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How does the Belt and Road policy affect the level of green development? A quasi-natural experimental study considering the CO_2 emission intensity of construction enterprises

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The ‘Belt and Road’ (B&R) Initiative has received attention from environmental researchers. However, there are no studies explaining the impact of the B&R policy on the green development (GD) of construction enterprises. We aim to find a mechanism for how the B&R policy impacts the GD level of construction enterprises. Consequently, on the basis of a fixed effects model, we consider the B&R policy and the background of GD in the construction industry and construct a model of the GD level of construction enterprises. Meanwhile, we use panel data for 28 provincial administrative regions of the Chinese government from 2010 to 2020 and analyse the implications of the B&R policy on the GD level of construction enterprises using Stata 16.0. The main conclusions are as follows. (1) A positive promotion effect is evident in the planned focus areas of the B&R policy on construction enterprises’ GD levels. (2) Research and development (R&D), regional development, education, labour productivity and investment in sewage treatment significantly affect the intensity of CO_2 emissions of regional construction enterprises, thus increasing and hindering the GD of construction enterprises. Taking the findings of this study into account, this study contributes to the econometrics of construction enterprises in the area of sustainable development. Additionally, it provides policy ideas for the government to further build a green B&R.

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Introduction

In 2015, the Chinese government published the 'Belt and Road' (B&R) vision (NDRC, MOFA & MOFCOM, 2015). By 2020, 66 countries have participated in the B&R Initiative (Cuiyun and Chazhong, 2020). Under severe ecological and environmental situations, the implementation of green development (GD) has become the dominant value in the world (Skea and Nishioka, 2008). In China, society has begun to focus on GD as a new way of producing and living and has made some progress. First, GD is an approach that has received much attention from both academia and industry to address the environmental problems associated with the process of economic growth. GD acts as a complex adaptive system that integrates policy, livelihoods, production and the community of human and natural life (Li et al., 2019, 2021). Second, organizational behaviours such as GD behaviours arise in the production and management of enterprises. Third, the process of production activities in construction enterprises is also inseparable from GD. For example, in the remanufacturing supply chain of construction waste, the role of technological innovation cannot be ignored (Long et al., 2020; Liu et al., 2020; Li et al., 2021).

As one of the mainstays of national economies around the world (Zhang et al., 2019), the construction industry is characterized by high energy consumption, waste, and sloppy production methods in its production process (Hong et al., 2016). According to previous studies, the construction activities in the construction sector consume the majority of the world's overall energy (Levermore, 2008) and create nearly one-third of the global carbon dioxide (CO_2) emissions (Wu et al., 2018). As a result, many countries have proposed retrofitting existing energy-intensive and dysfunctional buildings, and building technology innovation is used to reconcile rapid sustainable urban development with environmental sustainability (La Rosa et al., 2017).

In 2013, Chinese President Xi Jinping proposed the *New Silk Road Economic Belt* and the *21st Century Maritime Silk Road* in Kazakhstan and Indonesia, respectively (Li, 2020). In 2015, the Chinese government released the official document on the B&R policy, which represents the official implementation of the B&R policy (Duan et al., 2018). In addition, 19 provincial administrative regions in China are planned as key planning areas under the B&R policy. In 2017, the Chinese government issued the Guidance on Promoting a Green B&R, which clearly promotes a green B&R and safeguards the ecological environment. The core connotation of building a green B&R is to integrate the concept of GD with the whole process of the B&R Initiative to achieve a new GD model of harmonious coexistence between humans and nature (Xue et al., 2021). For this purpose, the Chinese government still insists on green construction as the key to B&R construction and promotes the sustainable construction of the ecological environment in the provinces and countries along the route.

To clarify whether the B&R policy has an impact on the GD level of construction enterprises, we take into account the context of the GD of construction enterprises based on the differences-in-differences (DID) and propensity score matching (PSM) methods and construct a fixed effects model of the GD level of construction enterprises. Using panel data of the Chinese government from 2010 to 2020, we empirically tested the following three questions:

- How does the B&R policy plan affect the GD of construction enterprises in provincial administrative areas?
- Does the degree of regional development have an effect on the level of GD of construction enterprises in essential areas?
- Does the research investment of the government and enterprises have an effect on the level of GD of construction enterprises in essential areas?

The main contributions of this paper are as follows. First, we construct a fixed effects model of the GD level of construction enterprises. We use the DID and PSM-DID methodologies and panel data for 28 provincial administrative regions of the Chinese government from 2010 to 2020 to empirically examine the impact of the B&R policy on the GD levels of Chinese construction enterprises. Second, given the late start of GD for Chinese construction enterprises, there are few intensive studies on the GD of construction enterprises from an econometric point of view. Therefore, this research is based on an econometric perspective and introduces several control variables for analysis. Third, this paper broadens the research perspective on the GD of construction enterprises and offers evidence from China for the field. Thus, this paper provides new ideas for econometric research related to the GD of construction enterprises. Fourth, this paper provides evidence from the construction industry for the government's construction of a green B&R and provides a reference for local government policies related to the GD of construction enterprises.

Theoretical background

Under the perspectives on the GD of construction enterprises, Table 1 gives a theoretical background. Among these, the studies on influencing factors, policy evaluation and GD levels are relevant to the research intent of this paper. Therefore, the current status of domestic and international research is analysed from two aspects.

GD of construction enterprises. GD is an innovative twist on traditional production methods (Fu and Geng, 2019) and a new approach to ensuring economic development and environmental protection. With the growing concern for environmental

Table 1 Studies related to the GD of construction enterprises and the evaluation of the B&R policy.

