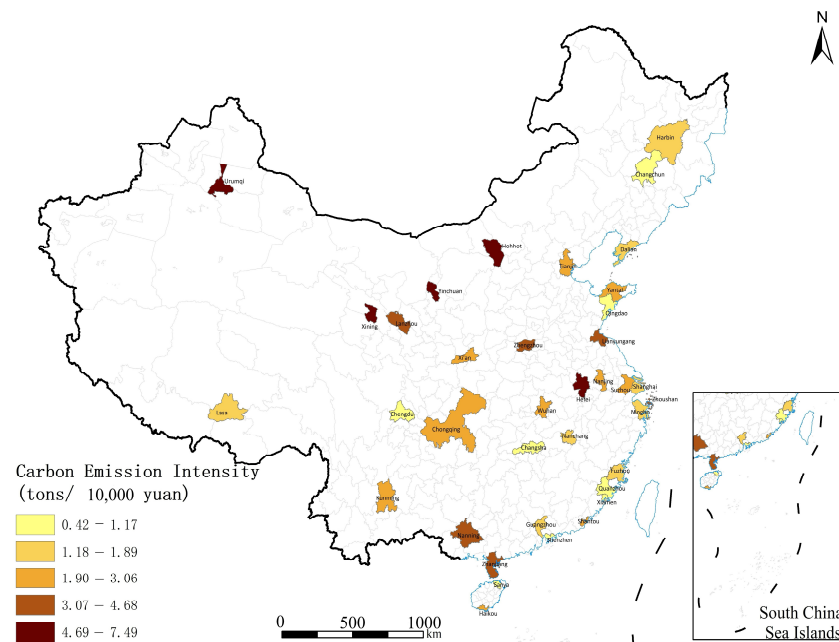


Figure 5. Carbon emission intensity in cities along the route in China, 2003. (Source: EDGAR database, China City Statistical Yearbook 2004).

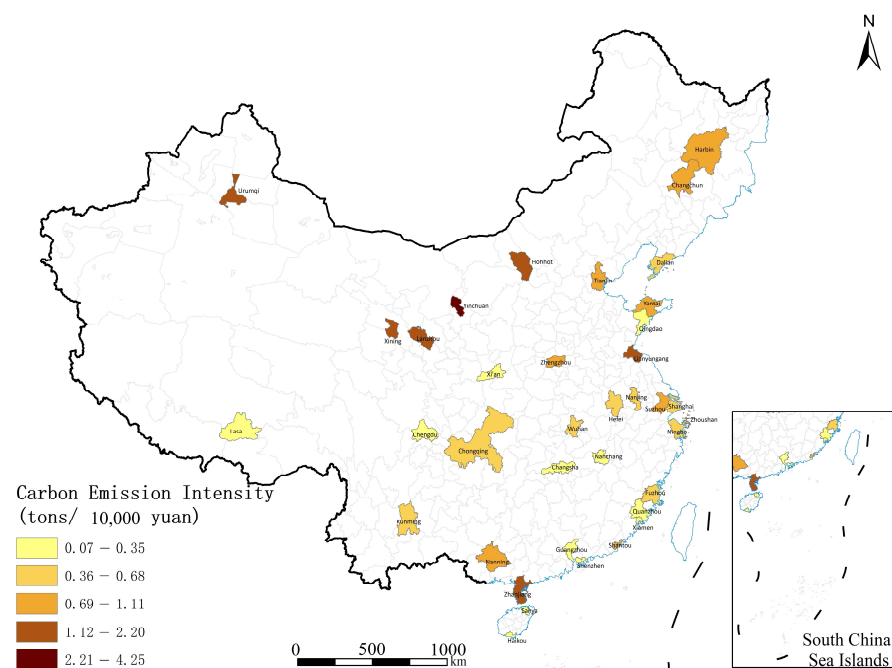


Figure 6. Carbon emission intensity in cities along the route in China, 2023. (Source: EDGAR database, China City Statistical Yearbook 2024).