Research topics	Dimensions	Source papers
GD of construction enterprises	Definition of GD	Fu and Geng (2019) & Long et al. (2021)
	Factors influencing GD	Elmualim et al. (2012), Darnall et al. (2010), Ahn et al. (2013), Xu et al. (2019) & Xu et al. (2020)
	Drivers of GD in construction enterprises	Zhang et al. (2020) & Li et al. (2022b)
	Assessment of the level of GD of construction enterprises	Sun et al. (2018) & Yang et al. (2015)
B&R Policy Assessment	Regional perspectives on the impact of the B&R policy on economic levels	Foo et al. (2020) & Du and Zhang (2018)
	Assessing the impact of the B&R policy on the national ecological environment	Saud et al. (2020)

protection, sustainable socioeconomic development and the rational use of resources, GD has achieved a worldwide consensus (Long et al., 2021). As one of the pillar industries of national economies, the construction industry generates a large amount of pollution. Therefore, the GD of the construction industry has gradually become the focus of scholars in various countries.

In addition, there are three major hotspots of research on the GD of construction enterprises: (i) a study of the factors influencing GD in construction enterprises; (ii) research on how to promote the level of GD of construction enterprises; and (iii) research on the evaluation of the level of the GD of construction enterprises. First, we research the factors affecting GD in construction enterprises and their mechanisms of action. Related studies have explored the influence on the GD level of construction enterprises from the perspectives of governmental behaviour (Elmualim et al., 2012), industry scale (Darnall et al., 2010), natural resources (Ahn et al., 2013), urban construction development (Xu et al., 2019) and research and development (R&D) investment in science and technology (Xu et al., 2020). Second, existing research on the analysis of the drivers of GD levels in construction enterprises focuses on the following areas, i.e., business models, green production, public environmental needs, level of social development and issues organized around how to improve GD levels in construction enterprises (Zhang et al., 2020; Li et al., 2022a). Finally, we evaluate the level of GD of construction enterprises. Some researchers analysed the GD level by establishing an indicator system, information entropy model and comprehensive weighting method. Moreover, other studies assessed the level of GD through indicator systems and information entropy models (Sun et al., 2018; Yang et al., 2015).

In summary, based on the importance of the construction industry, existing studies have gradually begun to focus on GD in construction enterprises. However, most studies have only analysed it from the perspective of various influencing factors; policy is only one of the factors, and no detailed assessment of a specific policy has been carried out.

The Belt and Road Policy assessment. As seen in the previous section, the B&R policy has been in place for almost a decade now. In recent years, scholars around the world have evaluated the policy from multiple perspectives and with different methods. Among them, Foo et al. (2020) used an enhanced gravity model of international trade to assess the impact of the B&R policy on international trade in the Association of Southeast Asian Nations (ASEAN) region. The study concluded that the B&R policy is a mechanism that can facilitate trade for ASEAN countries. The B&R policy, as a global and inclusive development policy, involves 65 countries around the world, and its perspective is not limited to Asia. Therefore, Du and Zhang (2018) assessed the B&R policy from the perspective of China's favourable level of direct investment in overseas countries. Since 2017, when the Chinese government proposed the construction of the 'green B&R', 'green' and 'sustainable' have been gradually integrated into the concept of the B&R policy. Saud et al. (2020) used an econometric approach to assess the financial development and ecological environment of the B&R Initiative countries. The study also examined the ecological environment of the B&R Initiative countries.

In summary, scholars have extensively used multiple perspectives and methods to assess the effectiveness of the B&R policy. However, few studies have been conducted to assess the impact of the B&R policy on the GD of construction enterprises. Therefore, based on existing studies, we establish a fixed effects model of the GD level of construction enterprises using a PSM-DID method to assess the impact of the B&R policy on the GD level of construction enterprises in China.

Research hypotheses

Impact of the B&R policy on the GD of construction enterprises. Since the implementation of the B&R policy, it has been committed to promoting the economic development of countries and regions along the route (Huang, 2016). With the Chinese government's announcement to start building a green B&R, the impact of the B&R policy on GD has gradually become a focus of scholars' attention. Among them, Liu and Xin (2019) argued that the B&R policy has boosted the total factor productivity of provinces along the route and supported the construction of a green B&R. Mao and Wang (2022) found that the B&R policy initiative was able to fully motivate enterprises in developing countries along the route to reduce carbon emissions. Grillitsch and Hansen (2019) linked regional preconditions to various pathways of green industry development to determine whether policy impacts based on different regions supported the development of green industries in the region. We propose the following hypotheses with the above analysis.

Hypothesis 1: The B&R policy has a significant positive effect on the GD level of construction enterprises.

Impact of urban development on the GD of construction enterprises. Urban development is often seen as a barrier to GD. Rapid urbanization in China has led to high energy consumption as well as carbon emissions (Ji et al., 2017). Similarly, rapid urban development has led to an increase in transport infrastructure, which in turn has directly contributed to higher carbon emissions (Meng and Han, 2018). In addition, developing countries are facing increasing challenges in achieving urbanization and reducing carbon emissions (Yao et al., 2018). Therefore, the following hypothesis is proposed with the above analysis.

Hypothesis 2: The level of urban development has a significant negative effect on the GD level of construction enterprises.

Impact of labour productivity on the GD of construction enterprises. As a typical representative of a labour-intensive industry, the construction industry's productivity has a profound impact on the GD of the industry. Lin and Wang (2021), after using grey models and scenario analysis, concluded that the increase in labour productivity significantly raises carbon emissions. At the same time, in the construction industry, which uses a large amount of cement materials, the increase in labour productivity is also the main reason for the higher carbon emissions in the cement industry (Lin and Zhang, 2016). Therefore, the following hypothesis is proposed with the above analysis.

Hypothesis 3: Labour productivity has a significant inhibitory effect on the GD level of construction enterprises.

Impact of investment in pollution control input on the GD of construction enterprises. Investment in pollution control has a large impact on carbon emissions as well as GD. Among industrial sectors, differences in investment in industrial pollution control and environmental regulations have a greater impact on carbon emissions in the western region (Xu and Lin, 2021). At the same time, the mediating role associated with fiscal decentralization and market segmentation promotes the control of carbon emissions by enterprises (Guo et al., 2022). Therefore, the following hypothesis is proposed with the above analysis.

Hypothesis 4: Investment in pollution control has a significant inhibitory effect on the GD level of construction enterprises.

Impact of research and development input on the GD of construction enterprises. R&D input has been widely studied by researchers as a key factor influencing GD. Zheng et al. (2011) argued that at the industrial level, R&D reduces emission intensity by lowering production costs. At the regional level, R&D investment still contributes to the reduction in energy intensity, thus contributing to GD (Huang et al., 2017). At the national level, R&D curbs CO_2 emissions (Zhang and Li, 2021). Therefore, the following hypothesis is proposed with the above analysis.

Hypothesis 5: R&D has a significant positive effect on the GD level of construction enterprises.

Impact of education level input on the GD of construction enterprises. Current research suggests that there is a threshold for the impact of education level on ecology and GD (Zhu et al., 2021). On the one hand, Mahalik et al. (2021) argued that the primary education level has a significant contribution to carbon emissions and that carbon emissions are suppressed when the higher education level increases. On the other hand, Jin et al. (2019) argued that the level of education in eastern China increases the green total factor productivity of industrial water resources in the region, while the level of education in the western region plays a suppressive role. In summary, the following hypothesis is proposed with the above analysis.

Hypothesis 6: Education level has a significant inhibitory effect on the GD level of construction enterprises.

Methods and indicators

Some researchers adopted the PSM-DID method for policy analysis, while industrial emissions and waste emissions were used as explanatory variables and R&D investment, investment in pollution control, industry scale, development level and education level were considered control variables (Nie et al., 2022; Liu et al., 2022; Yang et al., 2022; Guo et al., 2020; Shi et al., 2018). Therefore, to explore the mechanism of the B&R policy on the carbon emissions of construction enterprises, we take full account of the previous studies related to policy analysis and determine the research methodology, explanatory variables and control variables in this paper.

Methods. The PSM-DID method was proposed by Heckman and Vytlacil (2001) to make intervention and control groups as comparable as practicable in all aspects of characteristics and to eliminate selection bias. Thus, the PSM-DID method is chosen to more accurately assess the effect of the application of the B&R policy on improving the GD of construction enterprises. As shown in Fig. 1, the technical roadmap based on the GD level model of construction enterprises clearly shows how the B&R policy affects the GD level of construction enterprises.

Differences-in-differences (DID). The DID method is a common method used to evaluate the effect of a policy or programme developed at a particular point in time (Stuart et al., 2014). The DID method has the following advantages: (i) the endogeneity problem can be largely avoided; (ii) omitted variable bias is mitigated by the use of fixed effects estimation; and (iii) the DID model setup is more scientific compared to the traditional method. Figure 2 gives the basic principle of the DID method.

Propensity score matching (PSM). PSM is a statistical method used to process data from observational studies (Abadie, 2005). In observational studies, data bias and confounding variables often occur due to environmental influences and multifactorial interventions. Therefore, PSM is used to reduce the effects of these biases and confounding variables to make more reasonable comparisons between intervention and control groups.

Indicator selection and data sources

The level of GD. The level of GD. Referring to the study by Fu et al. (2018) and based on the characteristics of the GD in construction enterprises, we choose to represent the level of GD in construction enterprises by the CO_2 emission intensity of construction enterprises located in each provincial administrative region. Since the Chinese government does not publish relevant data on the carbon emissions of construction enterprises, we refer to Du et al. (2019) model for measuring carbon emissions from the construction industry, while researchers argue that direct CO_2 emissions can measure carbon emissions (Bai et al., 2018; Ogungbile et al., 2021; Zhang et al., 2022). Therefore, we refer to Tang (2012) and Pan et al. (2008) by aggregating the standard coal consumption of construction enterprises from the *China Statistical Yearbook* (National Bureau of Statistics NBS, 2021a).

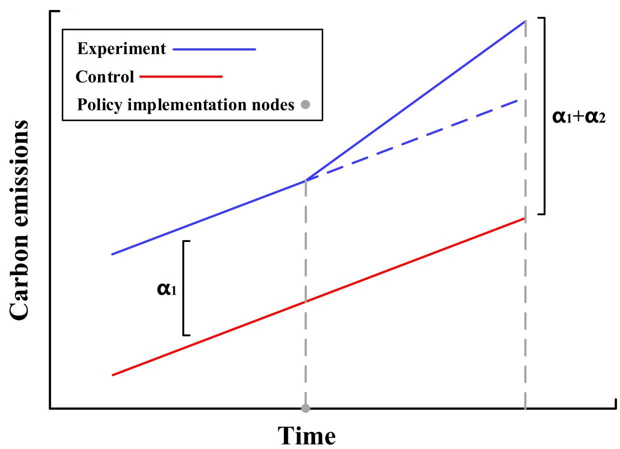

Fig. 2 Schematic diagram of differences-in-differences estimators. The experimental group (solid blue), the control group (solid red), and the policy implementation node (solid grey dots) are shown.