5.1. Urban Location and Geographic-Economic Conditions

There are systematic differences between eastern and central-western Chinese cities in terms of economic advancement, productive specialization, and technological capabilities. To examine the regional heterogeneity of the BRI's impact on CEI, this study categorizes the sample into eastern and central-western cities based on their distinct development levels. As shown in columns (1) and (2) of Table 8, the Initiative's mitigating effect on CEI is significantly stronger in central-western cities than in eastern ones. This regional disparity can be attributed to the eastern region's stronger economic foundation, more advanced industrial upgrading, and higher levels of green technology innovation [61].

These advantages have enabled the eastern region to achieve a relatively low level of CEI at an earlier stage, leading to diminishing marginal returns in further reductions. In contrast, the central-western regions, which start from a higher baseline, benefit more substantially from infrastructure improvements, industrial restructuring, and the spillover of green technologies facilitated by the Initiative, thus exhibiting a more pronounced reduction effect.

Table 8. Heterogeneity tests.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	Eastern Cities	Central-Western Cities	Key Environmental Protection Cities	Non-Key Environmental Protection Cities	Old Industrial Base Cities	Non-Old Industrial Base Cities	Logistics Hub Cities	Non-Logistics Hub Cities
DID	−0.4445 *** (0.1485)	−1.5297 ** (0.6618)	−1.6365 ** (0.7551)	−0.2663 * (0.1525)	−0.7403 ** (0.3640)	−0.4029 * (0.2139)	−0.3120 * (0.1799)	−1.5347 *** (0.4982)
Cons	3.9812 *** (0.7215)	3.4348 ** (1.6294)	4.5690 *** (1.1557)	3.5444 *** (1.3294)	4.4758 *** (1.5408)	4.7341 *** (1.1855)	3.5384 *** (0.9411)	3.2181 *** (0.6704)
Control	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
City FE	YES	YES	YES	YES	YES	YES	YES	YES
N	2520	3402	2373	3549	2520	3402	1491	4431
R ²	0.308	0.215	0.360	0.201	0.254	0.210	0.250	0.194

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.2. Environmental Protection Stringency

In accordance with the classification outlined in the National Environmental Protection “Eleventh Five-Year Plan,” this study divides the sample into key environmental protection cities and non-key environmental protection cities for subgroup analysis. The results in columns (3) and (4) of Table 8 show that the BRI demonstrates a greater carbon-reducing effect in key environmental protection cities, suggesting that regions with a more established environmental governance framework can more effectively leverage policy benefits. This is primarily because prioritized cities possess more developed infrastructure and higher environmental standards, accelerating the adoption and diffusion of green technologies, clean energy, and external investments [62]. In addition, these cities tend to have stronger institutional enforcement, public oversight, and corporate environmental awareness. These factors collectively further the fulfillment of the BRI’s green goals, resulting in more pronounced reductions in CEI.

5.3. Industrial Foundation

Drawing on the classification from China’s National Plan for the Adjustment and Renovation of Old Industrial Bases, this study divides the sample cities into old industrial base cities and non-old industrial base cities for subgroup analysis. The estimates in columns (5) and (6) of Table 8 show that the BRI significantly reduced CEI in both city groups, with the decrease being more pronounced in old industrial base cities. This indicates that the policy yields greater environmental benefits in regions characterized by heavier industrial structures and stronger transformation pressures. Non-old industrial base cities generally feature lighter industrial structures and higher energy efficiency; consequently, further emission reductions depend more on green innovation and institutional improvements, which limit the marginal policy effect. In contrast, old industrial base cities are constrained by long-term path dependence on heavy industry and high-carbon lock-in. The BRI, how-

ever, facilitates green investments, international capacity cooperation, and technology transfer. These initiatives help integrate domestic and foreign resources, optimize energy structures, and improve production efficiency, thereby leading to more substantial carbon reduction outcomes.