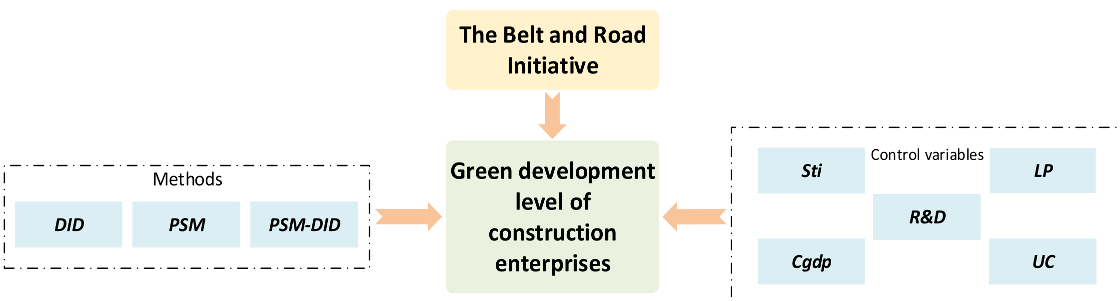

Fig. 1 Technology roadmap of the 'B&R Initiative' policy to the GD level of construction enterprises. Three methods are used to explore the impact of the B&R policy on the green development of construction enterprises with five control variables. Sti sewage treatment investment, R&D research and development investment, LP labour productivity, Cgdp per capita GDP, UC undergraduate students in colleges and universities, DID differences-in-differences, PSM propensity score matching.

Then, the carbon emissions of construction enterprises in each provincial administrative region are calculated according to the energy conversion coefficients in the *General Rules for the Calculation of the Comprehensive Use of Resources* (National public service platform for standards information, 2022), denoted as CCO_2, where the energy conversion coefficients for China are shown in Table 2. Meanwhile, Fig. 3 shows the situation of China's provincial administrative regions before and after the five years (2010 and 2020) of the implementation of the B&R policy. The CO_2 emission intensity can be used to measure economic growth, energy consumption, and regional GD (Wang et al., 2016). As a result, when the implementation of the B&R policy leads to the reduction in CO_2 emission intensity, it means that the GD level of construction enterprises in the area is improved, and the greater the reduction is, the higher the GD level.

Control variables. Control variables. In this study, on the basis of the studies by Zhu et al. (2020) and Fu et al. (2018), important variables that directly and indirectly affect the level of GD of the construction industry, such as R&D investment, pollution control investment, labour productivity, education level and development level, are selected as control variables, and the specific indicators are as follows: (i) R&D investment, which is measured by the investment in technological input by industrial enterprises above the scale, denoted as *R&D* (Li and Long, 2020; Li et al., 2022b); (ii) investment in pollution control, which is constrained by the usability of data in this study, so the completed investment in sewage control projects are indicated by *Sti* (Fu et al., 2018); and (iii) labour productivity, which according to Soomro et al. (2021) has a certain influence on GD. Therefore, we select the labour productivity of construction enterprises calculated by the total construction output value to measure labour productivity, denoted as *LP*; (iv) the education level, based on the study by Sun et al. (2021); the number of undergraduate students in general higher education schools is selected to measure this, denoted as *UC*; and (V) the development level, because the gross domestic product (GDP) of national economic accounting is the most intuitive measure of regional development. Therefore, we choose regional GDP per capita as an indicator of the degree of development, denoted as *Cgdp*.

Based on the data availability, we use panel data for 28 provincial administrative regions (excluding Tibet, Ningxia, Chongqing, Hong Kong, Macao, and Taiwan) for the period 2010–2020. The original data sources are as follows: final energy consumption in the construction industry, GDP per capita, investment in scientific and technological research of industrial enterprises above the scale, investment in sewage treatment, labour productivity in the construction industry, and the number of undergraduate students in general higher education institutions from the *China Statistical Yearbook* (National Bureau of Statistics NBS, 2021a), *China Environmental Statistical Yearbook* (NBS, 2021b), and *China Energy Statistical Yearbook* (NBS, 2021c).

Model construction. We construct a GD level fixed effects model for construction enterprises at the administrative level in each province of China to verify the impact of the B&R policy on the carbon intensity of construction enterprises in each province in China. In this study, the sample is divided into an intervention group of key regions (mentioned in the B&R policy document) and a control group of nonkey regions (not mentioned in the B&R policy document). In this paper, 17 provincial-level administrative regions, including Shanghai, Beijing, and Tianjin, are set as the intervention group, while the remaining regions are set as the control group. Since the B&R policy was officially implemented in 2015, we take 2015 as the time point, i.e., 2010–2014 as the preimplementation period and 2015–2020 as the postimplementation period. The effect of the policy is evaluated by comparing the changes in carbon emissions of construction enterprises in the intervention group and the control

Table 2 Conversion factors of different energy units.

Project (unit)	1 GJ	1 t Standard coal	1 kw h	1 t CO_2
Joule (GJ)	1.00	29.27	3.6×10^{-3}	11.19
Standard coal (t)	0.03	1.00	0.1227×10^{-3}	0.38
kw h	0.278×10^{-3}	8.137×10^{-3}	1.00	3.106×10^{-3}
CO_2 (t)	0.09	2.26	0.322×10^{-3}	1.00

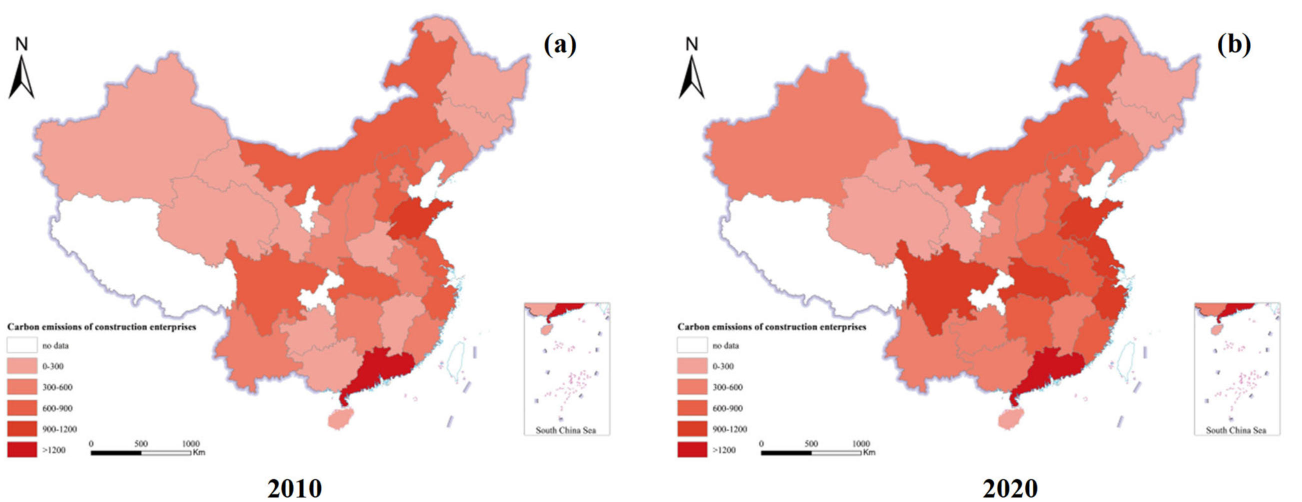

Fig. 3 Carbon emissions of China's provincial administrative regions in 2010 and 2020. a Shows the carbon emissions of construction enterprises in China in 2010. **b** Shows the carbon emissions of China's construction enterprises in 2020.

group in the two periods. Based on this, a specific baseline regression model is set as shown in Eq. (1):

$$\mathrm{CCO2}_{it} = \alpha_0 + \alpha_1 \mathrm{TREATED}_i + \alpha_2 \mathrm{TIME}_t + \alpha_3 (\mathrm{TREATED}_i \times \mathrm{TIME}_t) + \mu_{it} \quad (1)$$

where i represents the region and t represents the time. CCO_2 represents the GD level of construction enterprises; $\mathrm{TREATED}_i$ represents the regional dummy variable, $\mathrm{TREATED}_i = 1$ indicates that region i is planned as a key region by the B&R policy; TIME_i represents the time dummy variable, $\mathrm{TIME}_i = 1$ indicates that the B&R policy was implemented at time t; and $\mathrm{TIME} = 0$ indicates that the B&R policy was not implemented at time t. The interaction term $\mathrm{TREATED}_i \times \mathrm{TIME}_i$ is the core explanatory variable, which reflects whether the corresponding policy has been implemented in the control group; μ is the disturbance term.

The level of GD of construction enterprises is not only the result of policy implementation. Therefore, we add a series of control variables to the baseline regression model. Since the explanatory variable of this paper is the level of GD of construction enterprises, we refer to previous studies that have already been conducted to include key variables that directly and indirectly affect the level of GD of construction enterprises, such as *R&D*, *Sti*, *UC*, *LP*, and *Cgdp*, as control variables to obtain a new regression model, as shown in Eq. (2).

$$\mathrm{CCO2}_{it} = \alpha_0 + \alpha_1 \mathrm{TREATED}_i + \alpha_2 \mathrm{TIME}_t + \alpha_3 (\mathrm{TREATED}_i \times \mathrm{TIME}_t) + \sum \alpha_j \mathrm{Control}_{ijt} + \mu_{it} \quad (2)$$

where j denotes the jth control variable, Control represents each control variable, and the other variables have similar meanings as in the baseline regression model.

Empirical analysis

Parallel trend test. The parallel trend test is one of the key and important prerequisites for the use of DID. The DID method can only be used if the parallel trend test is satisfied before the policy occurs. The B&R policy was officially implemented in 2015, and several provincial administrative regions were planned as key regions. Therefore, we select 2015 as the node of policy intervention, the key regions planned as the intervention group and the unplanned regions as the control group. Since the data selected for this paper are panel data with multiple periods, we use a graphical approach to examine parallel trends by referring to the studies by Guo et al. (2020), Luo et al. (2022) and Tang et al. (2021).

Figure 4 shows that the trend of CO_2 emissions is the same for all cities, including the control group (i.e., red dashed line) and the experimental group (i.e., blue solid line), before 2015, i.e., the experimental and control groups had the same trend before the B&R policy was implemented. When the B&R policy is implemented, the rise in CO_2 emissions in the control group coincides with the fact that the control group acts as a natural state without experimental disturbance. This result is supported by Huang et al. (2018), i.e., CO_2 emissions from the construction sector have had an upwards trend in recent years. However, as shown in Fig. 4, the CO_2 emission trends of the control and experimental groups show differences after 2015, i.e., the implementation of the B&R policy can curb the upwards trend of CO_2 emissions from construction enterprises in the experimental group (i.e., blue solid line after 2015). This result is similar to the findings of Chen et al. (2017), which concluded that the policies formulated by the government have a suppressive effect on the CO_2 emissions of construction enterprises.