5.4. Logistics Hub Function

Following the National Plan for the Layout and Construction of Logistics Hubs, this study conducts a sub-sample analysis by dividing cities into logistics hub cities and non-logistics hub cities. The estimates in columns (7) and (8) of Table 8 show that the BRI has a significantly weaker carbon-reduction effect in logistics hub cities than in non-logistics hub cities. This difference can be explained by institutional lock-in and the resource curse hypothesis. Logistics hub cities have long relied on high-carbon transportation and warehousing industries, creating path dependence at both technological and institutional levels. The accumulation of specialized assets and the rigidity of their industrial structures not only increase transformation costs but also diminish incentives for green governance. As a result, these cities exhibit slower responses to informal environmental regulations, such as the social credit system, which reduces the effectiveness of carbon reduction policies.

6. Discussion

This study provides robust empirical evidence that the BRI significantly reduces CEI in participating Chinese cities, offering valuable insights into the environmental implications of large-scale development strategies. Treating the BRI as a quasi-natural experiment, our findings reveal that the initiative's impact on CEI is not only statistically significant but also economically meaningful, with effects that strengthen over time. This pattern aligns with the gradual deepening of policy implementation and infrastructure connectivity.

The mechanism analysis helps explain how the BRI influences urban CEI. We identify three distinct yet interconnected pathways, namely industrial structure optimization, energy intensity reduction, and market integration. This finding suggests that the environmental benefits of the BRI are not incidental but are embedded in its core design of fostering economic transformation and regional coordination. Notably, these mechanisms operate synergistically. Industrial structure optimization reallocates resources toward less carbon-intensive sectors. Reduced energy intensity reflects efficiency gains from technological progress, while market integration facilitates the reallocation of resources toward cleaner production. Among these, energy intensity reduction emerges as a particularly salient channel, underscoring the importance of technology diffusion and energy efficiency improvements as key drivers of low-carbon transition under the BRI framework.

The moderating role of government intervention adds another layer of complexity to our understanding. The finding that government intervention amplifies the BRI's carbon-reducing effect underscores the critical function of public policy in steering large-scale initiatives toward sustainable outcomes. This result resonates with the institutional economics literature, which emphasizes that market-based mechanisms alone are insufficient to correct environmental externalities, particularly in the context of infrastructure-led development. The positive moderation effect suggests that proactive fiscal policies, regulatory oversight, and strategic allocation of resources by local governments can effectively reinforce the environmental dividends of the BRI.

The heterogeneity analysis reveals several noteworthy patterns. The pronounced effect in central-western cities results from substantial gains from infrastructure improvements, industrial restructuring, and green technology spillovers facilitated by the BRI. In key environmental protection cities, the amplified effect indicates that pre-existing regulatory stringency creates a conducive environment for leveraging the BRI's green opportunities,

suggesting complementarity rather than trade-off between environmental regulation and development initiatives. The significant reductions observed in old industrial base cities are particularly encouraging, as these regions have historically struggled with carbon lock-in and structural rigidities. This finding implies that the BRI may serve as a catalyst for breaking path dependence and facilitating green transformation in traditionally high-carbon regions. The stronger effect in non-logistics hub cities also warrants attention, as it may reflect a latecomer advantage whereby these cities bypass carbon-intensive development stages by directly adopting cleaner technologies and practices facilitated by the BRI.

Regarding the replicability of the BRI experience in other developing regions, our findings suggest a more nuanced interpretation. The marked heterogeneity observed across Chinese regions with varying institutional capacities, industrial structures, and development stages implies that successful application abroad requires deep contextual adaptation rather than mechanical transplantation. The environmental effectiveness of the BRI in host countries likely depends critically on their institutional endowments, governance quality, and stage of development. This perspective aligns with the growing consensus in development economics that institutional compatibility and local ownership are essential determinants of policy effectiveness in cross-country settings.