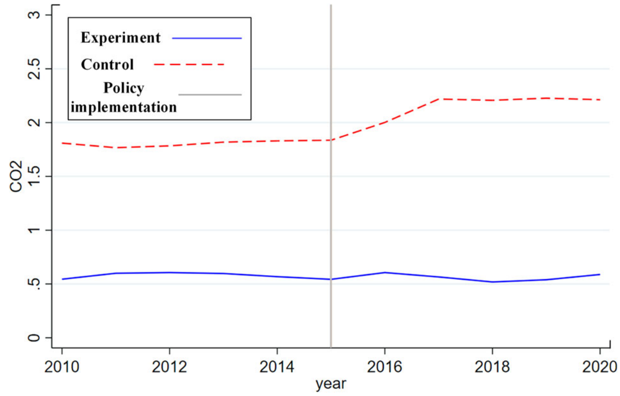

Fig. 4 Influence of the B&R policy on the GD level of construction enterprises—parallel trend test. The control group (red dashed line) and the cut-off line for the B&R policy implementation year (grey solid line) are shown.

Regression analysis. To make the coefficients of the nondummy variables easily comparable to each other, we logged the data after multiplication before the regression analysis. As a result, the regression analysis of the effect of China's B&R policy on the GD level of construction enterprises and its mechanism of action is conducted using DID and PSM-DID methods.

Differences-in-differences regression analysis. The DID regression analysis of the B&R policy and GD level of construction enterprises. Table 3 shows the outcomes of the DID regression analysis on the effect of the B&R policy on the GD level of construction enterprises. Model (1) is a baseline regression model devoid of any control variables, and five control variables, i.e., *Cgdp*, *R&D*, *Sti*, *UC* and *LP*, are added from Model (2) to Model (6). With the sequential addition of the control variables, neither the significance nor the sign of the coefficient of the core explanatory variable interaction term TREATED × TIME change fundamentally. Meanwhile, the coefficients as well as the significance of the other control variables change as the control variables increase.

The coefficients of the core explanatory variable TREATED × TIME are significantly negative at the 1% significance level. Table 3 shows that the application of the B&R policy has a significant inhibitory effect on the upwards trend of CO_2 emissions of construction enterprises from the key regions planned in the policy. Thus, the application of the policy in the planned key regions is conducive to improving the GD of construction enterprises. In terms of the magnitude of the coefficient, the CO_2 emission intensity of the construction enterprises in the planned areas is reduced by 0.346 units after the application of the B&R policy.

In terms of control variables, *R&D* is significantly negative at the significance test level of 1%. This indicates that an increase in scientific and technological research inputs reduces the CO_2 emission intensity of construction enterprises in the policy planning area, i.e., it increases the level of GD of construction enterprises in the area. The increase in *R&D* raises the level of green technological innovation of construction enterprises, which strengthens the green production capacity and ultimately reduces the emission of pollutants in production, i.e., the intensity of CO_2 emissions.

Compared to *R&D*, *Cgdp* and *UC* are positive at the 1% level of significance, while *Sti* and *LP* are positive at the 10% level of significance and nonsignificant, respectively. From the results, the increase in *Cgdp*, *UC* and *Sti* will strengthen the CO_2 emission intensity of construction enterprises in the planned area, thus reducing the GD level of construction enterprises in the area. The

Table 3 Influence of the B&R policy on the GD level of construction enterprises—DID.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
TREATED	−1.21858***	−1.27929***	−1.83662***	−1.44010***	−1.45242***	−1.40504***
	(−2.72)	(−2.80)	(−3.75)	(−2.78)	(−2.76)	(−2.63)
TIME	0.32276***	0.207998*	0.21765**	0.256355**	0.257908**	0.262988**
	(3.97)	(1.89)	(2.02)	(2.40)	(2.42)	(2.48)
TREATED × TIME	−0.345619***	−0.324080***	−0.415850***	−0.463279***	−0.439914***	−0.445729***
	(−3.32)	(−3.10)	(−3.93)	(−4.42)	(−4.18)	(−4.25)
Cgdp		0.733341	2.90335***	4.63256***	4.72153***	4.44386***
		(1.54)	(3.73)	(4.98)	(5.08)	(4.66)
R&D			−1.17095***	−1.59397***	−1.5921***	−1.68158***
			(−3.47)	(−4.45)	(−4.45)	(−4.64)
UC				1.91731***	1.811109***	2.02155***
				(3.23)	(3.01)	(3.27)
Sti					0.123214	0.117180*
					(1.75)	(1.67)
LP						0.569588
						(1.41)
_cons	1.80164***	1.25605**	−0.010755	−5.25282***	−5.16875***	−5.62108***
	(5.16)	(2.51)	(−0.02)	(−3.04)	(−2.98)	(−3.19)
N	307	307	307	307	307	307
R^2	0.2592	0.2388	0.2356	0.1629	0.1597	0.1698

***, ** and * denote the significance levels of 1%, 5% and 10%, respectively, and the values in parentheses are *t*-values.

higher the levels of *Cgdp* and *UC* are, the higher the number and productivity of construction enterprises and the higher the CO_2 emissions of the production process, which reduces the GD level of construction enterprises in the region. Based on the availability of data, we select *Sti* when determining the indicators to measure the factors of a completed investment in sewage control projects. From the analysis of the regression results, the effect of *Sti* on the CO_2 emission intensity of the policy planning area is significant; from the analysis of the regression coefficients, *Sti* increases the CO_2 emission intensity, but the effect is relatively small.