Despite its contributions, this study has several limitations that warrant consideration. First, data constraints may introduce measurement errors in city-level energy statistics, and the use of linear interpolation to impute missing values could artificially smooth the data and potentially overstate model fit. Limited data availability also prevented us from examining several potentially important mechanisms, including green technology spillovers, R&D investment, and heterogeneity related to digitalization. Second, from a methodological perspective, although we conducted parallel trend and placebo tests, the possibility of unobserved time-varying confounders cannot be entirely dismissed, and serial correlation may persist in long panels. Our instrumental variable—historical Silk Road status—likely falls short of satisfying the exclusion restriction, as historical factors may exert a direct influence on current environmental outcomes through persistent channels. Furthermore, the mediation analysis captures associational rather than causal relationships, given the strong and untestable assumptions it entails. Third, the analysis is limited to Chinese prefecture-level cities, which constrains the generalizability of our findings to other institutional settings along the broader Belt and Road region. Future research should seek to address these limitations by leveraging richer datasets, more robust identification strategies, and cross-country comparative designs.

7. Conclusions and Policy Implications

7.1. Conclusions

The BRI presents new opportunities for China's low-carbon transition. Treating the BRI as a quasi-natural experiment, this study employs a DID model using panel data from 282 Chinese cities over the period 2003–2023 to systematically examine the initiative's impact on CEI of cities along the routes. The main findings are as follows: (1) The BRI significantly reduces CEI in cities along its routes, a conclusion that withstands a comprehensive battery of robustness and endogeneity tests. (2) The results of the mechanism analysis indicate that the BRI lowers CEI through three channels: industrial structure optimization, energy intensity reduction, and enhanced market integration. (3) Moderation analysis demonstrates that government intervention strengthens the carbon-reducing effect of the BRI. (4) Heterogeneity analysis indicates that the impact of the BRI varies across regions and city types. Geographically, central and western cities exhibit a more pronounced decline in CEI than eastern cities. Regarding environmental regulation, the effect is significantly

stronger in key environmental protection cities. In terms of industrial foundation, the BRI yields greater reductions in old industrial base cities. Finally, concerning logistics hub status, the effect is larger in non-logistics hub cities than in logistics hub cities.

7.2. Policy Implications

Based on the above conclusions, the policy implications are as follows.

First, drawing on the baseline findings that the BRI significantly reduces CEI, the initiative offers a strategic opportunity for cities along its routes to pursue low-carbon development. To capitalize on this, policymakers and regulators are advised to actively guide and encourage market participants to undertake technological upgrades for improved energy efficiency and reduced emissions, which will spur the transition to a green, low-carbon economy and propel long-term sustainable development.

Second, consistent with the mediation analysis, the BRI lowers CEI in Chinese cities primarily by promoting industrial structure optimization, reducing energy intensity, and alleviating market fragmentation. In response, municipal governments should prioritize industrial transformation by fostering a modern, green, and low-carbon industrial system. Specific actions include implementing robust regulatory frameworks for key energy-consuming sectors, enforcing dual control over total energy consumption and energy intensity, phasing out outdated production capacity, and advancing regional market integration to enhance resource allocation efficiency.

Third, the moderation analysis confirms that government intervention significantly amplifies the BRI's carbon reduction effect, underscoring its critical role as a positive moderator. Accordingly, a multi-level policy intervention system should be established. Under this framework, central authorities should set clear carbon emission standards and binding assessment targets, while local governments and financial regulators can provide complementary support such as preferential tax policies and expanded green credit access to incentivize compliance and innovation at the firm level.

Fourth, in light of the pronounced heterogeneity in the BRI's impact on CEI across different city types, local governments should tailor carbon reduction pathways to local industrial structures. In central and western cities, governments should focus on the deep integration of high-tech industries and services, strengthen green technology innovation and facilitate the export of green standards. In key environmental protection cities, local authorities must strictly enforce ecological red lines and intensify efforts to regulate and phase out high-pollution industries. In old industrial base cities, local governments should establish dedicated funds to support traditional sectors such as steel and chemicals in adopting energy-saving and carbon-reducing technological upgrades. In non-logistics hub cities, local governments can leverage ecological and cost advantages, actively attract the relocation of regional green industries, and foster distinctive low-carbon economies.