In summary, the implementation of the B&R policy has a noticeable influence on the GD level of construction enterprises in the planned key regions. At the same time, among the control variables, *R&D* has a positive contribution to the GD level; the negative inhibitory effect of *Cgdp*, *UC*, *LP* and *Sti* on the GD level gradually decreases.

PSM-DID regression analysis. The DID method used to evaluate the policy effect inevitably suffers from self-selection bias because the real-life B&R policy is inherently a quasi-natural experiment. Additionally, to make the intervention and control group cities as similar as possible in all aspects of characteristics, selection bias was eliminated. To this end, a PSM-DID method is used to conduct a robustness check to more accurately assess the implication of the B&R policy on the GD of construction enterprises in the planning area. The specific idea is to use the psmatch2 programme to match the samples with CCO_2 as the dependent variable and the control variables as the covariates using the 1:1 matching method. The results after the balance test of PSM are shown in Table 4 and Fig. 5.

As seen in Table 4 and Fig. 5, the data for each variable converged to 0 after matching, and the significance tests for the *t*-statistic values all changed from significant to nonsignificant. This result means that the primary assumption of no systematic discrepancy between the intervention and control groups is admitted. This indicates that the matching result is valid and suitable for estimation using the PSM-DID method. Thus, Table 5 gives the effect of the B&R policy on the GD level of construction enterprises in the planned key regions with PSM-DID. Model (1) does not contain the corresponding control variables, and Model (2) contains the corresponding control variables.

Table 5 shows that the interaction term TREATED × TIME in both Model (1) and Model (2) is significantly negative at the significance test level of 1%. It shows that the coefficient of the interaction term has changed only slightly compared with Table 3. Thus, the implementation of the B&R policy has a suppressing effect on the upwards trend of the CO_2 emission intensity of construction enterprises in the planned key regions. In summary, the implementation of the policy has promoted the GD level in construction enterprises.

Discussion

The B&R policy and the GD level of construction enterprises. The main results of the previous analysis show that the implementation of the B&R policy has inhibited the upwards trend of the CO_2 emission intensity of construction enterprises in key development areas of policy planning. This demonstrates that the enforcement of the policy has contributed significantly to the GD level of construction enterprises. Therefore, **Hypothesis 1** passes the test. Huang and Li (2020), in a related study, also concluded that the B&R policy had a positive effect on the reduction in pollutant emissions in China. However, they argued that it is difficult to have a unified standard to assess the GD level of each country when studying the effect of the B&R policy on the GD of the countries along the route. Therefore, we build on the original research by providing evidence from the Chinese construction industry.

Level of urban development and GD level of construction enterprises. Additionally, according to the results of the analysis of control variables in the previous paper, *Cgdp* has a certain inhibitory effect on the level of GD of construction enterprises, and according to the coefficients, it has a comparatively substantial impact on the GD of construction enterprises. According to the results of a previous study, the economic level of a city has a dampening effect on GD (Liu and Xin, 2019). Wang et al. (2020) argued that an increase in the intensity of CO_2 emissions increases the GDP per capita of a region, and the same increase in

Table 4 The influence of the B&R policy on the GD level of construction enterprises—DID.

Variable	Unmatched	Mean		% bias	% reduct |bias|	t-test	
	Matched	Treated	Control			*t*	*p* > |*t*|
Cgdp	U	0.95389	0.82751	66.5	96.7	5.62	0.000
	M	0.93898	0.94315	−2.2		−0.15	0.878
UC	U	1.7024	1.9517	−79.4	87.9	−6.73	0.000
	M	1.7508	1.7809	−9.6		−0.66	0.513
Sti	U	−0.00827	0.43634	−75.4	99.0	−6.62	0.000
	M	0.10976	0.10515	0.8		0.05	0.959
LP	U	0.5702	0.48352	70.5	72.1	5.62	0.000
	M	0.55636	0.58054	−19.7		−1.35	0.178
R&D	U	0.13979	0.25717	−19.7	20.5	−1.65	0.099
	M	0.19919	0.29252	−15.6		−1.01	0.315

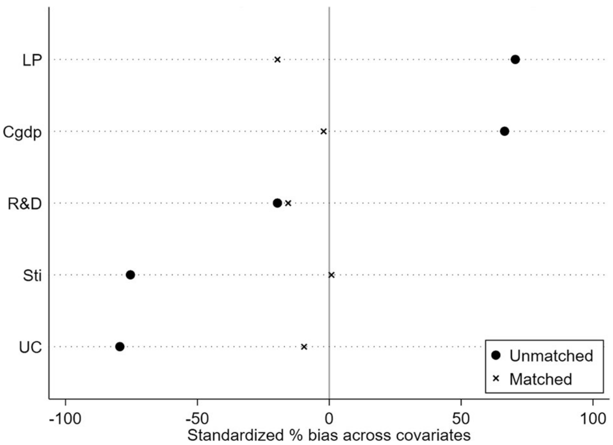

Fig. 5 Influence of the B&R policy on the GD level of construction enterprises—propensity score matching balance. The equilibrium of each variable before matching (solid black dots), the equilibrium of each variable after matching (x dots), and the equilibrium point (solid black line) are shown.

Table 5 Impact of the B&R policy on the level of GD of construction enterprises—PSM-DID.