Author Contributions: Conceptualization, J.C. and J.L.; Methodology, H.Y.; Validation, H.Y.; Software, Y.L.; Data Curation, J.L.; Writing—Original Draft Preparation, J.L.; Resources, X.L.; Writing—Review and Editing, J.C. and Y.L.; Supervision, J.C.; Funding Acquisition, J.C. and X.L. All authors have read and agreed to the published version of the manuscript.

Funding: This paper was supported by the National Social Sciences Foundation of China (Grant No. 23BJL094).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The processed analytical datasets generated in this study are available from the corresponding author upon reasonable request.

Acknowledgments: The authors wish to express their profound gratitude to the editors and anonymous reviewers for their insightful and thorough comments, which have significantly improved the quality of this manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Lashof, D.A.; Ahuja, D.R. Relative contributions of greenhouse gas emissions to global warming. *Nature* **1990**, *344*, 529–531. [\[CrossRef\]](#)
2. Zhao, B.; Wang, S.; Hao, J. Challenges and perspectives of air pollution control in China. *Front. Environ. Sci. Eng.* **2024**, *18*, 68. [\[CrossRef\]](#)
3. Abban, O.J.; Wu, J.; Mensah, I.A. Analysis on the nexus amid CO₂ emissions, energy intensity, economic growth, and foreign direct investment in Belt and Road economies: Does the level of income matter? *Environ. Sci. Pollut. Res.* **2020**, *27*, 11387–11402. [\[CrossRef\]](#)
4. Bai, J.; Yu, X. The impact of global value chain embedment on energy conservation and emissions reduction: Theory and empirical evidence. *China Finance Econ. Rev.* **2024**, *13*, 46–66. [\[CrossRef\]](#)
5. Grossman, G.M.; Krueger, A.B. Economic growth and the environment. *Q. J. Econ.* **1995**, *110*, 353–377. [\[CrossRef\]](#)
6. Cole, M.A. Trade, the Pollution Haven Hypothesis and the Environmental Kuznets Curve: Examining the linkages. *Ecol. Econ.* **2004**, *48*, 71–81. [\[CrossRef\]](#)
7. Slameršak, A.; Kallis, G.; O'Neill, D.W. Energy requirements and carbon emissions for a low-carbon energy transition. *Nat. Commun.* **2022**, *13*, 6932. [\[CrossRef\]](#)
8. Yu, Y.; Su, J.; Du, Y. Impact of global value chain and technological innovation on China's industrial greenhouse gas emissions and trend prediction. *Int. J. Environ. Sci. Technol.* **2023**, *20*, 13347–13358. [\[CrossRef\]](#)
9. Peters, G.P.; Minx, J.C.; Weber, C.L.; Edenhofer, O. Growth in emission transfers via international trade from 1990 to 2008. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 8903–8908. [\[CrossRef\]](#)
10. Yang, M.; Liu, Y.; Tian, J.; Cheng, F.; Song, P. Dynamic evolution and regional disparity in carbon emission intensity in China. *Sustainability* **2022**, *14*, 4052. [\[CrossRef\]](#)
11. Pang, J.; Li, H.; Lu, C.; Lu, C.; Chen, X. Regional differences and dynamic evolution of carbon emission intensity of agriculture production in China. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7541. [\[CrossRef\]](#)
12. Lin, B.; Wang, C. Does Industrial relocation affect regional carbon intensity? Evidence from China's secondary industry. *Energy Policy* **2023**, *173*, 113339. [\[CrossRef\]](#)
13. Qin, H.; Huang, Q.; Zhang, Z.; Lu, Y.; Li, M.; Xu, L.; Chen, Z. Carbon dioxide emission driving factors analysis and policy implications of Chinese cities: Combining geographically weighted regression with two-step cluster. *Sci. Total Environ.* **2019**, *684*, 413–424. [\[CrossRef\]](#)
14. Banday, U.J.; Murugan, S.; Maryam, J. Foreign direct investment, trade openness and economic growth in BRICS countries: Evidences from panel data. *Transnatl. Corp. Rev.* **2021**, *13*, 211–221. [\[CrossRef\]](#)
15. Copeland, B.R.; Taylor, M.S. North-South trade and the environment. *Q. J. Econ.* **1994**, *109*, 755–787. [\[CrossRef\]](#)
16. Ascensão, F.; Fahrig, L.; Clevenger, A.P.; Corlett, R.T.; Jaeger, J.A.G.; Laurance, W.F.; Pereira, H.M. Environmental challenges for the Belt and Road Initiative. *Nat. Sustain.* **2018**, *1*, 206–209. [\[CrossRef\]](#)
17. Chen, Y.; Liu, S.; Wu, H.; Zhang, X.; Zhou, Q. How can Belt and Road countries contribute to global low-carbon development? *J. Clean. Prod.* **2020**, *256*, 120717. [\[CrossRef\]](#)
18. Dong, H.; Liu, Z.; Wei, L.-Y. The impact of the Belt and Road Initiative on cities' capacity for green development—Based on data from 280 Chinese cities. *Appl. Econ.* **2025**, *57*, 5507–5522. [\[CrossRef\]](#)
19. Liu, Z.; Xin, L. Has China's Belt and Road Initiative promoted its green total factor productivity?—Evidence from primary provinces along the route. *Energy Policy* **2019**, *129*, 360–369. [\[CrossRef\]](#)
20. Cao, X.; Zhang, H.; Huang, X.; Li, P. Can the Belt and Road Initiative reduce pollution in enterprises?—Evidence from quasi-natural experiments. *Energy Rep.* **2022**, *8*, 11683–11694. [\[CrossRef\]](#)
21. Cao, X.; Zhao, F.; Wang, Y.; Deng, Y.; Zhang, H.; Huang, X. The Belt and Road Initiative and enterprise green innovation: Evidence from Chinese manufacturing enterprises. *Front. Ecol. Evol.* **2023**, *11*, 1176907. [\[CrossRef\]](#)
22. Tan, D.; Xiao, Z.; Hong, X. Modeling green technological imports in the Belt and Road economies. *Humanit. Soc. Sci. Commun.* **2025**, *12*, 732. [\[CrossRef\]](#)
23. Dai, W. Belt and Road Initiative: Driving innovation in tech enterprises through global value chains. *Financ. Res. Lett.* **2025**, *74*, 106796. [\[CrossRef\]](#)
24. Hu, H. The double-edged effects of regional environmental governance: Evidence from policy tools of belt and road initiative. *Environ. Dev. Sustain.* **2025**. [\[CrossRef\]](#)

25. Cai, X.; Zhao, Y.; Wu, X.; Ge, D.; Long, X. The green Halo Effect of China's OFDI: Evidence from countries along the Belt and Road. *Environ. Sci. Pollut. Res.* **2023**, *30*, 68290–68312. [[CrossRef](#)] [[PubMed](#)]
26. Cheng, G.; Shi, Y.; Zhou, H. Analysis of the effects of green technology innovation and industrial structure upgrading on carbon emission intensity. *Int. Rev. Econ. Finance* **2025**, *102*, 104163. [[CrossRef](#)]
27. Dechezleprêtre, A.; Glachant, M.; Haščič, I.; Johnstone, N.; Ménière, Y. Invention and transfer of climate change-mitigation technologies: A global analysis. *Rev. Environ. Econ. Policy* **2011**, *5*, 109–130. [[CrossRef](#)]
28. Hu, Y.; Man, Y. Energy consumption and carbon emissions forecasting for industrial processes: Status, challenges and perspectives. *Renew. Sustain. Energy Rev.* **2023**, *182*, 113405. [[CrossRef](#)]
29. Hou, J.; Yang, S.; Fan, G.; Xu, H. The impact of energy consumption on carbon emissions intensity in China: Evidence from a dynamic panel quantile regression model. *Int. J. Low-Carbon Technol.* **2024**, *19*, 268–288. [[CrossRef](#)]
30. Simonov, M. The Belt and Road Initiative and partnership for global infrastructure and investment: Comparison and current status. *Asia Glob. Econ.* **2025**, *5*, 100106. [[CrossRef](#)]
31. Jiang, S. Fragmented rules, global flows: How legal differences shape the cross-border data landscape—Evidence from the EU, US, and China. *Lect. Notes Educ. Psychol. Public Media* **2025**, *96*, 47–57. [[CrossRef](#)]
32. Jiang, L.; Zhang, M.; Hu, S. Digital economy, green innovation and regional resource allocation efficiency: Evidence from 257 cities in China. *Front. Environ. Sci.* **2025**, *13*, 1529946. [[CrossRef](#)]
33. Zhao, J. How do innovation factor allocation and institutional environment affect high-quality economic development? Evidence from China. *J. Innov. Knowl.* **2024**, *9*, 100475. [[CrossRef](#)]
34. Saqib, N.; Usman, M. Are technological innovations and green energy prosperity swiftly reduce environmental deficit in China and United States? Learning from two sides of environmental sustainability. *Energy Rep.* **2023**, *10*, 1672–1687. [[CrossRef](#)]
35. Zhang, M.; Zhang, C.; Li, F.; Liu, Z. Green finance as an institutional mechanism to direct the Belt and Road Initiative towards sustainability: The Case of China. *Sustainability* **2022**, *14*, 6164. [[CrossRef](#)]
36. Ning, S.; Jie, X.; Li, X. Institutional pressures and corporate green innovation; Empirical evidence from Chinese manufacturing enterprises. *Pol. J. Environ. Stud.* **2022**, *31*, 231–243. [[CrossRef](#)] [[PubMed](#)]
37. Lu, S.; Dong, R.; Ye, C. Does “the Belt and Road Initiative” promote high-quality exports—Evidence from firms in China. *China Ind. Econ.* **2021**, *3*, 80–98.