Variable	Level of GD of construction enterprises	
	(1)	(2)
TREATED	−0.1185147**	−1.221019**
	(−2.00)	(−2.19)
TIME	0.6173156***	0.4940706***
	(4.44)	(3.19)
REATED × TIME	−0.6644929***	−0.6811376***
	(−4.17)	(−4.33)
_cons	1.4995***	−3.552635*
	(4.11)	(−1.68)
Control	No	Yes
N	230	230
R^2	0.2977	0.2521

***, ** and * denote the significance levels of 1%, 5% and 10%, respectively, and the values in parentheses are *t*-values.

GDP per capita also leads to the intensity of CO_2 emissions. Therefore, Hypothesis 2 passes the test.

Labour productivity and the GD level of construction enterprises. Lannelongue et al. (2017) argued that green innovation contributes to *LP*, which appears to be the dependent variable in their study on the GD theme. However, it has also been argued that *LP* has an impact on CO_2 emissions, while this result is persistent and stable in the long term (Soomro et al., 2021). This result is in agreement with the results in this paper, and we find that an increase in the *LP* of construction enterprises inhibits the level of GD in construction enterprises. Therefore, Hypothesis 3 passes the test.

Investment in pollution control and the GD level of construction enterprises. As one of the important factors regarding GD, *Sti* should minimize energy consumption as well as carbon emissions in the process of sewage treatment. According to studies, a large amount of CO_2 is produced during sewage treatment (Ekama et al., 2011). Additionally, domestic sewage treatment involves energy input, organic matter degradation and biological nutrient removal, resulting in on-site greenhouse gas emissions (Fine and Hadas, 2012). We conclude that the increase in investment in wastewater treatment indicates a higher volume of sewage treatment and thus a corresponding increase in the production of CO_2. In turn, it shows that the increase in *Sti* in construction enterprises correspondingly leads to an increase in the intensity of CO_2 emissions, which reduces the level of GD of construction enterprises. Therefore, Hypothesis 4 passes the test.

R&D and the GD level of construction enterprises. Previous studies on the effect of *R&D* on the level of GD in the industry are numerous, among which Zhang and Li (2021) concluded that *R&D* contributes substantially to the GD economy in the long term. Bai et al. (2019) argued that *R&D* has a catalytic effect on green innovation in the industry. Sánchez-Sellero and Bataineh (2021) found that *R&D* efforts promote the green innovation activities of enterprises. In this paper, after research and analysis, a similar conclusion is drawn that *R&D* promotes the level of GD in construction enterprises. Therefore, Hypothesis 5 passes the test.

Education level and the GD level of construction enterprises. This study finds that the *UC* in a region has a dampening impact on the level of GD of construction enterprises in that region. This differs from the conclusion that higher education contributes to environmental sustainability (Foo, 2013). Therefore, after a comparative analysis, our conclusions are as follows. First, the research object of higher education selected by Foo is limited to the level of higher education for GD, while the research object chosen for this paper is the level of higher education in the region, i.e., there is a discrepancy in the selection of the research object. Second, the research region chosen by Foo is Malaysia, while the research region chosen in this paper is the provincial administrative region of China, i.e., there is also a difference in the research area. Third, the research is limited to the level of GD in the construction industry. In summary, it is clear that this study is limited to examining GD levels in the construction industry, while the study by Foo concerns the GD level of the industry as a whole. In summary, these three reasons may be the reasons for the inconsistent results of the two studies. Therefore, Hypothesis 6 passes the test.

Conclusions and policy implications

Conclusions. In this paper, DID and PSM-DID methods are used to investigate the mechanism of the application of the B&R policy on the GD level of construction enterprises in China with panel data for 28 regions in China from 2010 to 2020. The main conclusions are as follows:

(1) The B&R policy has curbed the upwards trend of CO_2 emission intensity of construction enterprises in the key regions of the policy plan, thus improving the GD level of construction enterprises in these regions.

(2) The level of regional development, education, labour productivity and investment in pollution control hinders the GD of construction enterprises.

Policy implications. The B&R policy has been committed to the interconnection of the Asian, European and African continents and nearby oceans to promote the prosperity and development of the countries and regions along the route. Since the announcement of the construction of a green B&R, the policy has promoted not only economic development but also ecological civilization to combat climate change. Therefore, this paper enriches the theoretical research on the GD mechanism of construction enterprises and provides some insights into the strategic GD planning of government policies and management practices of various industries along the policy line.

(1) This study provides a reference for other countries along the B&R to promote the GD of construction enterprises.

(2) Both enterprises and the government should appropriately increase R&D inputs to improve the GD level of construction enterprises.

(3) On the one hand, the government should expand the coverage of the B&R planning area and urge enterprises to promote cleaner production in multiple dimensions. On the other hand, the government should strengthen education related to GD through multiple channels and improve the labour productivity of industry employees as well as their awareness of GD.

Similar to the majority of studies, this paper has some limitations. In terms of data selection, since some regional governments have not yet provided relevant data, this paper only includes data from 28 provincial administrative regions. Meanwhile, there are many factors that affect the level of GD of construction enterprises, such as market maturity and the willingness of construction enterprises to pursue GD. This study did not examine the abovementioned factors that are difficult to quantify, which also provides an opportunity for researchers to further verify the mechanism of these factors in the GD of construction enterprises in the future using computer simulation and other means.

Data availability

Some or all data, models, or codes that support the findings of this study are available from the corresponding author upon reasonable request.

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Competing interests

The authors declare no competing interests.

Ethical approval

This research did not require any ethical approval.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

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