38. Jiang, Y.; Zhao, R.; Qin, G. How does digital finance reduce carbon emissions intensity? Evidence from chain mediation effect of production technology innovation and green technology innovation. *Heliyon* **2024**, *10*, e30155. [[CrossRef](#)]
39. Chingiz, D.; Liu, J.; Malikov, M. The role of environmental poverty in shaping green growth in the One Belt One Road countries. *Sustain. Futur.* **2025**, *10*, 100935. [[CrossRef](#)]
40. Gan, C.; Zheng, R.; Yu, D. An empirical study on the effects of industrial structure on economic growth and fluctuations in China. *Econ. Res. J.* **2011**, *21*, 85–100.
41. Fisher-Vanden, K.; Jefferson, G.H.; Liu, H.; Tao, Q. What is driving China's decline in energy intensity? *Resour. Energy. Econ.* **2004**, *26*, 77–97. [[CrossRef](#)]
42. Anderson, J.E.; van Wincoop, E. Trade costs. *J. Econ. Lit.* **2004**, *42*, 691–751. [[CrossRef](#)]
43. Folster, S.; Henrekson, M. Growth effects of government expenditure and taxation in rich countries. *Eur. Econ. Rev.* **2001**, *45*, 1501–1520. [[CrossRef](#)]
44. Dusengemungu, D.-R.; Liu, J.; Zhou, Z. Does the belt and road initiative reduce the carbon emission intensity of African participating countries? *Environ. Sci. Pollut. Res.* **2023**, *30*, 29281–29299. [[CrossRef](#)] [[PubMed](#)]
45. Zhang, J.; Li, P.; Liza, F.F.; Ahmad, F.; Lv, C.; Cao, Z. How does the belt and road initiative affect the carbon emissions of China's cities? *Front. Environ. Sci.* **2023**, *10*, 1066122.
46. Glaeser, E.L.; Kahn, M.E. The greenness of cities: Carbon dioxide emissions and urban development. *J. Urban Econ.* **2010**, *67*, 404–418. [[CrossRef](#)]
47. Cole, M.A.; Elliott, R.J.R.; Okubo, T. Trade, environmental regulations and industrial mobility: An industry-level study of Japan. *Discuss. Pap.* **2010**, *69*, 1995–2002. [[CrossRef](#)]
48. Kwon, S.-H. Education expenditure and sustainable human capital formation: Evidence from OECD countries. *Sustainability* **2025**, *17*, 10848. [[CrossRef](#)]
49. Zhao, Y.; Sun, H.; Xia, X.; Ma, D. Can R&D intensity reduce carbon emissions intensity? Evidence from China. *Sustainability* **2023**, *15*, 1619. [[CrossRef](#)]
50. Yao, Y.; Ivanovski, K.; Inekwe, J.; Smyth, R. Human capital and CO₂ emissions in the long run. *Energy Econ.* **2020**, *91*, 104907. [[CrossRef](#)]
51. Sun, J.; Wu, X. Digital economy, energy structure and carbon emissions: Evidence from China. *Sage Open* **2024**, *14*, 2. [[CrossRef](#)]
52. Musa, M.S.; Jelilov, G.; Iorember, P.T.; Usman, O. Effects of tourism, financial development, and renewable energy on environmental performance in EU-28: Does institutional quality matter? *Environ. Sci. Pollut. Res.* **2021**, *28*, 53328–53339. [[CrossRef](#)]

53. Ferrara, E.L.; Chong, A.; Duryea, S. Soap operas and fertility: Evidence from Brazil. *Am. Econ. J. Appl. Econ.* **2012**, *4*, 1–31. [[CrossRef](#)]
54. Tsoutsoura, M. The effect of succession taxes on family firm investment: Evidence from a natural experiment. *J. Finance* **2015**, *70*, 649–688. [[CrossRef](#)]
55. Yu, D.; Li, X.; Li, H. Can the Belt and Road Initiative reduce pollution in cities?—Evidence from quasi-natural experiments. *Stat. Res.* **2021**, *38*, 44–56.
56. Zhou, S.; Wang, Y.; Luo, P. Does the Belt and Road Initiative (BRI) improve environmental quality of BRI countries? Evidence from a quasi-natural Experiment. *Appl. Econ.* **2023**, *55*, 7094–7110. [[CrossRef](#)]
57. Dong, K.; Sun, R.; Hochman, G. Do natural gas and renewable energy consumption lead to less CO₂ emission? Empirical evidence from a panel of BRICS countries. *Energy* **2017**, *141*, 1466–1478. [[CrossRef](#)]
58. Zhang, B.; Tian, X.; He, B.; Xin, Q.; Yang, Z. The impact of China’s green technology transfer on energy intensity in countries along the Belt and Road. *J. Environ. Manag.* **2025**, *373*, 123691. [[CrossRef](#)]
59. Wang, H.; Si, I.; Chen, Z. Does the Belt and Road Initiative promote China and the countries along the route to reconstruct the global value chain? Evidence from value-added trade. *Econ. Anal. Policy* **2024**, *81*, 63–83. [[CrossRef](#)]
60. Sohag, K.; Islam, M.; Hammoudeh, S. From policy stringency to environmental resilience: Unraveling the dose-response dynamics of environmental parameters in OECD countries. *Energy Econ.* **2024**, *134*, 107570. [[CrossRef](#)]
61. Zhang, Y.; Jin, Y.; Shen, B. Measuring the energy saving and CO₂ emissions reduction potential under China’s Belt and Road Initiative. *Comput. Econ.* **2020**, *55*, 1095–1116. [[CrossRef](#)]
62. Zhang, Q.; Cai, B.; Wang, M.; Wang, J.; Xing, Y.; Dong, G.-X.; Zhang, Z.; Mao, X.-Q. City level CO₂ and local air pollutants co-control performance evaluation: A case study of 113 key environmental protection cities in China. *Adv. Clim. Change Res.* **2022**, *13*, 118–130. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.